FOOD PACKAGING TECHNOLOGY

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Packaging is an essential part of processing, preservation and distribution of foods. Fish being extremely perishable food deteriorates rapidly and thereby the quality and potential life is reduced if they are not handled and stored properly. It needs a suitable packaging that can limit undesired microbial growth and sensory deterioration. Recent packaging technologies which are becoming increasingly significant include intelligent packaging, active packaging, etc. These emerging technologies play a considerable role in shelf life extension, prevention of undesirable changes to the appearance, flavor, odor, and texture. Moreover, there are advances in packaging of retort-processed seafood, frozen seafood, ready-to-serve and retail-ready seafood products, advances in bulk packaging for the transport of fresh and processed fish or fishery products, advances in the manufacture of sausage casings and advances in vacuum and modified atmosphere packaging of fish, crustaceans and other shellfishes. This paper discusses emerging technologies for the effective packaging of sea foods and reviews advances in packaging technology, focuses on developments in active packaging, controlled release packaging, environmentally-compatible packaging and emerging edible chitosan coatings technologies.

INTRODUCTION

In recent years there are notable advances in the packaging technology of fish and fishery products. The three basic functions of food packaging (storage, preservation and protection) are still required today for better maintenance of quality and handling of foods. Advance packaging technologies which are becoming increasingly significant include intelligent packaging, active packaging, etc. Since fresh fish can get spoiled very quickly, the development of packaging technology for post-harvest preservation and methodology convert to as fresh condition. The advance packaging helps in getting high price for the fishery product. The devices as indicators can provide directly information about product quality which is resulting from microbial growth or chemical changes within foodstuffs. The using of those indicators to inside or outside of cover we can call smart of intelligent packaging. Smart packaging utilizes chemical sensor or biosensor to monitor the food quality and safety from the producers to the costumers. A modern quality and safety assurance system should prevent contamination through monitoring, recording, and controlling of critical parameters during a product's entire life cycle, which includes the post processing phase and extends over the time of use by the final consumer.

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ROLES OF FOOD PACKAGING

The principal roles of food packaging are to protect food products from outside influences and damage, to contain the food, and to provide consumers with ingredient and nutritional information[10]. Prolonging shelf life involves retardation of enzymatic, microbial, and biochemical reactions through various strategies such as temperature control; moisture control; addition of chemicals (salt, sugar, carbon dioxide, or natural acids) removal of oxygen; or a combination of these with effective packaging[3]. Containment involves ensuring that a product is not intentionally spilled or dispersed. The communication function serves as the link between consumer and food processor. It contains mandatory information such as weight, source, ingredients and nutritional value and cautions for use required by the law. Secondary functions of increasing importance include traceability, tamper indication, and portion control. More recent innovations used include surface variations sensed by finger tips and palms, sound/ music or verbal messages, and aromas emitted as part of an active packaging spectrum[11]. The goal of food packaging is to contain food in a cost-effective way that satisfies industry requirements and consumer desires, maintains food safety and minimizes environmental impact.

ACTIVE FOOD PACKAGING

Active packaging is accurately defined as 'packaging in which subsidiary constituents have been deliberately included in or on either the packaging material or the package headspace to enhance the performance of the package system[3]. Developments in active packaging have led to advances in many areas, including delayed oxidation and controlled respiration rate, microbial growth and moisture migration. Other active packaging technologies include carbon dioxide absorbers/ emitters, odor absorbers, ethylene removers, and aroma emitters. Active packaging technologies include some physical, chemical, or biological action which changes interactions between a package, product, and/or headspace of the package. The most common active systems scavenge oxygen from the package or the product and may even be activated by an outside source such as UV light. However, allows packages to interact with food and the environment and play a dynamic role in food preservation. The packaging systems are developed with the goal of extending shelf life for foods and increasing the period of time that the food is high quality. Active packaging is typically found in two types of systems; sachets and pads which are placed inside of packages and active ingredients that are incorporated directly into packaging materials.

ACTIVE PACKAGING: SACHETS AND PADS

In order to absorb or emit gases to a package or headspace, sachets and pads are very commonly used. Sachets were developed in the late 1970s in Japan. For oxygen scavenging, the sachets essentially utilize the process of rusting, or the oxidation of iron compounds in the presence of oxygen and water. Oxygen scavengers can also be made based on enzyme technology. Oxygen absorbers are usually made of powdered iron or ascorbic acid. Iron based scavengers typically do not pass the metal detector inspections on most packaging lines, and in these incidences ascorbic acid is advantageous. These pads prevent the growth of molds or bacteria by absorbing water into superabsorbent polymer granules placed between two layers of micro porous nonwoven polymer. Although sachets work well in many applications, they are not appropriate for every situation. Sachets cannot be used in liquid foods.

