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Mini Review

Nanotechnology in Food Packaging

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Received: October 10, 2016; **Published:** October 14, 2016

Abstract

Nano-food packaging is a new field of packaging technology based on nanomaterials, which has become one of the fastest growing areas in nanotechnology and represents a radical alternative to the conventional food packaging. Because of the specific physical and chemical characteristics of nanomaterials, many industries have invested on various food packaging Nano sized materials, with extremely high gas barriers and antimicrobial properties. While Nano-food packaging offers various potential benefits, there are continuous concerns arising from the fact that certain nanomaterials need more studies. The present review provides the aspects of nanotechnology related to the food packaging, and gives applications.

Keywords: *Nanoparticles; Food packaging; Food safety; Quality; Benefits; Risks*

Introduction

Nanotechnology is the manipulation and use of materials and structures at the nanometer scale, approximately between 1 and 100nm, where 1 nm is 1×10^{-9}m [1]. Nanotechnology has invaded in the agri-food industry, with many applications. Some of them are the primary production, with reduced use of feed additives and lower use of agrochemicals, food processing, with novel food products with improved flavour, textures, colors and sensory characteristics, nutrition with reductions in fat or sugar content of products, delivery of additives (vitamins and minerals, antioxidants, phenolic compounds) to a specific target site in the body, addition of vitamins and minerals to products and food packaging [2]. Many industries of foodstuffs and agricultural products have already invested heavily in nanotechnology research and development [3] and nanotechnology is already being used in many countries in the production of agricultural products, processed foods and drinks, and in food packaging. Different types of nanomaterials (NMs) used in Agro food industry are nanoemulsions (NEs), nanoparticles (NPs), and nanoclays (NCs) [4]. The most important parameter of nanoparticle, that should be tested for characterization, and it is critical for determining the interaction of nanoparticles with living systems, is the size [5]. But a complete and extensive characterization of nanoparticle includes size distribution, crystallinity, surface area, surface chemistry, surface charge, porosity, shape, and solubility [6]. Food packaging is one of the most significant processes to maintain the safety and quality of food products for storage, transportation and end-use [7]. Physical and mechanical properties of nano - food packaging materials have been continuously developed, in order to provide materials with improved permeability, flame resistance, gas permeability, tensile strength and may extend the life of the food. Also, all these properties of nano - food packaging materials can offer consumers healthier packaged foods [8]. The present paper reviews the main applications of nanotechnology in the area of food packaging.

Importance of Nanotechnology in Food Packaging

Food industries are always searching for new and cheaper methods to produce and preserve food. Recent trends in food packaging are related to Nano reinforcement, in the field of active packaging the nanocomposite active packaging and in the field of smart packaging the nanocomposite smart packaging [9]. Polymers have replaced conventional materials (paper glass, metals, board and ceramics), in food packaging. The reasons why this happened are the light weight, low cost, functionality, and ease of processability. Polymer nanocomposites usually have much better polymer/filler interactions than the usual composites. Gaps of packaging materials be filled with the help of nano-reinforcement techniques and the final materials have increased viability and tensile strength [10].

Nanoclay, cellulose and other food packaging materials

Food packets obtain additional tensile strength with the process of Nano reinforcement. Nano reinforcement mainly uses nanoclays, cellulose and graphene. Nanocomposite active packaging integrates many useful systems (e.g. antimicrobial, enzyme immobilization systems and oxygen scavenging) along with the food packets. In the last twenty years, polymer clay nanocomposites (PCNs), a new class of clay filled polymers, has been developed. Two types of nanoscale composites may produce by the interaction between polymers and layered silicates, namely: intercalated nanocomposites, which result from the permeation of polymer chains into the intermediate layer region of the clay, producing an ordered multilayer structure with alternating polymer/inorganic layers [11]. Cellulose is another interesting material for food packaging materials with low cost, lightweight, and high-strength nanocomposites [12]. Tensile properties have been improved in several polymers such as polyethylene naphthalate [13] polyvinyl alcohol [14], polypropylene [15], and a polyamide [16] by addition of carbon nanotubes. Carbon nanotubes are cylinders with nanoscale diameters which may consist of a number of concentric tubes which is called multi-wall nanotube or one-atom thick single-wall nanotube. Carbon nanotubes have extremely high aspect ratios and their elastic modulus can be as high as 1 TPa [17]. Also a large number of polymers such as silica NPs (nSiO2) have been mentioned to improve tensile characteristics of polypropylene [18], starch [19], starch/polyvinyl alcohol [20], decreasing water absorption by starch [19, 20] and improving oxygen barrier of polypropylene [18].

