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Nano Technology: A Review On It's Applications In Food Industry And Food Packaging

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Abstract: ***Food nano technology is the newest emerging technolegy. This technology has tremendous applications in food industry in terms of food processing, packaging, safety and quality control. Nano technology derived smart and active packaging improves heat resistance, anti-microbial activity and bio-degradable properties. Nano capsules are nano sized carrier systems that improves the flavour, color, bioavailability of nutrients. Nano composites used for food packaging and material coating can improve thermal and fire resistance capacity of food packaging. Nano sensors used in food packaging can easily detect any physical, biological or chemical changes during food processing. Smart packaging with nano sensors can detect chemicals, pathogens and toxins as well as environmental changes occurring in foods. Nano sieves can filter out harmful microorganisms. Nano sized nutraceuticals are used as nutritional food additives. The technology also raises health concerns due to the toxicological effects of nano particles on foods, with emphasis on risk assessment and safety issues. Also, this review reflects the urgent need to implement regulatory framework needed to manage the possible risks associated with the accidental or deliberate use of nano technology in food industry.***

Keywords: ***nano technology, nano capsules, nano sensor, nano composites, risk assessment.***

I. INTRODUCTION

Nanotechnology is a promising and innovative idea, crossing many technology boundaries. In this technology, nano particles and nano tubes with at least one dimension less than one nm have been developed. Due to their small size, they possess some specific physico-chemical properties e.g. strength, chemical reactivity, electrical conductivity, magnetism, optical effects etc. make them so applicable in different fields. Apart from these, their size distribution,shape and surface reactivity are also remarkable factors. Nanotechnology appears to find it's wide application in science and technology for manufacturing new particles at nano levels. Research in physics, biology, chemistry and engineering renders the exploration of the nanotechnology field[1]. Recently huge advances in nano technology opens up a new era in the sector of different industries. Nanoparticles are successfully used in consumer and personal care products e.g. transparent sunscreens, antibacterial clothing, scratch-resistant paint for cars, self cleaning windows etc. Certain industries e.g. aerospace, microelectronics, pharmaceuticles have already begun using nano technology. Food industry also has started to explore nanotechnology in it's various aspects. Food undergoes various post harvest processing-induced modifications, affecting their biological and biochemical makeup, so nanotechnology developments in biology and biochemistry sectors could eventually impact food industry. Naturally, systems with structural features falling within the length range of nano particles could affect the aspects from safety of foods to molecular synthesis. Recently, innovative nano technology has made revolutionary changes in food industry. Nano particles have found their feasibility in food packaging, processing, storage and development of innovative food products. Nano technology by using nano-sized nutraceuticals and health supplements improves the texture, flavour, consistency, stability, taste of food products. The anti-

microbial properties of nano particles makes them usable in food packaging materials to enhance their shelf life and safe for human consumption. Moreover, various nano-formulated agro-chemicals such as pesticides, fertilizers, biocides, veterinary medicines, antimicrobials, detoxifying substances, additives have been developed by using encapsulated nano particles [4]. In food processing industry, nano capsules have been used as nano-sized ingredients, additives and nutritional supplements. In functional foods, use of nano capsules as well as nano food additives have provided with protective barrier, taste and flavour masking, controlled release and better dispensability of water soluble food additives and ingredients. Public concerns regarding the adverse effects of nano particles to human health and environment is gradually developing. Hence, regulatory systems to reduce and control the risks associated with the use if nano particles in foods need to be established.

This review provides a comprehensive study on the contemporary applications of nano technology in food industry beginning from food processing and packaging to food safety and quality control. Emphasis have also been given on toxicity and health concerns due to incorporation of nano particles to foods with a brief overview on the regulatory outlook.

II. POTENTIAL FOOD APPLICATIONS

Although, nano particles are potentially useful in all sectors of food production and processing, most of the methods of nano technology are either too expensive or too impractical to implement then on a commercial level. Therefore, nano techniques are most cost-effective in the various sectors of food industry such as food formulation, product development, packaging and storage. This review mainly focuses on the application of nano techniques in those areas of food industry that have greater chance of commercial viability now and in near future.

