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Prospect of nanotechnology in food and edible packaging: A review

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Abstract
Nanotechnology represents an efficient and important tool for increasing the shelf life of food. Reducing the size of Nanometric scale gives material distinct and improves the properties when compared to a larger system. Edible coatings are usually prepared with the help of natural polymers that are non-toxic, economical and readily available. The new tendencies are to use edible coating as carries of functional ingredient by incorporating antimicrobial, ant browning, and nutraceutical agent to improve the quality of fruits and vegetables. In recent research, it has been found that nanotechnology can bring revolutionary changes in various department of food, post harvesting management, food storage and packaging, bio sensor, medicine, nutrient and nutraceutical delivery, ingredients and additives, and also bioprocessing of food.

Keywords: Nanomaterial, nanoparticle, packaging, edible coating

Introduction
Norio Taniguchi, for the first time in the year 1974, used the term "Nanotechnology" and the information was deeply given by Richard Feynmane and gave aknowledge about carbon based structure like buckyball. Normally 1-100 nm is size considered as nanomaterial. Nanomaterial size less than 100 nm is very useful in latest technology development (Paul *et al.*, 2019) [33]. It is also used in harvesting, food processing and modifications of food processing and all those technology attached with biological makeup. (Thiruvengadam *et al.*, 2018) [39] In the coming years, we can see many changes in food industry throw the nanotechnology. It is built in two forms: food additive (nanotechnology is inside of packaging) and food packaging (nanotechnology is outside of packaging). A food additive are use for increasing the shelf life of product, nutrient factors, flavor, and texture and also helps to detect the food pathogens. Nanoparticles has limited diameter and high surface area for reactions and its beneficial for metallic nanoparticles that attracts more consideration (Hamelian *et al.*, 2018) [21]. Recently, many nonmetallic particles are give good chemical, magnetic, optical electronic properties that's why they use in nanosensors and nanoparticles based edible coating. Every year near about 25% to 80% of harvested fruits and vegetables lost because of spoilage. (Hamelian *et al.*, 2018) [21] Edible coating concept helps to increase consumption of raw and perishable vegetable and fruits and control the horticulture crop losses (Nisha *et al.*, 2016; Hazirah and Armylisas, 2016) [30]. Edible coating base material has developed by polysaccharides, proteins and lipids. Chitosan will be used in organic based coating for preventing food spoilages and contaminations. According to Zambrano-Zaragoza *et al.*, (2020) [44] edible coating controls the respiration rate, control microbial growth during preservation of fruits and vegetables.
In food packaging nanotechnology give positive response and also inorganic and organic nanoparticles are use in edible coating. (Saravanakumar *et al.*, 2020) [36] Inorganic nanoparticle like silver np, titanium oxide np, zinc oxide np, silver oxide np are mostly use in food packaging as a detector, control the food borne diesis and increasing the shelf life of the poultry meat, citrus juice, melon slides, beef meat exudates. Bio material based packaging materials are on demand because of they are non-toxic, biocompatible & environmentally friendly and used to control the humidity, toxic gases and lipids between food and outside of packaging material. Smart packaging gives the information regarding the internal environments and also gives data about how much food spoil and how much food is sheaf. During transportation smart packaging is very helpful because they have a time indictors.(Nile *et al.*, 2020) [29] In Nanotechnology various types of nanobiosensors are available and those are used in detecting size, color, shape of fruits and vegetables.

("Enhancement the antibacterial agent of edible coating and films by incorporating it with green metallic nanoparticles using Luria mobiles leaves," 2020) [14] Latest nanosensors are useful in detecting juice content in the orange. In 2006 FDA defined nanomaterials as "particles with dimensions less than micrometer scale that exhibit unique properties". Thus in this review different types of nanomaterials and their varied range of applications in food has been discussed in detail

Nanoparticles in food formulations

Nanotechnologies are applied in food production machinery. Some attentions may be required for different types of nanomaterials for filters or coatings, but each particle is not good for nanotechnology and nano materials. Now a day's nanotechnology is mainly focus on agro chain business and scientists are doing research on nano size additives, nano-biosensors, attractive packaging those gives all information about inside the packaging.

