Analysis on the Nanomaterial Application in the Industry of Food Packaging

LizhaoHuang

In the paper, the application of all kinds of nanometer materials to the food packaging has been reviewed comprehensively. In the meantime, the advantages of these nanomaterials adopted in the food packaging has been generalized. Moreover, the toxicity of nanomaterials that might affect different organelle or cell has been summarized and analyzed.

Keywords: Nanomaterials; Food packaging; Application; Poison rational
Tob Regul Sci.™ 2021;7(5-1):4216-4221
DOI:doi.org/10.18001/TRS.7.5.1.197

INTRODUCTION

With the development of industries and society, the packaging materials for foods are keeping on evolving, and people are seeing an increasing types of packaging materials. The purposes of packaging foods include protecting the foods from external pollution and saving the nutrition of food. Nevertheless, the substance exchange identified between the packaging materials and the foods is a issue that can be ignored. Some toxic substance of packaging materials might be absorbed by the foods, and impose negative impact on people's health. Lately, a lot of problems related with the foods are mostly caused by the packaging materials of foods, so it it urgent to find suitable and safe materials for the production of packaging materials of foods. Large sum of investment has been made by a lot of international companies specializing in food processing, hoping to develop and adopt nanomaterials in the packaging industry. In the paper, both advantages and disadvantages would be discussed regarding to the nanomaterials that might be adopted as food packaging.

NANOMATERIAL APPLICATION

Antimicrobial Packaging Material Made of Nanometer

There are a lot of nutrients in the foods, which become ideal environment for the breeding of microorganisms. For this reason, generally speaking, most of foods have the problems such as microbial deterioration and contamination. MOD series of nanometer material agents is a inorganic material with high performance, and it can be used as a packaging material which integrates the nanotechnology with the sterile composite packaging. The traditional process for production of antibacterial agent has been changed with the adoption of silver, zinc, copper and other metal ions. If the inorganic and antibacterial packaging material is adopted, there is a problem of color change, and with the adoption of the material, the problem of color change can be solved.

The antibacterial composites of ZnO/LDPE, which is developed by Gao yanling, has undergone a number of tests under different conditions. The test results show that, significant antibacterial effect is identified on four bacteria when the material is adopted. Excellent antibacterial performance is found by using the material, whicih not only inhibits the reproduction and growth of microorganisms in auced beef, but also prolongs the shelf life. Microorganisms are widely distributed in nature. They are small in size, various in variety, rapid in propagation and have strong ability to adapt to the environment. Most foods are rich in nutrition and high in moisture content, which are easy to be polluted by microorganisms and cause spoilage, which greatly shortens the shelf life of food. Relevant scientists have been working on how to extend the shelf life of food. In recent years, with the development of nanotechnology, the application of nanomaterials to achieve antibacterial function has become a research hotspot. the nano-sized ZnO/ polymer composites obtained after blending ZnO nanoparticles and polymers under certain conditions not only have good mechanical properties, ultraviolet absorption, but also have excellent antibacterial properties. they are widely used in antibacterial packaging of food.

Gao Yanling(2010) and others developed nano ZnO/LDPE antibacterial composite materials, and used Bacillus subtilis and other 6 kinds of food commonly contaminated bacteria as test strains, under three different conditions to test their antibacterial properties. The material has obvious antibacterial effect against four kinds of bacteria,

LizhaoHuang, School of food and environment,Dalian University Of Technology,Dalian 124221， China