They may not be used in a package made of flexible film, as the film will cling to the sachet and prevent it from performing its function.

APPLICATION OF ACTIVE PACKAGING

The following are commercial applications of active packaging system

- Oxygen scavenging
- Carbon dioxide emitters and scavengers
- Moisture control
- Ethylene absorbers
- Antimicrobials

OXYGEN SCAVENGERS

High level of oxygen present on food packages may facilitate microbial growth, off-flavor and off-odor development, colour changes and nutritional losses, thereby causing significant reduction in the shelf life of food. The control of oxygen level in food packages limit the rate of such deteriorative and spoilage reaction in food. Oxygen scavenger has been applied to materials incorporated into package structures that chemically combine with, and thus effectively remove, oxygen from the inner package environment. The substance is usually contained in sachets made of a material highly permeable to air but it can also be included in bottle closures or in the plastic film matrix. The most common substances used are iron powder and ascorbic acid[4]. The scavengers may be of self-reaction type or moisture dependent. In this latter case, the reaction only takes place after moisture has been absorbed from the food product, while in the first case, the reaction starts as soon as the scavenger is exposed to air. In both cases however, water is essential for the chemical reaction to occur. Scavengers also differ in the reaction speed, from immediate action (0.5 to 1 day) to slow action (4 to 6 days), on the application, particularly the moisture content of the food, and on the function, i.e., oxygen scavenging only or dual function, such as absorbing or generating carbon dioxide, besides removing the oxygen.

CARBON DIOXIDE EMITTERS AND SCAVENGERS

The function of carbon dioxide within a packaging environment is to suppress microbial growth. Therefore, a carbon dioxide generating system can be viewed as a technique complementary to oxygen scavenging[7]. Since the permeability of carbon dioxide is three to five times higher than that of oxygen in most plastic films, it must be continuously produced to maintain the desired concentration within the package[6]. High carbon dioxide level (10- 80%) are desirable for food such as meat, poultry and seafood in order to inhibit surface microbial growth and extend shelf life.

MOISTURE CONTROL

The main purpose of moisture control is to lower the water activity of the product, thereby suppressing microbial growth. Control of moisture is important for food preservation. Moisture control agents help control water activity, thus reducing microbial growth; remove melting water from frozen products and blood or fluids from meat products; prevent condensation from fresh produce; and keep the rate of lipid oxidation in check [5]. In most cases, the packaging material itself is responsible for the control of moisture transfer between the internal and external environment, providing an adequate barrier. Desiccants such as silica gels, natural clays and calcium oxide are used with dry foods while internal humidity controllers are used for highly perishable foods.

ETHYLENE ABSORBERS

Ethylene is a natural plant hormone produced by ripening produce. It accelerates produce respiration, resulting in maturity and senescence. Removing ethylene from a package environment helps extend the shelf life of fresh produce. The use of ethanol as an anti-microbial agent, particularly for surface sterilization and disinfection, is well known. It acts against vegetative cells of microorganisms in high concentrations, and it also has a preserving action in low concentrations. The most common agent of ethylene removal is potassium permanganate, which oxidizes ethylene to acetate and ethanol[2]. The level of ethanol in the packaging headspace depends obviously on the sachet size and on product water activity.

ANTIMICROBIAL

Antimicrobial agent is one of the applications of active packaging. It prevents surface growth of pathogenic microorganisms in food by use of antimicrobial agents where large portion of spoilage and contamination occurs. It allows a controlled release of antimicrobial agents into the food surface during storage and distribution. The classes of antimicrobial agents are Silver ions, Ethyl alcohol, Chlorine dioxide, Organic acids, Spice-based essential oils and Metal oxides this are all used for reduce the growth rate and maximum population of microorganisms (spoilage and pathogenic) by extending the lag phase of microbes or inactivating them.

INTELLIGENT PACKAGING

Intelligent packaging systems exist to monitor certain aspects of a food product and report information to the consumer. The purpose of the intelligent system could be to improve the quality or value of a product, to provide more convenience, or to provide tamper or theft resistance[3]. Intelligent packaging can report the conditions on the outside of the package, or directly measure the quality of the food product inside the package. In order to measure product quality within the package, there must be direct contact between the food product or headspace and the quality marker. In the end, an intelligent system should help the consumer in the decision making process to extend shelf life, enhance safety, improve quality, provide information, and warn of possible problems. Intelligent packaging is a great tool for monitoring possible abuse that has taken place during the food supply chain. Perhaps intelligent packaging will be able to inform a consumer of an event that occurred such as package tampering that may save their life. Examples include time-temperature indicators (TTIs), ripeness indicators, biosensors, and radio frequency identification. These smart devices may be incorporated in package materials or attached to the inside or outside of a package. However, the U.S. Food and Drug Administration (FDA) recognizes TTIs in the 3rd edition of the *Fish and Fisheries Products Hazards and Control Guidance*, so their importance may increase in the seafood industry.