Nanocapsule

Functional ingredients like drugs, vitamins, colorants, antimicrobials etc all those are classify in molecular weight, physical and chemical properties (GuhanNath *et al.*, 2014) [20]. All those ingredients are hardly used in nanocapsule as original form and they are gives very frequently result in fraction of the seconds. (Nile *et al.*, 2020) [29] Food additives are used as a delivery vehicle because they can help to delivery of functional food at targeted place. Secondly, functional ingredient may have to be protected from chemical or biological degradation. Third, they have control regarding the release quantity and it also detects the environment conditions then after release the drug or food ingredient. Fourth, the delivery system with the other components in the system has to be compatible, as well as with the physiochemical and qualitative attributes of end product. Some types of delivery techniques are use in under nanotechnology.

- Association colloids
- Bio polymeric nanoparticles
- Nano emulsion and so on.

The above mentioned points are discussed below:

Association colloids

A colloid system is a mostly useful system to spared tiny particles in around the surface and it's under controlled (GuhanNath *et al.*, 2014) [20]. Tiny particles are combined and make small atom or molecule under association colloid system. (Bahrami *et al.*, 2019) [6] some of the examples of colloid such as surfactant micelles, vesicles, bilayers are used to summarize and carry all type of food additives. Association colloid is one type of hydrophobic and naturally favorable process. Colloids are decrease connection between nonpolar materials. Surfactant molecules, co surfactant molecules, different concentration and other parameter (PH, Temperature) are affected on association colloid structure. Association colloid size is between diameters 15-100nm ranges because of that it is including in nanocapsles. Association colloid process is suitable in any environmental condition and transparent material that is main benefit of this system.

Bio polymeric nanoparticles

In nanometer rang biopolymers are developed by using food grade biopolymers via accumulation of polysaccharides or proteins or phase separation method (GuhanNath *et al.*, 2014) [20]. Polylactic acid (PLA) is mostly use in drug supplier; also provide food additives and some vitamins. (Ahmed *et al.*, 2019) [1] BSA and Sodium alginate are also nano particles based bio polymer it's develop by using emulsion solidification method. Polyalkylcyanoacrylate and polyanhydride are synthetic bio polymers those are created by nanomaterial. Gelatin and albumin proteins based bio polymeric nanoparticles are non-toxic and easily biodegradable. Albumin protein is a low immunogenic but they play role as extracellular antioxidant. Additionally they do attach to any other free radical and stop the harmful effect. Protein bio polymeric nanoparticles have a number of advantages that's why they got premier place.

Nano-emulsions

An emulsion can be defined as the mixture of two or more liquids that are not combine easily ("Enhancement the antibacterial agent of edible coating and films by incorporating it with green metallic nanoparticles using Luria mobiles leaves," 2020) [14] Normally nanoemulsion have 500 nm diameter but when solution pass under high pressure gauge homogenizer particle size is change under 50- 500nm range because of the food additives and food drugs in combined with the nano droplet at any phase. (Godbole, 2018) [19] Nano emulsions have varies physical and chemical properties. They are using these properties to make number of multiples or multilayer nano emulsions those are helpful in targeted delivery system as per particular environmental conditions. Some company such as Vadilal, Nestle are make nanoemulsion based frozen yogurt.

Nanofibres

Nanofibres have a high surface area to volume ration, range between 10-500nm rang (Guhan *et al.*, 2014) [20]. It has physicochemical properties those are helpful in artificial food development, make more attractive. (Paul *et al.*, 2019) [33] All well as use in bioactive compound for targeted delivery and bio sensors. Nano fiber is give stage to develop bacterial culture. Eco friendly food packaging are made and created varies type of food matrix due to the nanofibres. Now century, Researcher is mainly focus on development of nanofibres based biopolymer.

Nanocapsules

A nanocapsule is latest drug carrier system. Now days, nanocapsule is a famous as a nanovesicular process that is denoted inner core structure in which drug holder place. (Ravichandran, 2010) [35] Nanocapsules given protection against moisture content, temperature, PH value and oxidation- reduction. Nutraceutical material is transfer by using casein micelle based capsules or nanocarrier. Casein micelle carrier is very use full because of its stability and good sensing nature. Improving bioavailability in gastrointestinal food supplements are need those are providing throw the Nanocapsule.