and has strong antibacterial ability at natural light and room temperature, and the antibacterial effect against Bacillus subtilis is the strongest, and its antibacterial rate reaches the highest value of 99.99% at room temperature and under the condition of natural light irradiation. A nano ZnO/HDPE composite membrane was developed by Li Yana (2011), The preservation of cheese was investigated. Nano - ZnO/HDPE composite film has a strong inhibitory effect on microbial growth on cheese, After 7 d at room temperature, The number of cheese-recovered colonies in the nano ZnO/HDPE composite film package was 32×103 CFU/mL (total number of bacterial communities per milliliter sample, CFU : Colony2Forming U nit s), less than HDPE membranes (82×103 CFU/mL). Li Xihong (2009) studied the in vitro bacteriostatic effect of nano ZnO/PVC composite membrane on Escherichia coli and Staphylococcus aureus. It turns out, Bacterial suspensions with nano ZnO/PVC membranes, 4 h, of Light Oscillation Culture The total number of Escherichia coli colonies decreased by more than half; higher the content of ZnO particles in the nanofilm, The better the bacteriostatic effect, The inhibitory effect on Staphylococcus aureus was higher than that of Escherichia coli. Nano ZnO/PVC self-mucosa has long-acting antibacterial properties, And when the amount of nano ZnO is 2 phr, Its antibacterial rate is the highest. Anticorrosive and antibacterial nanomaterials have been developed by Li Hongmei, And use it to pack beef sauce. The antibacterial nanomaterials can effectively inhibit the growth and reproduction of bacteria in beef sauce, Reducing the production of volatile base nitrogen, Well preserved the color and flavor of the beef sauce, extended the shelf life.

The outstanding properties of nano-molecular sieve are high surface area and multi-micropore structure, Be able to select gas. Owing to the unique gas selectivity of molecular sieves to O2 and CO2, Make it a very suitable air conditioning packaging additive, Can get very good fresh-keeping effect. LDPE, by Wang Xuelian (2010) et al LLDPE, EVA, H2β molecular sieves and stearic acid, A new polyethylene composite membrane was obtained by blowing, And the cherry as a fresh object, The preservation effect of composite film and the influence of molecular sieve content were discussed. H2β the addition of molecular sieves largely inhibits cherry respiration, To extend the shelf life, The composite membrane with 7.5% molecular sieve content at room temperature had the best preservation effect on cherry, Its preservation time is more than 10 d. Guo Yuhua (2008) based on LDPE /LLDPE, Adding A nano - active molecular sieve, Development of air conditioning packaging film, In addition, the study on air-conditioned packaging of strawberry, lettuce, greasy wheat and spinach, The fresh-keeping effect is good. It turns out, Fresh period of strawberry can be increased by 2 d, at room temperature Combined with storage cabinet can reach more than 13 d; 4 d, of lettuce under room temperature Storage ℃ Up to 10 d; A fresh-keeping period of 4 d, at room temperature Storage ℃ preservation period up to 11 d; Fresh-keeping period of spinach up to 5 d, at room temperature If it's in a freezer, Shelf life can reach more than 10 d.

Nano SiO x is a non-toxic, tasteless, non-polluting inorganic nonmetallic material, Its proper amount can form a dense nano-film, The adsorption, dissolution, diffusion and release of CO2 and O2 by silicon-oxygen bond are used to regulate the exchange of CO2 and O2 inside and outside the membrane, Inhibition of respiratory intensity in fruits and vegetables, In order to play the role of preservation. Using PP film as substrate, surface coated nano SiO2, And used for strawberry preservation, And it turns out that when strawberries were stored in d 13, The weight loss rate is 6.9%, the decay index is 19%, The fresh-keeping effect is excellent. Xu Li (2008) studied the effect of nano SiO x chitosan coating on green and spicy preservation, 30 d, at room temperature The good fruit rate, water loss rate and decay rate of green pepper were 70%, 0.115% and 29.9%, The fresh-keeping effect is good. and then the nano SiO2 was added to chitosan, optimized chitosan film permeability CO2, And used for strawberry preservation, The storage period of strawberry was prolonged at room temperature and low temperature. After 6 d at room temperature, The decay index is 5.1% lower than the unoptimized film; When stored for 11 d at 4℃,The decay index was 23.9% lower than that of the unoptimized membrane. Zhang Yongmao (2010) developed nano SiO x fresh fruit wax, And applied it to the surface of Fuji apple to form a complete wax film, independently control the gas absorption and release of individual apples. Stored at room temperature for 3 months, Compared with the control, Apple hardness dropped 21%, The weightlessness rate decreased by 23 per cent, The fresh-keeping effect is good.

Nanometer Packaging Materials that Keep Food Fresh

With the adoption of fresh-keeping packaging material made of nanometer, the shelf life of vegetables and fruits can be extended. However, the spoiling of vegetables and fruits are often associated with the release1 of ethylene gas. When the ethylene content in a package exceeds certain level, the decomposition rate of vegetables and fruits is going up fast.

with the use of nano-ag powder, the decomposition and oxidation of ethylene can be catalyzed. It can accelerate the decomposition and oxidation of ethylene by adding some nano-ag powder to the materials of food packages,. According to the findings of Zhou Ling, the photosensitive properties of such material is much better than that made of PE plastic bag.

