Nanoparticles and Food Packaging

A review of novel way to control pathogens

Mohammadhasani.Fateme1
1. M.S Student of Esfahan's Medical science university
Email: amfa24247@yahoo.com

***Abstract*—Social changes, globalization, packaging life cycles, and the requirement for strict safety measures are increasing the pressure to produce new packaging systems, able to transport food items and that also allow the traceability along the food distribution chain. Consumers have increasingly interested in ready-to-eat commodities with fresh-like and healthy attributes. This manner is the reason of raising the commercialization of minimally processed foods. In fact, the Applications of polymer nanotechnology can provide new food packaging materials with improved mechanical barrier and antimicrobial properties, together with nano-sensors for tracing and monitoring the condition of food during transport and storage.**

Keywords: Nanoparticle, Pathogen control, Packaging, Silver Nano, Nano sensor

I. Introduction

Nanotechnology involves the characterization, fabrication and/ or manipulation of structures, devices or materials that have at least one dimension (or contain components with at least one dimension) that is approximately 1–100 nm in length. When particle size is reduced below this threshold, the resulting material exhibits physical and chemical properties that are significantly different from the properties of macroscale materials composed of the same substance [8].

Most materials currently used for food packaging are non-degradable, generating environmental problems. Several biopolymers have been exploited to develop materials for eco-friendly food packaging. However, the use of biopolymers has been limited because of their usually poor mechanical and barrier properties, which may be improved by adding reinforcing compounds (fillers), forming composites. Most reinforced materials present poor matrix–filler interactions, which tend to improve with decreasing filler dimensions. The use of fillers with at least one nanoscale dimension (nanoparticles) produces nanocomposites, which are appropriate for special uses.

Nanoparticles have proportionally larger surface area than their microscale counterparts, which favors the filler–matrix interactions and the performance of the resulting material. Besides nanoreinforcements, nanoparticles can have other functions when added to a polymer, such as antimicrobial activity, enzyme immobilization, biosensing, etc. The main kinds of nanoparticles which have been studied for use in food packaging systems are overviewed, as well as their effects and applications [10].

In particular the following main applications for polymer nanomaterials for food packaging will be discussed:

• "Improved" PNFP – the presence of nanoparticles in the polymer matrix materials improves the packaging properties of the polymer-flexibility, gas barrier properties, temperature/moisture stability;

• "Active" PNFP – the presence of nanoparticles allows packages to interact with food and the environment and play a dynamic role in food preservation;

• "Intelligent" PNFP – the presence of nanodevices in the polymer matrix can monitor the condition of packaged food or the environment surrounding the food and can also act as a guard against fraudulent imitation.

A. IMPROVED-PNFP

The possibility to improve the performances of polymers for food packaging by adding nanoparticles has led to the development of a variety of polymer nanomaterial [1-2]. Polymers incorporating clay nanoparticles are among the first polymer nanomaterials to emerge on the market as improved materials for food packaging. Clay nanoparticles have a nanolayer structure with the layers separated by interlayer galleries [2,4,6]. In order to take advantage of the addition of clay, a homogeneous dispersion of the clay in the polymer matrix must be obtained. It was reported that entropic and enthalpic factors determine the morphological arrangement of the clay nanoparticles in the polymer matrix [3–5]. Dispersion of clay in a polymer requires sufficiently favorable enthalpic factors that are achieved when polymer clay interactions are favorable. Several different polymers and clay fillers can be used for obtaining clay–polymer nanomaterials. The polymers most used are polyamide, nylon, polyolefin, polystyrene, ethylene–vinyl-acetate copolymer, epoxy resins polyurethane, polyimides and polyethylene terephthalate. The nanoclay generally used is the Montmorillonite (MMT),a hydrated alumina-silicate layered clay consisting of an edge-shared octahedral sheet of aluminum hydroxide between two silica tetrahedral layers [3].

B. ACTINE-PNFP

Silver, gold and zinc nanoparticles are the most studied metal nanoparticles with antimicrobial function, with silver nanoparticles already found in several commercial applications. Silver, that has high temperature stability and low volatility, at the Nano-scale is known to be an effective anti-fungal, anti-microbial and is claimed to be effective against 150 different bacteria [14-15].

Several mechanisms have been proposed for the antimicrobial property of silver nanoparticles (Ag-NP):

adhesion to the cell surface, degrading lipopolysaccharides and forming "pits" in the membranes [18]; penetration inside bacterial cell, damaging bacteria DNA [24], and releasing antimicrobial Ag+ ions [22] which bind to electron donor groups in molecules containing sulphur, oxygen or nitrogen. Silver nanocomposites have been obtained by several researchers and their antimicrobial effectiveness has been reported. Higher efficiency of silver nanocomposites against silver microcomposites is reported by Damm et al. [17] that compared the efficacy of polyamide 6/silver-nano and microcomposites against Escherichia coli. The same authors in another study reported the long persistence of the anti-bacterial activity of the silver nanocomposites [20].

Silver nanoparticles are also used in conjunction with Zeolites minerals and Gold nanoparticles. In these cases interesting and promising synergic effect against of some μ_0s are observed. The use of the combination silver/zeolite and silver/gold produces a greater anti-bacterial effect than silver alone, although no commercial application has been found at the moment [7].