Nanostructures and Nanoparticles in food

Nanotechnology is already present in nature like starch, it is a crystalline structure and process starch is converting in to gelatinization form. (Xing *et al.*, 2019) [42] During digestion starch is convert in gel formation at that time we can see 2D (two dimensional) nanostructure and it is nutritional benefit for human body. Nanostructure has good self control

properties of food and milk based product because of oil in water phase and air in water phase. Example of oil in water is milk, mayonnaise and air in water is tiny bubble in surface of cold drinks glass. Molecules stability is decides by using interface and provide example of 2D nanostructure. Surfactants are available in many foods structure that why unpredictability produces. Guhan *et al.*, (2014) [20] have also reported different type of raw material and latest technology based food processing, adjustment and build up of self developed nanostructure. (Nile *et al.*, 2020) [29] Additionally with the help of atomic force microscope we can easily understand of interaction between proteins and other molecules. Build the certainty of the protein that can be help in making khoya, paneer, etc.

Nanoparticles in food quality easement (Biosensors)

In resent year various technologies have developed in nanotechnology based on application in food safety like biosensors, detection system etc. (Paul *et al.*, 2019) [33] has focuses on research works and production. These technologies are giving potential benefits to both the public and private sector. Main applications of biosensor in food sector are upgrade in product quality control, traceability and food safety. The advantage of nanobiosensors in various production specters: raw material preparation, processing of food department, main monitoring of storage conditions. These are use as a cost effective tools for controlling quality & process controls as well as ensure the food safety.

Wegari Dera and Bogale Teseme (2020) [41] have developed novel nanomaterial with modifying electrode surface so that it can give faster electron transfer of bimolecular and also give better accuracy. This advantage has inspired research in coupling nanomaterial base biosensors. These types of sensor are applied in food safety, clinical analysis and environmental control. US University is developing "electronic tongue" for a food packaging material. The tongue is detecting the highly sensitive gases released by food. When gases are released, at that time sensor strip changes color and give clear visible signal about whether it is good for eat or not. Agro Micron has researched regarding the Nanobioluminescence detection spray where a detector such as luminescent protein. EU scientists developed the portable nanosensors to detect some chemical pathogens and toxin in food. In this project, they also developed DNA biochips based on another device that can detect pathogens (Thiruvengadam *et al.*, 2018) [39]. The technique is used to detection of harmful bacteria in fish and meat based product. In fruit, plant and water large amount of organophosphate is available with the help of pesticide detection based nanosensors so to clearly identify. Pesticides are easily soluble in water which is why they are speeded in all over the farm and reaches to the table. Semiconductor and metal based nanoparticles nanotubes have great optical and mechanical properties, and helps to increase the sensitive transducer signal improvement. Fluorescent semiconductor nanoparticles are used for detection of high sensitive pesticide.

Biosensor rapidly detects the pathogen of the food borne diesis in food and beverages, on the farm or during processing, in the laboratory or even better in storage. Salmonella and E.coli are mostly available in common food contamination. Streptavidin-coated ferrofluid (Fe_3O_4 nanoparticles) based biosensor used to detect the Salmonella bacteria. Here (Fe_3O_4) was used to improve the signal. Cheng *et al.* (2008) [9] developed Perfluorosulfonated cation-exchanger polymer with multiwalled carbon nanotubes based amperometric sensor to detect coli forms. E.coli. construct single bacterium detector in this sensor hetero-structured silicon/gold nanorode array functionalized with Salmonella antibodies.

Health consequence of nanoparticles

Nanotechnology has gave different types of material and unique products in various different areas (Thiruvengadam *et al.*, 2018) [39]. There have a better application in manufacture sector and domestic sector. When normal material convert in nanometre size then after improve safety issue regarding workers, customers as well as the human environment. Nanoparticles also hazards for human body and wildlife due to their small size.

Thiruvengadam *et al.*, (2018) [39] studied about toxicity of CuO nanoparticles on human blood lymphocytes. In human body Cu play very important roll. Particularly is used in the field of pharmaceutical, engineering and technical. CuO nanoparticles have been utilized as a semiconductor, catalyst, gases and solid ceramic pigment and sensors. In pharmaceutical field CuO–NPs is also useful in preventing and protecting human body and every disease that are occurred through Escherichia coli and staphylococcus aurous. Also some toxicity has been noted in many studies: see cell death in human lymphocytes because of CuO-NPs. In CuO-NPs have changes of glutathione levels, which trigger lipid per oxidation in the cell that oxidation stress induced. Mostly CuO-NPs was affected on two cells which include the liposome and mitochondria. The concentration of CuO-NPs related to human exposure levels can suppress the human immunity system by induction of cell death in lymphocytes.