The nano-molecular sieves are featured by multi-micropore structure and high specific area. Because special gas selectivity to carbon dioxide and oxygen has been identified from the molecule sieves, they are ideal materials for packaging additives with air-conditioning functions. The screening volume of H-β composite film is 7.5% at the room temperature, so withh the adoption of it, the cherries can be well preserved, with the time of presentation longer than 10 days.

LDPE /LLDPE serves as the base material, with the addition of nanometer active molecule sieves. According to the results, the strawberry's storage period can be extended by 2 days at the room temperature, and the period can be as long as 13 days if it is kept in the storage cabinet. For the food packaging materials, one of fundamental elements is high barrier. PET is widely used as a packaging material for beverage for it has good transparency. However, the blocking properties of PET isn't perfect enough for the application of bottle. For this reason, the gas barrier of PET should be improved.

Zhou Ling (2010) studied the effect of a new PE/Ag2O nano-package on apple cutting, And the safety of PE/Ag2O nano-package was evaluated. The sensory quality of PE/Ag2O nano-package is better than that of PE bag, Low weight loss, slow browning of apple cut surface, It has excellent preservation characteristics. PE/Ag2O nano - silver loaded on the nano - packaging bag is very stable, Hard to leak, It is safe to use the nano-bag for food preservation. Some scholars have proposed a new preservation technology, Ice crystal cooling technology and nano-silver ion sterilization and disinfection technology were applied to litchi and other vegetables and fruits. This technique works very well, The preservation period was significantly prolonged, The rate of good fruit has been greatly improved. Zhang (2005) proposed a three-stage compound pretreatment method to prolong the preservation period of perishable fruits and vegetables. First, the temperature of fruits and vegetables decreases rapidly by the rapid cooling of water control vacuum, In order to reduce its respiratory effect; Reusing high pressure mixed gas water structure to passivate fruit and vegetable enzyme activity; Finally, nano - silver antibacterial film, Reduce the decay rate of fruits and vegetables. To minimize the loss of fruits and vegetables through 3-stage compound pretreatment, To achieve the best quality, Thus prolonging the preservation period. Chen Li (2001) applied nano TiO2 to PVC preservation film, An anti O2 nano Fuji apple film was developed. Measured, The longitudinal tensile strength increased by 36%, The oxygen permeability decreased by 18%, The moisture permeability was reduced by 10%, Carbon dioxide permeability changes only 1.5. Experimental results show that, The preservation effect of PVC preservation film containing nano TiO2 is better than that of typical Fuji apple special preservation bag, The O2 of gas index during storage period is 3.1~5 The CO2 was 1.7 per cent ~2.6 per cent.

Chitosan is a kind of natural polymer compound made from shrimp and crab shell, It is the second most sugar in nature after cellulose. The main component of chitosan is the derivative of deacetylchitin, It has some excellent functional characteristics and potential application value, If it is safe and non-toxic, cheap, good biocompatibility, degradability, And its film-forming property has attracted more attention, And its characteristics are widely used in fruit and vegetable film preservation. Yuan Zhi (2010) used nano TiO2 to modify chitosan, Chitosan nano TiO2 composite membrane was optimized, And the tender ginger film preservation. Optimized membrane treatment of tender ginger, Vitamin C ,gingerol levels were 23% and 26% higher than those of uncoated ginger. Modified chitosan nano TiO2 composite preservation film is beneficial to prolong the preservation time of fruits and vegetables. Corn starch is a kind of natural polymer with abundant resources, low cost, renewable and good film forming property, The studies on corn starch membrane mainly focus on edible membrane and biodegradable membrane, Corn starch film can also be used in fruit and vegetable film preservation. Song Xianliang (2010) through high efficiency dispersant and ultrasonic dispersion technology, Disperse nano TiO2 evenly in corn starch coating solution, The holy fruit was coated. Nanometer TiO2 dosage of 0.025% of the best preservation effect. The coated virgin fruit was stored for 11 d, at 25°C, The decay rate decreased by 78.8%. Sunada K and Yang Q studies have pointed out that the combination of nano Ag and nano TiO2 can play a better effect. The pore structure of nano TiO2 can provide more binding sites for nano Ag and make up for the easy loss of nano-sized monomers. The safety of nano-packing materials is enhanced. Yu Wenhua et al developed a nano Ag/TiO2 fresh-keeping film, and applied the film to green pepper to keep fresh, which effectively inhibited the respiratory intensity of green pepper. The fresh-keeping period of green pepper could reach more than 3 months, the weight loss rate was less than 5 and the good fruit rate was more than 90%.