III. FOOD PACKAGING

The novel food packaging technology perhaps is the most promising and largest commercial benefits of nano technology in food industry. Companies are already making food packaging materials based on nano technology ranging from films, carbon nano tubes to waxy-nano coatings for some foods to improve the shelf life, mechanical barrier, anti-microbial property and safety of food and drinks. Nano particles can be used as a vehicle to provide antibodies, vitamins, enzymes, anti-browning agents, flavours to extend shelf life of foods, even after opening.

IV. SMART PACKAGING AND ACTIVE PACKAGING

The relevance of smart packaging involves the use of nano technology to develop the anti-microbial packaging. Smart packaging incorporating nano particles can respond to environmental changes or repair itself or alert a consumer about the contamination/presence of pathogens in foods. Numerous companies and universities are developing a range of smart packaging materials that can absorb oxygen, detect pathogens and alert consumers of spoiled foods. These smart packages will be able to detect pathogens like Salmonella and E. coli in foods. Similar techniques have been developed in US to detect possible terrorist attacks on US food supply. Scientists in Netherlands have developed a smart packaging technology that will not only sense when the food will start to spoil but also release a preservative to extend the shelf life of that food.

V. USING CLAY NANOPARTICLES TO IMPROVE PLASTIC PACKAGING OF FOOD PRODUCTS

A transparent plastic film called Durethan containing nano particle of clay prevents the entry of oxygen, CO2 and moisture into flesh foods and other foods. The nano particles are dispersed into plastics and those plastics are lighter, stronger and more heat resistant[7]. Clay nano composites used in making plastic bottles increases the shelf life of beer up to 6 months. Several companies are working on this technology to enhance the bottle shelf life by about 18 months. Several large beer makers are already using this technology.

VI. USING NANO TECHNOLOGY TO DEVELOP ANTI-MICROBIAL PACKAGING AND ACTIVE PACKAGING

Nano particles developed from some metals and metal oxides such as silver, iron, titanium dioxide, zinc oxide, magnesium oxide, silicon dioxide and carbon nano particles have been used as anti-microbial agents in food packaging. Recently, TiO2 is widely used in food packaging as it releases reactive oxygen species (ROS) that are toxic to pathogenic microorganisms [3]. Antimicrobial effects of silver nano particles against E. coli and Bacillus cereus spores can be greatly increased if combined with TiO2 and carbon nano tubes. Silver-doped TiO2 are toxic to Bacillus spores on aluminium and polyester surfaces and destroyed air-borne bacteria and moulds when added to air filters. Silver nano particles can be stabilized by adding SDS or PVP and increases it's anti-microbial property against Staphylococcus aureus and E. coli [11][13]. Hence, surfaces of refrigerators and food containers are coated with silver nano particles to prevent them from food-borne pathogens. Effects of TiO2 nano particles against some food-borne pathogens like Salmonella choleraesuis, Vibrio parahaemolyticus and L. monocytogenes have been reported [9]. Starch based colloidal coating filled with anri-microbial nano particle have been effectively used in food packaging. Covalently attached vancomysin molecule to gold nano particles showed more potential to protect vancomysin-resistant bacteria. Lysozyme coated polystyrene nano particles exhibited antibacterial action against L. monocytogenes. When combined with nisin, phytoglycogen nano particles showed antimicrobial action against L. monocytogenes.

SENSORS AND "ELECTRONIC TONGUE TECHNOLOGY" IN PACKAGING

Scientists are working on nano particle films embedded with sensors that will detect food pathogens. In Electronic Tongue technology, sensors can cause color reactions in the packaging if the food is contaminated or has begun to spoil.

"RELEASE ON COMMAND TECHNOLOGY" IN PACKAGING

Researchers in Netherlands have invented this technology where preservatives will release if the food has begun to spoil by means means of a bio-switch developed by nano technology.