For the first time Scientists have found out a mechanism by which nanoparticles causes damage to lung and have shown that it can fight back by blocking the process involved, taking a step towards directing the growing concerns over the safety of nanotechnology.

Nanotechnology is an industry with a projected annual market of around one trillion US dollars in the year 2015. It involves in controlling the atoms and molecules in order to create a new materials with a variety of useful functions, including many that could be really beneficial in medicine. Although it is not clear that how the nanoparticles causes damage to lungs.

Nanopackaging

The main goal of packaging is to physical protection in order to protect the food from external shocks and vibrations, microbial infestation and also to give protection against the temperature providing barrier protection by scavenging oxygen and other hazards gases. (Al-Naamani *et al.*, 2016) [3] Now a day's packaging material are made by biodegradable material and green synthesis based nanoparticles that helps to reduce the environment pollutions. Nanoparticles could impart as their active and intelligent properties to food packaging as they can protect the food against the external facture (Al-Naamani *et al.*, 2016) [3]. Nanoparticles based material improves various properties like barrier properties to moisture, UV- protection, gasses and some volatiles components, thermal resistant, mechanical strength and seal ability. Nanotechnology also has shown its potential future in smart packaging. (Bahrami *et al.*, 2019) [6] Nanoclay provide gas barrier, for antimicrobial protection nano – Zinc oxide and nano – Silver oxide, for UV protection use nano – Titanium dioxide, nano – Titanium nitride for mechanical strength and

nano silica use for surface coatings etc.

Across the world nanotechnology has already immerged with packaging industries with extraordinary systems. Paul *et al.*, (2019) [33] have reported applicability of silver nano particle with some types of polymeric material such as PVC, PE, and PET etc. Silver nano particles helps to kill bacteria, fungus, viruses and pathogens and are used as a better and safe packaging material. For storage of milk, juice and other perishable food nanoparticle based packaging material is 100 times better than the regular packaging. In food packaging material one film namely "hybrid system" has a number of silicate nano particles. They mostly stop the entrance of oxygen and other food spoilage gases and also remove moisture and volatiles thus protect the food from drying. They also helps in modifying the permeating behavior of foils improve mechanical and heat resistance and increasing the barrier properties of packaging material.

(Zambrano-Zaragoza *et al.*, 2018) [44] Many types of nano particles shows good results for packaging materials like TiO_2, SiO_2, silver nano particles, nano clay etc. TiO_2 is UV resistant, transparent and is also sold by many companies as a filler particle in foils or plastic containers. Approved by food department so many safety data refers to the larger form of TiO_2 and still have no record of any type of investigations to prove whether packaging material containing Nano TiO_2 is only inert (not generally reactive) as those containing the high "bulk" form. It cannot be ruled out that nano TiO_2 particles migrates from packaging to the food and all the particles provide protection for the food for example controlling the permeability of foils, blocking UV light and act against the bacteria and fungi. Paul *et al.*, (2019) [33] produced nanocomposite films with the help of polybutylene adipate-co-terephthalate (PBAT) and silver nanoparticles. At 435 nm range, it has showed maximum plasmonic absorbs the silver nanoparticles. Moreover, it improves water permeability and tensile strength of film. Enormous potential and nanocomposite are the least material that are used in production of active packages. In Europe, polymer nano composite industries are use in this type of material but are going slow. The main reasons are acceptance by customers in market, the cost price of material and processing, restriction due to the legislation, lack of knowledge and influence of nanoparticles on the ecological and on human health. In this type of film, it has high surface to volume ration of nanofillers which is why they are protected for microbial spoilage.

Chitosan, gelatin, poly lactic acid, alginate and polyglycolic acid, blends of starch and sodium caseinate are some of the material used in the production of bio plastic with application in edible thin film. The edible film can be developed from edible nano laminates that mostly protect the food from lipids, gases, off-flavor and orders. This type of material can be prepared with polysaccharides, lipids or proteins. Lipid based film provides barrier against oxygen and carbon dioxide but this film is not protected against moisture. Lipid film is good but they offer limited resistance.