APPLICATION OF INTELLIGENT PACKAGING

- Time Temperature Indicators (TTIs)
- Gas Indicators
- Thermo chromic Inks
- Radio Frequency Identification (RFID)
- Leak indicators (CO_2, O_2)
- Pathogen indicators

TIME TEMPERATURE INDICATORS (TTIs)

The intelligent packaging design that is leading the way in packaging technology is the time temperature indicator (TTI). TTI is useful because it can tell the consumer when foods have been temperature abused. If a food is exposed to a higher temperature recommended, quality of food can deteriorate much quicker. A TTI can be placed on shipping containers or individual packages as a small self-adhesive label, and an irreversible change, like a color change, will result when the TTI experiences abusive conditions. TTIs are particularly useful with chilled or frozen foods, where the cold storage during transportation and distribution are important for food quality and safety. TTIs are also used as freshness indicators for estimating the shelf life of perishable products. A TTI technology known as Time strip is currently being employed by Nestle in their food service products in the UK.

GAS INDICATORS

Food is a complicated material to package because it is capable of respiration and therefore may change its own atmosphere when inside a package. The gas composition within a package can easily change due to the interaction of food with its environment. Gas indicators are a helpful means of monitoring the composition of gases inside a package by producing a change in the color of the indicator though a chemical or enzymatic reaction[1]. The indicators must be in direct contact with the gaseous environment directly surrounding the food in a package. Indicators are capable of signaling whether there is a gas leakage in the package, or they may be used to verify the efficiency of an oxygen scavenger. Oxygen in the air can cause oxidative rancidity, unwanted color changes in foods, and allow aerobic microbes to grow on foods. Oxygen indicators typically result in a color change when oxygen is present, and the presence of oxygen can indicate that the package has a leak or, has been tampered with. Oxygen indicators can also indicate improper sealing of a package. Gas indicators are also being developed to detect water vapor, ethanol, and hydrogen sulfide.

THERMO CHROMIC INKS

Inks are available that are temperature sensitive and can change colors based on temperature. These inks can be printed onto packages or labels such that a message can be conveyed to the consumer based on the color of the ink they are seeing. Thermo chromic inks can let a consumer know whether a package is too hot to touch, or cold enough drink. Thermo chromic inks are becoming a popular technology for beverages[3]. The inks used can be adversely affected by UV light and temperatures over 121°C, so consumers should not fully rely on the inks message when it comes to deciding the proper time to consume a food.

RADIO FREQUENCY IDENTIFICATION (RFID)

Radio Frequency Identification (RFID) tags are an advanced form of data information carrier that can identify and trace a product. They are currently used for tracking expensive items and livestock. In a typical system, a reader emits a radio signal to capture data from an RFID tag. The data is then passed to a computer for analysis. RFID tags contain a microchip connected to a tiny antenna. This allows for the tags to be read for a range of 100 feet or more in more expensive tags, to 15 feet in less expensive tags. The RFID tag could offer much more than a conventional barcode. In contrast to a barcode, RFID does not need to be in a direct line of sight to be recognized by a scanner. RFID tags could also store information such as temperature and relative humidity data, nutritional information and cooking instructions. They could be integrated with a time temperature indicator or a biosensor to carry time temperature information or microbiological data. RFID technology in the food system is still in the early stages. Simple applications like tracking and identification are the focus of most food science matters, and these must be perfected before more complex applications can come to light.

LEAK INDICATORS (CO_2, O_2)

A leak indicator gives information on the package integrity throughout the whole distribution chain which attached into the package. The indicator can be formulated as a label, a printed layer, a tablet, or it may also be laminated in a polymer film[12]. The leak indicators are used in modified atmosphere packaging which is classified as active packaging method[8]. In these cases MAP, the atmosphere consists of a lowered concentration of O2 and a heightened concentration of CO_2. A leak in MAP means a considerable increase in the O_2 concentration and a decrease in the CO_2 concentration, which in turn, enable aerobic microbial growth to take place. Thus, the leak indicators for MAPs are much more than active packaging, since they become smart packaging and they should rely on the detection of O_2 rather than on the detection of CO_2. Internal gas-level indicators are placed into the package to monitor the inside atmosphere[9]. Oxygen indicators interact with oxygen penetrating the package through leakages to ensure that oxygen absorbers are functioning properly. When oxygen is absent in the headspace (>0.1%), the indicator displays a pink color. When oxygen is present (<0.5%), it turns blue. A typical oxygen indicator consists of a redox-dye (such as methylene blue), an alkaline compound (such as sodium hydroxide, potassium hydroxide) and a reducing compound (such as reducing sugars). Carbon dioxide indicators are also used in modified atmosphere packages (MAP) in which high carbon dioxide levels are desired. The indicators display the desired concentrations of carbon dioxide inside the package[9].