VII. USING FOOD PACKAGING SENSORS IN DEFENCE AND SECURITY APPLICATIONS

Researchers in US have developed biosensors in food packaging that will detect the presence of pathogens very quickly and easily and play a crucial role in the event of terrorist attack on food supply. US Department of Agriculture is working to develop a hand-held sensor that would be able to recognize a specific pathogen instantaneously in any food sample.

NANO ENCAPSULATION

Nano Capsules in the form of liposomes, micelles or protein based carriers are actually nano sized carrier systems which are used as food additives, supplements to mask the undesirable taste, flavour, increase the bioavailability and the dispersion of insoluble additives without the need for surfactants or emulsifiers. During encapsulation, nano composite polymer e.g. octenyl succinic anhydride polylysine is used to enclose the food additives for controlled release. Anti cancer effects of curcumin has been enhanced by encapsulating in hydrophobically modified starch. Use of lipid based nano encapsulation e.g. nanoliposome, nanocochleate, nanoarchaeosome as nano-delivery system for enzymes, additives, nutraceuticals and antimicrobials have been reported. Nano encapsulation of probiotics has been also targated to the specific regions of G.I tract [4].

Encapsulated nano materials are also used to produce nano-based agro-chemicals such as pesticides, fertilisers, biocides etc. Nano capsules are more potent, long-lasting and help in the controlled release of active ingredients. Nano capsules can be used in manufacturing animal feeds to add nano additives, anti-microbials and detoxifying compounds e.g myco-toxin binding.

NANO COMPOSITE

The development of nano composites is one of the most prevailing applications of nano particles. Nano composite can be used for packaging and material coating. Incorporation of nano scale fillers into polymer matrix makes it lighter, stronger, fire resistant, less permeable to gases and better thermal properties. Polymer silicate based nano composites have been developed to improve it's barrier quality, physical strength and thermal stability[10]. Nano-sized fillers namely montmorollonite, kaolinite clays, graphite nanoplates are used for food packaging to increase their permeability. Carbon nanotubes have been developed to punp out excess CO2 or absorb undesirable flavour have been also developed. Nanoclay in design of nanocomposite (bentonite) can be used to manufacture bottles and food packagings renders more gas-impermeable, O2 and moisture resistant, prevent drink destabilization and food spoilage. Incorporation of clay nano particles to foods provides O2 resistant capacity as well as improved shelf life. Different nano-sized filler and bio-polymers can be used to form bio-composite food packaging materials. Possible designs of bio-degradable nano composites by using starch, polylactic acid, polyhydroxybutyrate biopolymers have been reported. Large number of biopolymers e.g polyamides, nylons, polyolefins, polystyrene, ethylene vinylacetate, epoxy resins, polyurethane have been used in design of non-clay based nano-composites[13].

NANO SENSORS AND NANO SIEVES

The use of nano particles in making nano sensors is another innovative invention in the field of nano technology. They are useful for detecting toxins, pathogens, contaminants in foods as well as analysis of food flavour, color, drinking water etc. They aim to reduce pathogen detection time from days to hours or even seconds.They are placed on food packagings to detect the chemicals released during food spoilage. Nano sensors incorporated into food packaging can detect any physical, biological or chemical modifications of foods during processing [5]. Smart packaging with nano sensor can detect toxins, pathogens, chemicals. Smart packaging with nano sensor can also record the internal and external environmental changes. Nano sensors based on microfluidics devices can detect pathogens more efficiently in real time with higher sensitivity.

The use of micro and nano technologies in managing food quality and safety are more suitable as they are capable to detect and control any adulteration in packaging and storage conditions. Moreover, nano particles have been used as nano sieves to filter out bacteria. Several biosensors are available for detecting many common food-borne pathogens such as E. coli, Listeria monocytogenes, Salmonella sp, mycotoxins present in foods. Magnetic nanoglodimmuno sensor can be used to identify aflatoxins of Aspergillus flavus and A.paraciticus. Pathogen detectionof biosensors is based on their ability to vibrate at different frequencies in dependence on the biomass of the pathogenic microorganisms.