Inorganic nano-particles

Inorganic nano-particles are becoming popular due to their widespread applicability. Different applications of inorganic nano-particles in edible coating have been shown in Table 1.

Metal oxide nanoparticles based coating

Edible coating developed by incorporating metal oxide nano-particles *viz*. Titanium dioxide (TiO_2) and Zinc oxide (ZnO) nanoparticles are reported to have better moisture barrier properties (Nasim *et al*. 2019; Seyed Amir *et al*. 2016; Xin Zhang *et al*. 2019) [42]. (Nasim *et al*. 2019) [29] Has developed sesame protein isolate based bionanocomposite film using casting method and reported better mechanical and water barrier properties due to addition of 3% w/w of TiO_2 nanoparticle in SPI film at that time. Additionally TiO_2 nanoparticle based film exhibited better oxygen scavenging agility and the pigment of photo degradation potential is noted at accepted level. (Mahmood *et al*. 2017) improved efficiency of cellulose nanofibres (CNF) due to incorporation of TiO_2 nanoparticle. Xin Zhang *et al*. (2019) [42] also reported better water resistant properties, mechanical strength and improved ethylene scavenging properties for the edible film based on black plum peel extract (BPPE), Chitosan (cs) and TiO_2 based nanoparticle. Bahram fathi-Achachlouei *et al*. (2018) [6] reported UV- shielding and also provides mechanical properties for nanocomposite films based on novel carboxymethylcellulose (CMC), sodium montmorillonite (Na-MMT) and titanium dioxide (Tio_2) nanoparticles, respectively. Similarly (Aswathy Jayakumat, 2019) [24] reported enhanced water registrant properties, UV resistance, mechanical and chemical properties for PVA-starch based film in combination with nutmeg oil, ZnO nanoparticles and jamun extract. ZnO nanoparticle based composite film has been found to their antimicrobial properties (Emamifar and Mohamadizadeh *et al*. 2020) [13]. Also reported antimicrobial properties of chitosan zinc oxide nanocomposite coating on PE films. Recently Joshy *et al*. (2020) [25] have reported applicability of ZnO encapsulation xanthan-based edible coating in controlling weight loss of fresh produces. (Emamifar and Mohamadizadeh *et al*. 2020 [13] have reported antimicrobial strawberry juice packaging put in ultrasonication and a significant changes been noticed under 4 and 12 min time as compared to other sample and both the time have given the same treatment, which is why +US 4 treated showed the highest ranked sensory attribute was found compare to other and + US 12 treated packaging controlled the microbial growth.

Silver nanoparticle based films

Silver nano-articles Kandasamy *et al*. (2019) [26] have reported extended shelf life of cut fruits coated with silver nanoparticles; which was found to be effective in controlling the toxicity of pathogens. (Nicolli *et al*. 2016) [30] reported about control lactic acid bacteria on chicken sausages for 30 days with the help of silver nanoparticle, D-glucose and green route based film. Has reported improve efficiency of kinnow fruit for 4 months at 4 °c and 2 months at 10 °c due to incorporation of silver nanoparticles, carboxy methyl cellulose, guar gum powder.

Organic nanoparticles (organic synthesis)

Now a day's edible coatings are being developed by using organic nano-materials, which are effective in maintaining post-harvest quality and control loss of horticulture crop loses (Table 2).

Chitosan

Earlier studied have reported that chitosan based edible coating delays the decay of the horticultural produces (Eshghi *et al.*, 2014; Esyanti *et al.*, 2019) [15, 16]. (Eshghi *et al.*, 2014) [15] has reported effect of nanochitosan (50-100nm) based edible coating on strawberry. Without Copper and with copper loaded nanochitosan based fruit store under 4°c and

70% RH for 20 working days. Both the coatings gave good result but without copper loaded nanochitosan based coating is better than copper loaded strawberry. Anthocyanin level is increases in those fruits are coated without copper concentration and anthocyanin is decrease in with copper coated fruits during 12 days. Copper loaded nanochitosan based strawberry fruit gives very fast reduction of ascorbic acid content and shows unaccepted response on nutritional value. It also shows visual damage in nanochitosan based coating but delays in color changes, off flavor development and dehydration.

