



INTELLIGENT PACKAGING AS DEVICE FOR MONITORING OF RISK FACTORS IN FOOD

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ABSTRACT

The goal of food packaging system is to prevent, minimize or delay undesirable changes to the appearance, sensory characteristics like flavor, odor and texture. The devices as indicators can provide directly information about product quality which is resulting from microbial growth or chemical changes within foodstuffs. Microbiological quality may be determined through reactions between indicators included within the package and metabolites which are produced during microbial growth. The using of those indicators to inside or outside of cover we can call smart or intelligent packaging. Smart packaging utilizes chemical sensor or biosensor to monitor the food quality and safety from the producers to the costumers.

Keywords: food packaging, intelligent packaging, food quality and safety

INTRODUCTION

The three basic functions of food packaging storage, preservation and protection are still required today for better maintenance of quality and handling of foods (Galić *et al.*, 2011). However, consequently of the evolution of society and development of new type of

foodstuffs, packaging industry must find new possibilities for provision food quality and safety for long time during shelf-life of food. The safety and quality of perishable food products is concerned, microbial quality has got a remarkable role. The indicators can give information about the product quality directly, the package and its headspace gases and the storage conditions of the package (**Ahvenainen et al., 1998; Ahvenainen, Hurme, 1997; Hurme, Ahvenainen, 1996; Hurme et al., 1998; Gestrelus et al., 1994; Smolander et al., 1997**). In this paper, we focus on the aspects of smart packaging concepts which give informations on the microbial quality and safety of packaged food products. To the indicators can include also leak indicators and freshness and microbial indicators.

Leak indicators (CO₂, O₂)

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 (**Otles and Yalcin, 2008**). The leak indicators are used in modified atmosphere packaging which is classified as active packaging method (**Shen et al., 2006**). In these cases MAP, the atmosphere consists of a lowered concentration of O₂ and a heightened concentration of CO₂. A leak in MAP means a considerable increase in the O₂ concentration and a decrease in the CO₂ 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 O₂ rather than on the detection of CO₂ (**Smolander et al., 1997**). Internal gas-level indicators are placed into the package to monitor the inside atmosphere (**Ahvenainen and Hurme, 1997**). Very often O₂ sensitive MAP indicators are used in combination with O₂ absorbers. Oxygen indicators interact with oxygen penetrating the package through leakages to ensure that oxygen absorbers are functioning properly.

For example, Ageless Eye sachets (Mitsubishi Gas Chemical Company, Japan) contain an oxygen indicator tablet in order to confirm the normal functioning of Ageless absorbers. When oxygen is absent in the headspace (>0.1%), the indicator displays a pink color. When oxygen is present (≤0.5%), it turns blue (**Ahvenainen and Hurme, 1997; Abe, 1994**).

There are also some other companies producing commercial O₂ indicators to confirm proper O₂ removal by O₂ absorbers (**Hurme and Ahvenainen, 1996**).

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) (**Kuswandi et al., 2011**). Oxygen indicators based on oxidative enzymes have also been reported in literature (**Gardioli et al., 1996**).

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 (**Ahvenainen, Hurme, 1997**). This allows incorrectly packaged product to be immediately repacked, and eliminates the need for destructive, labor-intensive and time-consuming quality control procedures. Very important is fact that during the first 1–2 days after the packaging procedure, CO₂ will be dissolved into the product, and then its concentration in the headspace increased, and will be decreased in the final concentration. After this period a considerable decrease in CO₂ concentration, is certainly an evident sign of leakage in a package. Another drawback of CO₂ indicators is related to the production of CO₂ in the microbial metabolism. A leak in a package by decreasing in the CO₂, is often followed by microbial growth, which means increase in the CO₂, in the worst case, due to this phenomena, the CO₂ will remain constant even in the case of leakage and microbial spoilage.

Another company Cryovac-Sealed Air Ltd. has developed label indicator type for the checking of correct gas composition (**Kuswandi et al., 2011**). It can be used in MAP to identify machine faults and gas flushing problems. The desired gas mixture composition (oxygen and carbon dioxide) can also be checked by this indicator (**de Kruijf et al., 2002**).

Moonstone Co. has designed a label containing a gas-sensitive dye, which can be inserted into a package. The dyes produce different colors at different gas concentrations. When carbon dioxide has leaked or diffused out of the MAP, the dye changes from dark blue to a permanent yellow color (**Summers, 1992**).

The disadvantage of these oxygen and carbon dioxide indicators is that the color changes are reversible, which may cause possible false readings. For example, if the food is contaminated by microorganisms, they will consume the oxygen inside the package and produce carbon dioxide, which will maintain the carbon dioxide levels in the headspace high even though the package has been compromised. Therefore, the food is no longer safe to be consumed as a result of microbial contamination; however, the indicator still displays a "normal" status color, resulting in a false reading (**Ahvenainen and Hurme, 1997**).

Sensors for pathogens and contaminants in food

Many concepts are being developed for the detection of contaminants or pathogens, but they are very low. Even if the indication of microbial growth by CO₂ is difficult in MAPs, which often already contain a high concentration of CO₂, it is possible to use the increase in CO₂ concentration as a means of determining microbial contamination or pathogen only in packages not containing CO₂ as protective gas (**Mattila et al., 1990**).

The color indicators based on reactions caused by microbial metabolites and other concepts for contamination indicators have been proposed in the literature. The color indicators could be based on a color change of chromogenic substrates of enzymes produced by contaminating microbes (**DeCicco and Keeven, 1995**), the consumption of certain nutrients in the or on the detection of microorganism itself (**Kress-Rogers, 1993**).