Also zinc nano crystals have been recently used as an anti-microbial, anti-biotic and anti-fungal agent, when incorporated plastic matrix [16] some nanoparticles based on silver that have anti-microbial activity, are able also to absorb and decompose ethylene [19]. Ethylene is a natural plant hormone produced by ripening process. Removing ethylene from a package environment helps to extend the shelf life of fresh products like fruits and vegetables.

C. INTELIGENT-PNFP

Intelligent food contact materials are mainly intended to monitor the condition of packaged food or the environment surrounding the food [21-23]. This technology can inform with a visible indicator the supplier or consumer that foodstuffs are still fresh, or whether the packaging has been breached, kept at the appropriate temperatures throughout the supply chain, or has spoiled. Key factors in their extensive application are: cost, robustness, and compatibility with different packaging materials. First developments were based on devices which were incorporated with the product in a conventional package with the aim to monitor the package integrity and the time–temperature history of the product and the effective expiration date).

Several types of gas sensors have been developed, which can be used for quantification and/or identification of μ_0s based on their gas emissions. Metal oxide gas sensor is one of the most popular types of sensors because of their high sensitivity and stability. DNA-based biochips are also under development which will be able to detect the presence of harmful bacteria in meat or fish, or fungi affecting fruit.

Other advances in the field at an early stage of research include devices that will provide a basis for intelligent preservative-packaging technology that will release a preservative if food begins to spoil [9].

II. CONCLUSION

Nanotechnology will likely impact virtually every aspect of the food sector in some way. This review has discussed in some detail, a few of the most promising applications, including food packaging material. [8]

Application of polymer nanotechnology can provide new packaging materials with improved performances and market analysis predicts billion dollar markets for food materials produced with nanotechnology within five years [9].

In the search of Avelina Fernández and et all: Fresh-cut melon pieces were stored for 10 days at 4 °C under natural modified atmosphere packaging, in presence or absence of silver loaded absorbent pads. The evolution of headspace gas composition, quality parameters, and the antimicrobial activity against spoilage related μ_0s were investigated. The cellulose-silver nanoparticle hybrid materials released silver ions after melon juice impregnated the pad. The released silver ions were particularly useful to control the population of spoilage-related μ_0s in cellulose based absorbent pads in contact with vegetable matrices, showing a low chelating effect against silver ions; the lag phases of the μ_0s were considerably incremented and microbial loads in the pads remained in average approx. 3 log10 CFU/g below the control during the investigated storage period. Furthermore, the presence of silver loaded absorbent pads retarded the senescence of the melon cuts, presenting remarkably lower yeast counts, lower °Brix values, and a juicier appearance after 10 days of storage [11].

In the search of foroughi and et all: 14 samples of cocktail sausages from a defined brand are selected haphazardly and divided into two groups "A" as control with 7 samples and B" as case with remained another 7 samples. Group "A" samples were in the original packaging, but the group "B" packed in nanofilms of Nanosilver coated on Titanium dioxide (TiO2). All the samples (A and B) had put in an empty refrigerator.

With the information from the questionnaires and SPSS analysis of parameters it could be said that: 40 percent of group "A" and 74.3 percent of group "B" were acceptable for the color parameter.42.9 ; percent of group "A" and 74.3 percent of group "B" were acceptable for the taste parameter.48.6 ; percent of group "A" and 80 percent of group "B" were acceptable for consistency parameter.45.7 ; percent of group "A" and 85.7 percent of group "B" were acceptable for visual inspection ;40 percent of group "A" and 80 percent of group "B" were acceptable for the odor parameter. Analysis of results show that nanofilms can extend the shelf life of cocktail sausages and "B" samples in the nanofilms were acceptable and consumable for visual inspection and color even after expiry date, but the group "A" was unacceptable and inconsumable after expiry date because of notable changes in odor, color and visual inspection [25].

In the search of Emamifar and et all: Nanocomposite LDPE films containing Ag and ZnO nanoparticles were prepared by melt mixing in a twin-screw extruder. Orange juice was sterilized and was inoculated with 8.5 log cfu/mL of lactobacillus plantarum. Packages prepared from nanocomposite films were then filled with this orange juice and then stored at 4 C. Microbial stability of the juice was evaluated after 7, 28, 56, 84, and 112 days of storage. The results showed that microbial growth rate significantly reduced as a result of using this nanocomposite packaging material. Reduced numbers of L. plantarum were observed ($p < 0.05$) in nanocomposite packages of orange juice containing nanosilver and nano-ZnO. Moreover, packaging made from nanocomposite film containing nanosilver showed a more pronounced antimicrobial effects, as compared with nano-ZnO during 112 days storage of inoculated orange juice. However, LDPE þ 5% P105 packages, showed a significant antimicrobial activity compared with others [13].

Moreover, several nanoparticles can provide active and/or ‘‘smart” properties to food packaging materials, such as antimicrobial properties, oxygen scavenging ability, enzyme immobilization, or indication of the degree of exposure to some degradation related factor [10]. So, nanocomposites not only protect the food against environmental factors passively, but also, they incorporate properties to the packaging material. so it may actually enhance stability of foods, or at least to indicate their eventual inadequation to be consumed.

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