BIOLOGICAL POLYMER NANOCOMPOSITES

Cellular refers to a linear crystalline hydrophilic, and there is strong hydrogen bonding between and in molecules. Compared to the general edible films, the ability of blocking water vapor of the composite significant has been greatly improved when CNF dosage level reached 10%. By adding 36% CNF, for the composite films, its tensile strength has been increased by 114%, and the permeability of water vapor has been decreased by 37%.

Starch is a completely degradable raw material, and it is not expensive. As a kind of biodegradable material, nano-silicate is perfect material for food packaging. After adding 5% zno-cmc, the tensile strength remains as 3.9 Mpa, while the permeability of water vapor is greatly reduced, so is its rate of fracture pull.

Proteins lead to the spatial structures which is associated with the amino acids condensation, and it is frequently used as an edible coating or film in the industry of food packaging. Chen has implemented research on the relationship between performance and structure in the system of legume protein. Their electrostatic effect is critical to the improvement of systemic performance. When 16% MMT is added, the tensile strength has been raised by 15.43mpa from the original 8.77mpa.

He Toxicity of Nanomaterials

Currently, nanomaterial is a material that has wide application in the industry of food packaging. However, the migration of nanomaterials from food packaging to foods results in the contamination of foods and potential risk of safety. For this reason, the research on nanomaterials independence is necessary. According to some scholars, for these non-toxic substance, if their particle size is reduced to certain level, the substance turns toxic and their toxicity is increased. For this reason, nanomaterials isn't quite ideal for the application of food packaging due to safe concerns as shown by an evaluation result of traditional material studies.

According to the studies, there is toxic effect of nanomaterialson the cells. Toxicity is identified by checking the integrity of cell membranes and the number of living cells. Due to the damages to the cell membranes, it is possible that the cytoplasm LDH is released. For this reason, through detection of LDH activity, the cell membrane integrity can be examined. Lin et al. find that, the levels of dose ranging from 10 to 100 micrograms/ml can reduce the rate of cell survival within 48 hours independently from the dose.

The area of nanomaterial surface is large, so the adsorption capacity is good. When the proteins are absorbed, the general physiological conception of proteins can be changed to a certain extent, leading to inactivation or denaturing of them. Mitochondria is widely found in the cells, and its function includes transforming organic matter into body energy. It is found that the particles penetrate the cells via a number of pathways, and they deposit at the mitochondria and disperse at the cytoplasm. The potential of mitochondrial membrane is a positive and negative potential difference in the cells, and it is an indicator that shows mitochondrial state of function intuitively. When the nanoparticles penetrate the broken mitochondria, a decreased potential of membrane is created.

Duan has the endothelial cells exposed directly to the nano-silicate particles by means of intravenous administration, and according to the result, the DNA damage is greatly increases in all cases. Moreover, DNA damages can be regulated by the oxidative stress, and it is dependent on the balance between antioxidant function and ROS production. With the adoption of nanoparticles that have large surface area, the breeding of reactive oxygen species can be promoted, which leads to the damage to oxidative DNA.

The Damage of Nanomaterials to Organisms

At present, there are many detection techniques for nanomaterials, such as X photostability analysis. Because the phase and crystal structure of nanomaterials play a very important role in the properties of nanomaterials. Because different electron movements occur within the atoms of matter and the wavelength of the emitted light is different, the properties of nanoparticles and their crystal structure can be studied by spectral analysis, the crystalline state, crystal structure and so on can be determined by X ray diffraction spectra, and the elements of nanomaterials can also be scientifically analyzed.