Antimicrobial Packaging

Active packaging technology can be divided into two categories [21]. Ethylene, oxygen, carbon dioxide, excessive water or other undesirable compounds can be removed by scavengers or absorbers, which constitute the first category. The second category is the controlled releasing systems, which actively adds or emits compounds at desirable rates to the packaged foods or into the headspace of the package such as antimicrobials, carbon dioxide, antioxidants, and preservatives to supply continuous replacement of active compounds, inhibit bacterial growth and extend product shelf life. Considerable research has been done on the use of nanoscale materials for the antimicrobial activity as growth inhibitors [22], killing agents [23,24], or antibiotic carriers [25]. Antimicrobial activity has been reported for the Ag^+ ions by dissolution of silver nanoparticles [26]. Silver NPs have also been reported to absorb and decompose ethylene, which may contribute on extending shelf life of fruits and vegetables [27]. Also antibacterial properties have been reported for carbon nanotubes [28]. Maturity of packed products and the presence of pathogens may be detected by nanosensors developed for this purpose [29]. These are likely to be in the form of "buttons" on the packaging which change colour.

This could also be useful as mean of checking whether the packaged food is displayed or stored in appropriate environmental conditions. Antibacterial activities also have been reported for the zinc oxide when zinc oxide nanoparticles incorporated in the polymer of a food packaging material. Furthermore, nanoparticles of zinc oxide have demonstrated UV blocking and barrier properties, white appearance, mechanical strength and stability [30].

Oxygen-scavenging packaging

Traditionally, sensitive to oxygen foodstuffs and drinks have been packaged in such a way as to minimize their exposure to oxygen. This oxygen may be situated in the package at the time of the closing of the package, or may enter the package by permeation or leakage over the storage life. Oxygen (O_2) participates in many chemical reactions, related to food deterioration such as browning reactions and rancid flavours. Very low levels O2 levels in food packaging systems can be achieved by incorporation of O_2 scavengers. Oxygen scavenger films have been reported to literature by adding TiO_2 NPs to different polymers [31]. Inhibition of the growth of undesirable food component that can occur through UV irradiation could be a significant benefit for the TiO_2 nanoparticle-incorporated food packaging films. More over these films have good transparency [32].

Enzymes in food packaging

Many enzymes have been used with the process of the immobilization in packaging materials. The use of enzymes has many advantages such as, stability to temperature and resistance to protease and other denaturing compounds. Also catalysis of a reaction by enzymes could cause the reduction of an undesirable substance and increase the nutritional value of food [33].

Soares and Hotchkiss [34] improved the nutritional value of grapefruit juice by immobilizing the enzyme naringinase in a plastic packaging. Naringinase actually hydrolysed naringine which is responsible for the bitter taste of the citrus juices. Also other enzymes such as, cholesterol reductase or lactase could increase the nutritional value in the foodstuffs when incorporated with packaging materials providing healthy options to the consumers [35].

Potential risks and safety concerns of nanotechnology

Nowadays, consumers would pay more for higher quality foods and convenient packed foods. The rapid development of nanotechnology cause the unavoidable human exposure to nanomaterials. While there are several investigations with the development of nanomaterials in food packaging, few studies exist on possible toxicity caused to human health. As it concerns the carbon nanotubes, there are published data suggesting that carbon nanotubes may also have cytotoxic effect to human cells, at least when in contact with skin [36] or lungs [37]. Once present in the food packaging material, the nanotubes might eventually migrate into food. Therefore, it is obligatory to know any potential health effects of ingested carbon nanotubes.

Besides, the migration of substances from packaging material to food is a critical issue and can affect the safety of food, causing great concern to the consumer. For this reason, all new packaging materials either contain nanomaterials or not, are subject to migration tests as established by Commission Regulation (EU) No 10/2011 [38] on plastic materials in contact with food.

Conclusions

As happens with any new technology, the use of nanotechnology in the food packaging, it takes some time until gain consumers acceptance. Nanotechnology offers a variety of some exciting benefits for food packaging, including improvement the quality and hygiene of food, and extension of shelf life etc. Its use for food packaging are promising, with many innovative applications, with packaging materials providing excellent protection, antimicrobial properties and nanosensors that can detect microorganisms or chemical contaminants at amazingly low levels. However, there are major knowledge gaps in relation to the current understanding of the properties, behavior and effects of nanomaterials. Current uncertainties for potential risk and exposure assessment of nanomaterials, resulting from limited information on various topics including toxicity, behavior, bioavailability, biodistribution, and bioaccumulation.

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Volume 5 Issue 3 October 2016