The methods as electrochemical transduction method, optical-based biosensors systems for detecting microbial contaminants have been used for targeting the presence of contaminating microorganisms on food such as staphylococcal enterotoxin A and B, *Salmonella typhimurium*, *Salmonella* group B, D and E, *E. coli* and *E. coli* 0157:H7 (**Rani and Abraham, 2006; Terry et al., 2004**).

Biosensors such as conducting polymers can also be used by detecting the gases released during microbe metabolism (**Retama, 2005; Ahuja et al., 2007**). The biosensors are formed through inserting conducting nanoparticles into an insulating matrix, where the change in resistance correlates to the amount of gas released. Such sensors have been developed for detecting food borne pathogens through quantification of bacterial cultures (**Arshak et al., 2007**). Furthermore, such sensors coupled with a neural network were demonstrated to provide a means of evaluating meat freshness (**Galdikas et al., 2000**).

Freshness and pathogen indicators

The idea of freshness indicators is that they monitor the quality of the packed food by reacting in one way or another to changes taking place in the fresh food product as a result of microbiological growth and metabolism (**Smolander, 2008**). Most of these concepts are based on a color change of the indicator tag due to the presence of microbial metabolites produced during spoilage (**Smolander, 2003**).

Freshness indicators are designed to respond to chemicals released by food as a result of spoilage; usually an oxidative process is effected by bacteria, yeasts and fungi, which break

down food carbohydrates, proteins, and fats to a wide variety of low-molecular-weight molecules, such as CO₂ (**Mattila et al., 1990**), lactic and acetic acids (**Kakouri et al., 1997**), aldehydes, alcohols (ethanol) (**Cameron and Tasila, 1995; Randell et al., 1995**), sulfurcontaining species (hydrogen sulphide) (**Smolander et al., 1998**) and nitrogen-containing molecules, such as ammonia (**Pacquit, 2007; Horan, 1998**) and amines (**Wallach and Novikov, 1998; Okuma et al., 2000**). For example, when proteins are bacterially decomposed, the products are amines that are related to the original amino acids that make up the protein. Thus, arginine is converted to putrescine, lysine, to cadaverine while histadine is converted to histamine. Putrescine, cadaverine and histamine are volatile amines, responsible for the smell of rotting protein, such as meat and seafood (**Mills, 2009**).

By integrating the indicator into the food package, the freshness indicators can be realized as visible indicator tags going through a color change in the presence of the analyte.

COX Technologies' "FreshTag" color-indicating tags consist of a small label attached to the outside of the packaging film. It is used to monitor the freshness of seafood products, and consists of a reagent-containing wick contained within a plastic chip. As the seafood ages, spoils, and generates volatile amines in the headspace, these are allowed to contact the reagent, causing the wick in the tag to turn bright pink (**Han et al., 2005**).

Hydrogen sulfide indicators can be used to determine the quality of modified atmosphere packaged poultry products. Freshness indication is based on the color change of myoglobin by hydrogen sulphide (H₂S), which is produced in considerable amounts during the ageing of packaged poultry during storage. The indicators were prepared by applying commercial myoglobin dissolved in a sodium phosphate buffer on small squares of agarose (**Ahvenainen et al., 1997; Smolander et al., 2002**).

The indicator correlates with the color of myoglobin, which correlates with the quality deterioration of the poultry product (**Ahvenainen et al., 1997**). In addition to hydrogen sulfide indicators, there are also indicators sensitive to microbial metabolites. **Cameron and Talasila (1995)** have investigated the potential of detecting the unacceptability of packaged, respiring products by measuring ethanol in the package headspace with the aid of alcohol oxidase and peroxidase.

Honeybourne (1993), Shiers and Honeybourne (1993) have developed a diamine dye-based sensor system responding to the presence of diacetyl vapour. Diacetyl is a volatile metabolite emitted from microbially spoiled meat. Diacetyl migrating through the packaging material would react with the dye and induce a colour change of indicator.

In addition to indicators dependent on microbial metabolites, there are also other types of indicators that are based on other food deterioration factors (**Han et al., 2005**). **DeCicco and Keeven (1995)** described an indicator based on a color change of chromogenic substances of enzymes produced by contaminating microbes. This kind of indicator is suitable for detecting contamination in liquid health-care products. **Kress-Rogers (1993)** invented a knife-type freshness probe for meats. The freshness of the meat product is assessed based on the glucose gradient on the surface of that product. During microbial growth the surface glucose is consumed, and therefore, as glucose is being consumed, the probe can detect the level of bacterial contamination and hence the product's freshness (**Han et al., 2005**).

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 (**Bodenhamer, 2000**). 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 (**Goldsmith, 1994**). If the particular microorganism is present the bar code is converted unreadable.

Specific indicator material for the detection of *Escherichia coli* O157 enterotoxin has been developed at Lawrence Berkeley National Laboratory (**Quan and Stevens, 1998**). This sensor material, which can be incorporated in the packaging material, is composed of cross-polymerized polydiacetylene molecules and has a deep blue color. The molecules specifically binding the toxin are trapped in this polydiacetylene matrix and as the toxin is bound to the film, the color of the film changes from blue to red (**Smolander, 2000**).

CONCLUSION

Changes in consumer preferences have led to innovations and developments in new packaging technologies. Intelligent packaging is an emerging and existing area of food technology that can provide better food preservation and extra convenience benefits for consumers. Proper selection and optimizing of packaging are of major importance to food manufacturers due to aspects such as economy, marketing, logistics, distribution and future prospect. The integration of a sensor in food packaging and new smart packaging development will focus more on food safety (detecting microbial growth, oxidation, improving tamper visibility), food quality (detection of volatile flavors and aromas), shelf-life, tracking, authentication, convenience, and sustainability of food products.

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