Nanomaterials have very special photoelectric and other characteristics. At present, they have been widely used in the food packaging industry, because new food packaging materials based on nanomaterials can be seen everywhere in people's lives. Therefore, people attach great importance to its safety performance. The safety detection of nanomaterials can be verified by oral toxicity test in animals. There are two different kinds of toxic effects of nanoparticles in organisms: no correlation between toxic effects and the composition of nanoparticles, a large number of reactive oxygen species produced by nanoparticles, which will show a certain amount of toxicity in organisms, and a direct relationship between the composition and toxic effects of nanoparticles, such as metal nanoparticles partially in organisms. Binding to Pr causes abnormal protein function, while metal alloys and other substances indirectly or directly reflect genetic toxicity. Although many scientific research institutions at home and abroad have studied the safety of nanomaterials, there is no accurate conclusion on the safety of nanomaterials. In addition, the problem of how nanomaterials work in human body has not been solved.

Due to the special properties of light, heat and electricity, nanomaterials have been widely used in the field of food packaging. New food packaging materials based on nanomaterials are everywhere, and people have to face and attach importance to their biosafety problems. The size, solubility, chemical composition, surface structure, shape and aggregation state of nanomaterials can affect their biological effects.

Although there are few studies on the migration of nanoparticles in packaging materials such as polymer films, ceramics, glass and paper, for consumers, the safety of nanoparticles in food packaging materials has always been the focus of attention. The safety of nanomaterials can be confirmed by oral toxicity and cytotoxicity in animals. toxicity of nanoparticles to organisms is manifested in two different types of effects. one toxic effect is not related to the composition of nanoparticles, is to produce a large amount of reactive oxygen species (ROS) through nanoparticles, which will show some toxicity in organisms. the other toxic effect is directly related to the composition of nanoparticles, such as the binding of some metal or metal oxide nanoparticles to proteins in organisms, which can lead to abnormal protein function, while some nanoparticles, such as metal alloys, carbon nanotubes, show direct or indirect genetic toxicity.

The nanoparticles are similar with gases in terms of their properties, and they can be described as Brownian motion. It is very dangerous if the nanoparticles enters the respiratory tract. Long-time stimulation and inflammation would lead to fibrosis and granuloma at the lung tissues. Moreover, if the nanoparticles are accumulated in the lungs, they would penetrate the alveolar interstitium, and then infiltrate the capillaries, and then they would spread to the body and result in a number of adverse reactions. According to the rodent experiments, the nanomaterials travel through the alveolar capillary barrier, and then they would join the bloodstream, leading to cardiovascular disease and so on.

According to the result of a transgenic mouse model, the nanomaterials enters the vascular endothelial cell by the bloodstreatm, and large amount of ROS might be produced, and thus damage the vascular endothelial cell. ROS are then released in the bloodstream. Moreover, ROS that the endothelial cells release will bind rapidly to the smooth muscle cells, which releases NO and have them depleted. Then, the relaxation of smooth muscle cells are inhibited, and the risk of myocardial infarction and hearth arrhythmia is increased. The nanomaterials adsorbed by the mice nasal mucosa is further entering the olfactory bulb tissues through the olfactory mucosa, and then they penetrate the blood-brain barrier and reach the brain, leading to oxidative damage to the brain. When the nanomaterials affect the central nervous system, it is possible to induce some neurodegenerative diseases, for example, Parkinson's disease.

Among living animals, the liver is the site where most of toxin is accumulated. If the nanoparticles are taken by the body and entering the blood circulation, then it is very likely they reach the liver and get accumulated. A lot of nanomaterials are not degradation, and their deposit in the liver would lead to a number of biological reactions, and the normal metabolism might be disturbed. Especially, if the phagocytosis is performed by macrophage, cytokines, enzyme and inflammatory mediators are secreted, causing damages to liver tissues, and further lead to liver cirrhosis, hepatitis and liver cancers and so on.