PATHOGEN INDICATORS

Very important in food chain is monitoring and detection of a certain pathogen microorganism which can cause various diseases endangering of humane health. Commercially available Toxin Guard by Toxin Alert Inc. (Ontario, Canada) is a system to build polyethylene-based packaging material, which is able to detect the presence of pathogenic bacteria (*Salmonella sp*., *Campylobacter sp*., *Escherichia coli* O157 and *Listeria* sp.) with the aid of immobilized antibodies. As the analyte (toxin, microorganism) is in contact with the material it will be bound first to a specific, labeled antibody and then to a capturing antibody printed as a certain pattern[13]. The method could also be applied for the detection of pesticide residues or proteins resulting from genetic modifications. Another example of microbial indicators for the detection of specific microorganisms like *Salmonella* sp., *Listeria* sp. and *E. coli* is Food Sentinel System. This system is also based on immunochemical reaction, the reaction taking place in a bar code. Specific indicator material for the detection of *Escherichia coli* O157 enterotoxin has been developed at Lawrence Berkeley National Laboratory. This sensor material, which can be incorporated in the packaging material, is composed of cross polymerized polydiacetylene molecules and has a deep blue color.

CONCLUSIONS

The new advances have mostly focused on delaying oxidation and controlling moisture migration, microbial growth, respiration rates, and volatile flavors and aromas. New packaging technology of active and intelligent packaging is very helpful of consumer to indicate the quality of food. A modern quality and safety assurance system should prevent contamination through the monitoring, recording, and controlling of critical parameters such as temperature during a food product's entire life cycle. The advancement of electronic devices that can be made cheaply will also help drive the innovate direction of active and intelligent packaging. As society continues to advance, the expectations of the consumer will continue to advance. The use of active and intelligent packaging will likely become more popular as more technologies make their way to the market, innovate packaging in active and intelligent systems will become more common place. Perhaps active and intelligent packaging will completely replace traditional packaging itself.

REFERENCES

1. A.R. De Jong, H. Boumans, T. Slaghek, J. Van Veen, R. Rijkand and M. Van Zandvoort, *J Food Sci,* **72**(3), 39 - 55, 2005.
2. A. Lopez-Rubio, E. Almenar, P. Hernandez-Munoz, J.M. Lagaron, R. Catala, R. Gavara, Overview of active polymer based packaging technologies for food applications, *Food Rev Int*, **20** 4, 357-387, 2004.
3. G. L. Robertson, Food packaging principle and practice, 2012, 3rd edn., CRC Press.
4. J.P. Smith, Y. Abe and Hoshino, Interactive packaging involving sachet technology, In: M. L. Rooney (ed.), Active Food Packaging, 1995, 143 – 172, Chapman & Hall.
5. L. Vermeiren, F. Devlieghere, M. Van Beest, N. De Kruijf and J. Debevere, *Trends Food Sci Technol*, **10**(3),77-86, 1999.
6. M. Ozdemir and J. D. Floros, *Critical reviews in food science and nutrition*, **44**, 185-93, 2004.
7. P. Suppakul, J. Miltz, K. Sonneveld and W. S. Biggers, *Journal of food science*, **68** (2), 2003.
8. Q. Shen, F. Kong and Q. Wang, *Journal of Food Engineering,* **77** (2), 348–354, 2006.
9. R. Ahvenainen and E. Hurme, *Food Additive Contaminants*, **14** (6/7), 753-763, 1997.
10. R. Coles, D. Mcdowell and M. J. Kirwan, Food Packaging Technology, 2003, 346, Blackwell Publishing, Oxford, UK.
11. S. Landau, The future of flavor and odor release. In the future of caps and closures - latest innovations and new applications for caps and closures, Intertech - Pira conference, 20-21 2007.
12. S. Otles and B, yalcin, *Log Forum,* **4** (3), 2008.
13. W.T. Bodenhamer, Method and apparatus for selective biological material detection. (*TOXIN ALERT, INC., CANADA*), *US Patent* 6051388. 2000.