NANO-SIZED ADDITIVES AND NUTRACEUTICALS

Nano sized particles and nutraceuticals can be used as nutritional additives to foods e.g vitamins, antimicrobials, antioxidants, preservatives to improve taste, rate of absorption and bioavailability. Some nano additives such as lycopene, phytosterol, beta carotene have been used in carriers that can be incorporated into healthy foods to prevent the accumulation of cholesterol.

VIII. FOOD PROCESSING

Application of nano particles ro improve nutritional value, color, flavour, flow property, stability and shelf life. Further, nano technology may be used to develop healthy foods with low fat, sugar and salt content to prevent the development of degenerative diseases. SiO2 and TiO2 have been selected as permitted food additives. Effective hydrolysis of olive oil by using nanoscale SiO2 to provide stability has been reported. Development of designs of several micro and nano-structured assemblies of nano particles to encapsulate food additives, food ingredients, functional foods, nutritional supplements have also been reported.

IX. TOXICOLOGICAL ASPECTS OF NANO PARTICLES IN FOODS

Inspite of having a wider range of application in food industry, due to their increased contact surface area they might have toxic effects on human body that are not apparent in bulk materials. There is increasing public concerns regarding their toxic effects on human body and environment. As long as the nano particles remain bound to food packagings, they can not get exposed to human body directly. Risk begins when nano particles are transmitted to human body from foods incorporated with nano particles[1].

Recently, it was reported that TiO2 nano particle can induce tumor like cell growth in exposed human cells. In study it was also revealed that with decreasing size, the toxicity of nano particles also decreases. Nano particles with higher reactivity can even cross membrane barriers and capillaries [8]. Some nano particles can interact with certain proteins and enzymes, causing reactive oxygen species generation, oxidative stress, leading to mitochondrial destruction and apoptosis [2]. Although there is limited studies on the potential toxicity of nano particles on human body, but animal studies on their potency of toxicity have revealed adverse effects on liver, kidney and immune system. Therefore, risk assessment studies to evaluate detrimental effects of nano particles on human body need to be critically investigated.

X. REGULATION OF NANO TECHNOLOGY IN FOOD INDUSTRY

Though there are lots of opportunities for using nano technology for promoting food production, safety, preservation and quality, specific risk assessments and safety standards need to be met before introducing of any nano food to market [8]. In US, nano foods and food packaging are regulated by USFDA. In Australia, the production of nano additives is regulated by FSANZ [6]. The raising concerns about regulatory issues have enforced many countries to implement regulations to manage the risks that may be caused by consuming nano foods. Recently, EU regulation has made it mandatory that nano foods must undergo safety assessment before being authorised for use.

In August, 2006 FDA formed a Nano Technology Task Force that has the following goals:

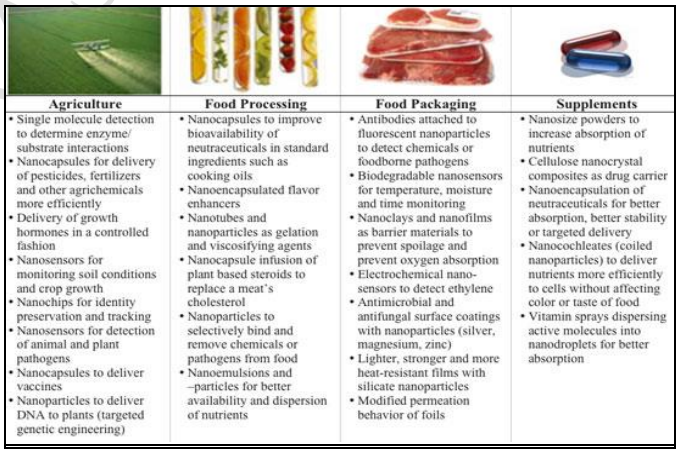
- ✓ To evaluate the effectiveness of regulatory approach of the agency to face any unique challenge that may be caused by the use of any nano food in FDA regulated products.
- ✓ Develop opportunities to foster innovation by using nano foods to explore safe and effective drugs, foods, feeds, cosmetics, biologics and devices.

In many other countries incomplete food safety regulations have been introduced due to lack of proper knowledge about exposure, toxicity and availability to human. In fact, there is urgent need for establishment of International Safety Regulations for using nano particles.