(Esyanti *et al.*, 2019) [16] Have reported the utilization of chitosan based nanoparticles as good coat and noted its effect on (Musa acuminate AAA group) Cavendish banana ripping process. In this paper, synthesized and characterized chitosan nanoparticle is studied and it shows that the chitosan nanoparticles rapping effects on the fruit ripening process. Ionic gelation method could be used for synthesis of chitosan nanoparticles with average size ranging 102.4 – 370 nm and the polydispersity index of 0.251 – 0.303. In Fourier Transform Infrared Spectroscopy (FTIR) shows that the one new peak indicates the amine group in chitosan and tripolyphosphate group in NaTPP. Surface of banana analyzed by the Scanning Electron Microscope (SEM) shows a smoother skin contour on coated banana compared to without coated banana. Fruit coated with chitosan nanoparticles 0.2% has a slower skin discoloration by 2-3 days compared to control treatment.

(Nisha *et al.*, 2016) [30] Reported effectiveness of chitosan based film for controlling microbial activity. Chitosan based coating affects positively on the apple and tomato. Chitosan silver nanocomposite based coated samples have showed delay in time of ripening of the fruits in compared to other two groups. Chitosan and silver nanocomposite based coating controls the moisture content between the fruits and the external environment. Eman *et al*. (2020) [13] developed edible film of gelatin powder incorporated with $AgNo_3$ nanoparticles. Luria leaves and glacial acetic acid are used for development of silver nanoparticles. They have reported prolong shelf life of strawberry during storage at 0.5°C and 90-95% relative humidity for 12 days due to antimicrobial action of silver nitrate $AgNO_3$.

Bio-based coating

Vegetable based oil is mostly used in fruit and vegetable coating because the application of nanotechnology based strategies for bio-based edible coating improved moisture barrier properties and extended shelf life of fruits and vegetables. (Hazirah and Armylisas, 2016) [23] Has reported promising results for bio-based edible coating of palm oil. Palm oil has a two fractions palm stern and palm olein and is mostly helpful in development of edible based nano coating materials. Apart from being safe, non toxic and biodegradable that has high productivity of oil palm ensures continuous supply of the raw materials. Palm oil based nanocoating is effective in inhibit enzymatic browning and provides prolong the shelf life to raw produces. (Zambrano-Zaragoza *et al.*, 2020) [44] studied about beeswax based edible coating on fruits for increasing storage life of strawberry fruit. These edible coating is made by using xanthan gum and propylene glycol and different concentration of beeswax solid lipid nanoparticles (BSLN). All concentration is applied on strawberry without any outer treatment. They have found L best result for 10 g/ BSLN and noted low weight loss compared to higher concentrations of BSLN.

Table 1: Inorganic nanomaterial and its application

No.	Nanomateriales	Application	Example	Reference
1	Nano silver	Strong disinfection & Storage Rich in 22 essential vitamins and minerals Sterilization & quality control Antibacterial Antibacterial agent	Nano-silver salad bowl, storage box, Daily vitamin Boost Nano colloidal silver Nano silver sol. Food packaging	(Nile *et al.*, 2020) [29]
2	Silicon dioxide	Biosensor Prevent UV light Pesticides & herbicides Edible coating	Detect food colorant hygroscopic, drying agent Food packaging Fruits and vegetable based coating	(Jones *et al.*, 2008) [25]
3	Titanium dioxide	Biosenser	Used as whitener in dairy (milk, cheese)	(Zhao *et al.*, 2008) [44]
4	Nano clusters Iron np 30nm	Development of functional food	Nano cuticles slim shake vanilla, fortified fruit Juice	(Nile *et al.*, 2020) [29]
5	Zinc oxide	Food preservations Edible coating	Antimicrobial agent Improve strawberry, banana etc. fruits properties	(Zhao *et al.*, 2008) [45]
6	Nano Gold	Detector	Pathogen, glucose detector	(Zhao *et al.*, 2008) [45]
7	Carbon Nano Tube	Food packaging	Wine, honey	(Nile *et al.*, 2020) [29]