SUMMARY AND OUTLOOK

Nanotechnology is one of the most advanced and widely used technologies in the 21st century. The development of nano-packing materials has greatly promoted the development of food packaging industry. The application of nanomaterials in food packaging will have a great impact on food consumption habits. At the same time, safety is the guarantee of the application and popularization of nanomaterials in food packaging. Therefore, it is necessary to pay attention to and explore the potential impact of nanomaterials on human beings through food, and provide scientific basis for the rational application of nanomaterials in food packaging. Nowadays, nanomaterials are frequently adopted in the industry of food packaging, and the adoption of nanomaterials can help enhance the barrier performance, safety and antibacterial function of food packages. These nanomaterials are playing quite important roles. In the meanwhile, the safety issue of nanomaterials is concerned by a lot of people. The nanomaterials vary in terms of their toxicity, as there are a lot of different types of nanomaterials, and the same nanomaterials have different toxicity to different cells. For this reason, efforts should be made to figure out the toxicity of nanomaterials, and propose solutions to elimination of toxicity from the nanomaterials.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, author- ship, and/or publication of this article.

Funding

The author(s) received no financial support for

the research, authorship, and/or publication of this article.

Reference

1. Bradley E L, Castle L, Chaudhry Q. Applications of nanomaterials in food packaging with a consideration of opportunities for developing countries[J]. Trends in Food Science & Technology, 2011, 22(11):604-610.
2. Bradley, E. L., Castle, L., & Chaudhry, Q. (2011). Applications of nanomaterials in food packaging with a consideration of opportunities for developing countries. Trends in Food Science & Technology, 22(11), 604-610.
3. Taylor M R. Assuring the Safety of Nanomaterials in Food Packaging: The Regulatory Process and Key Issues[J]. Woodrow Wilson International Center for Scholars, 2008.
4. Bumbudsanpharoke N, Choi J, Ko S. Applications of Nanomaterials in Food Packaging.[J]. Journal of Nanoscience & Nanotechnology, 2015, 15(9):6357.
5. Ayhan Z. Potential Application of Nanomaterials in Food Packaging and Interactions of Nanomaterials with Food[M]// Ecosustainable Polymer Nanomaterials for Food Packaging. 2013.
6. Ayhan Z. Potential Application of Nanomaterials in Food Packaging and Interactions of Nanomaterials with Food[M]// Ecosustainable Polymer Nanomaterials for Food Packaging. 2013.
7. Tsagkaris A S, Tzegkas S G, Danezis G P. Nanomaterials in food packaging: state of the art and analysis[J]. Journal of Food Science & Technology, 2018:1-9.
8. Zhou Ling, he Guiping, Yan Mengyun, et al. PE/Ag2O effect of nano-package on quality of apple cutting [J]. Food Technology ,2010,35(6):56-59.
9. Yuan Zhi, Wang Mingli, Wang Lijuan, et al. Study on permeability of modified chitosan TiO2 composite film [J]. China Agronomy Bulletin ,2010,26(11):67-72.
10. Song Xianliang, Ye Shengying, Huang Wei, et al. Study on the effect of nano-sized TiO2/ corn starch composite coating on the preservation of holy fruit [J]. Food Science ,2010,31(12):255-259.
11. Wang Xuelian, Huang Zhen, Zhang Jing, et al. Application of polyethylene 2 molecular sieve composite membrane in fresh-keeping packaging of cherries [J]. Food Technology ,2010,35(4):44-47.
12. Guo Yuhua, Huang Zhen, Teng Lijun, et al. Development of novel nano-active air-conditioned packaging film for fruits and vegetables [J]. Packaging Engineering ,2008,29(3):47-48.
13. Xu Li, Tan Shuming, Ye Fang. The effect of nano SiO x on the storage and preservation of green pepper at room temperature [J]. processing of agricultural products 2008(8):22-25.
14. Zhang Yongmao, Jie Minhua, Tian Shilong, et al. Research and Development of Nanosilicon-based Oxide (SiO x) Fresh Fruit Wax [J]. Agricultural Engineering Technology ,2010(5):42-46.
15. Gao Yanling, Jiang Guowei, Zhang Shaohui. Preparation of Nanometer ZnO/LDPE Antibacterial Food Packaging Material [J]. Food Science ,2010,31(2):102-105.
16. Li Yana, he Qinghui. antimicrobial preservation of cheese by nano ZnO/HDPE membranes [J]. food science ,2011,32(4):237-240.
17. Li Xihong, Li Weili, Zhang Peipei, et al. Study on bacteriostatic properties and application of nano ZnO/PVC film [J]. Food Science ,2009,30(10):5-7.