NANOFOOD, HOW FAR WE ARE?

The benefits of nanofoods-foods manufactured using nano technology are really miraculous. Back in the early 2000's, the topic of nano foods was very hot and many renowned food companies were eager to implement the nano technology in the production of various food products. But as critical voices of NGOs and food safety regulators appeared, the food industry got into silent mode [10]. This does not mean that nano food technologies are not researched in lab around the world. Here are some examples of applications of nano technology in food and agricultural fields:

APPLICATION OF NANOFOODS



Agriculture	Food Processing	Food Packaging	Supplements
• Single molecule detection to determine enzyme/ substrate interactions • Nanocapsules for delivery of pesticides, fertilizers and other agrichemicals more efficiently • Delivery of growth hormones in a controlled fashion • Nanosensors for monitoring soil conditions and crop growth • Nanochips for identity preservation and tracking • Nanosensors for detection of animal and plant pathogens • Nanocapsules to deliver vaccines • Nanoparticles to deliver DNA to plants (targeted genetic engineering)	• Nanocapsules to improve bioavailability of neutraceuticals in standard ingredients such as cooking oils • Nanoencapsulated flavor enhancers • Nanotubes and nanoparticles as gelation and viscosifying agents • Nanocapsule infusion of plant based steroids to replace a meat's cholesterol • Nanoparticles to selectively bind and remove chemicals or pathogens from food • Nanoemulsions and –particles for better availability and dispersion of nutrients	• Antibodies attached to fluorescent nanoparticles to detect chemicals or foodborne pathogens • Biodegradable nanosensors for temperature, moisture and time monitoring • Nanoclays and nanofilms as barrier materials to prevent spoilage and prevent oxygen absorption • Electrochemical nano-sensors to detect ethylene • Antimicrobial and antifungal surface coatings with nanoparticles (silver, magnesium, zinc) • Lighter, stronger and more heat-resistant films with silicate nanoparticles • Modified permeation behavior of foils	• Nanosize powders to increase absorption of nutrients • Cellulose nanocrystal composites as drug carrier • Nanoencapsulation of neutraceuticals for better absorption, better stability or targeted delivery • Nanocochleates (coiled nanoparticles) to deliver nutrients more efficiently to cells without affecting color or taste of food • Vitamin sprays dispersing active molecules into nanodroplets for better absorption

Examples for nanofood applications (Source: Nanowork)

Huge Western companies are working on developing nano foods, really nano food industry is a global phenomenon .In Australia, white breads are fortified with omega-3 fatty acids by using nano capsules containing tuna fish oil. According to the manufacturer, nano capsules of tuna fish oil not only provides the bread with essential nutrients, but encapsulation also prevents the breads from tasting fishy. In Israel, using NSSL technology, a healthier version of canola oil have developed. Besides, this technology also allowed the encapsulation of nutraceuticals, cosmeceuticals, essential oils, drugs in pharmaceuticals, foods and cosmetics[12]. Researchers in Tamilnadu's Agricultural University in India are trying to develop a weed seed coating by using nano technology to prevent the germination of weeds. Thus, the extent of research on nano technology and nano foods are growing enormously.

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XI. CONCLUSION

As development in nano technology continues to occur, it's applicability in food industry wiil surely increase. The aspect of nano technology in improving food quality wiil perceive as progressive changes in standard and accepted technology. Few health issues caused by deliberate or accidental use of nano technology in foods or food contact materials may provoke public concerns. It is therefore important to insure that consumers must have proper access to know about the merits and demerits of nano foods. The success of nano foods depends on the customer acceptance and exploration of regulatory systems. In this context, the manufacturers and companies must come forward to maintain the safety issues of foods. Many food companies are now conducting food research in nano technology to explore more new nano foods. Nano technology has already has made it's way in food industry and it is repoted that already 300 nano foods have been developed by using this technology. In future to sustain the leadership in food industry, companies must work with nano technology. The future belongs to new products and new techniques to ensure the safety and quality control of foods with the motto of customizing and personalizing the products.

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