Table 2: Organic nanomaterial and its application

No.	Nanomaterials	Applications	Examples	References
1	Nano liposome	Food processing	Specific delivery of nutraceutical Active and passive delivery of gene, protein & peptide Delivery of pesticides fertilizers	(Nile *et al.*, 2020) [29] (Pradhan *et al.*, 2015) [34]
2	colloidosomes	Food processing	Increasing the nutrient content of food	(Nile *et al.*, 2020) [29]
3	Chitosan np	Food processing (functional food)	Encapsulation antimicrobial agent plant growth promoting agent	(Jones *et al.*, 2008) [25]
4	Casein micelles	Nutritional supply	delivery sensitive product	(Nile *et al.*, 2020) [29]
5	Alginate & chitosan	Target delivery supply	Supply B-carotene, lycopene, vitamins A, D, E_3, Omega -3-fatty acids	(Nile *et al.*, 2020) [29]
6	Nanocochleates	Nutritional supply	Nutrients are efficient deliver without affecting color and test	(Gommans *et al.*, 2006) [19]

Conclusion

There is no doubt that Nanotechnology in the food industry has become gradually important. Food innovation has been observed as a sector where in the coming years the nanotechnology is expected to play a major role. Resources of Nano food packaging will improve the safety of food, nourishment of life and most importantly repairs any holes and tears present in packaging. Additionally Nano food packaging also helps in adding substances for increasing the life of food in terms of packaging. New and innovative nanotechnology has an exceptionally extraordinary property in food source chain such as precision farming technique, smart feed, improvement of food texture and quality, packaging, labelling, as well as the use of agrochemicals such as nano-fertilizers, nano-herbicides, and nano-pesticides etc, around the whole agricultural sector. Finally, nanotechnology enables to change in the existing food systems and processing to make sure that the products are safe, by creating a healthy food culture, and enhancing the nutritional quality of food.

References

1. Ahmed T, Hyder MZ, Liaqat I, Scholz M. Climatic conditions: Conventional and nanotechnology-based methods for the control of mosquito vectors causing human health issues. International Journal of Environmental Research and Public Health 2019;16:1-25.
2. Akhavan S, Assadpour E, Katouzian I, Jafari SM. Lipid nano scale cargos for the protection and delivery of food bioactive ingredients and nutraceuticals. Trends in Food Science and Technology 2018;74:132-146.
3. Al-Naamani L, Dobretsov S, Dutta J. Chitosan-zinc oxide nanoparticle composite coating for active food packaging applications. Innovative Food Science and Emerging Technologies 2016;38:231-237.
4. Alizadeh Sani M, Ehsani A, Hashemi M. Whey protein isolate/cellulose nanofibre/TiO2 nanoparticle/rosemary essential oil nanocomposite film: Its effect on microbial and sensory quality of lamb meat and growth of common foodborne pathogenic bacteria during refrigeration. International Journal of Food Microbiology 2017;251:8-14.
5. Assadian E, Zarei MH, Gilani AG, Farshin M, Degampanah H, Pourahmad J. Toxicity of Copper Oxide (CuO) Nanoparticles on Human Blood Lymphocytes. *Biological Trace Element Research* 2018;184:350-357.
6. Bahrami A, Delshadi R, Jafari SM, Williams L. Nanoencapsulated nisin: An engineered natural antimicrobial system for the food industry. Trends in Food Science and Technology 2019;94:20-31.
7. Boruah H, Dash KK, Mohanta D, Borah AJ, Chabukdhara M. (n.d.). Colocasia starch / zinc oxide nanocomposite film as a sustainable material for food packaging applications.
8. Carrillo-Inungaray M *et al*., Advances and Perspectives. Use of Nanoparticles in the Food Industry: Advances and Perspectives 2016;27:419-444.
9. Charles J, Hunt JA. Heterotopic bone formation in abdominal incisions. Hawaii medical journal, 1992;51:65-69.
10. Das RK, Pachapur VL, Lonappan L, Naghdi M, Pulicharla R, Maiti S *et al*. Biological synthesis of metallic nanoparticles: plants, animals and microbial aspects. Nanotechnology for Environmental Engineering, 2017;2:1-21.
11. Durán N, Marcato PD. Nanobiotechnology perspectives. Role of nanotechnology in the food industry: A review. International Journal of Food Science and Technology 2013;48:1127-1134.
12. Ealias AM, Saravanakumar MP. A review on the classification, characterisation, synthesis of nanoparticles and their application. IOP Conference Series: Materials Science and Engineering 263, 0-15.
13. Emamifar A, Mohamadizadeh M. Influence of sonication and antimicrobial packaging-based nano-ZnO on the quality of fresh strawberry juice during cold storage. Journal of Food Measurement and Characterization 2020.
14. Enhancement the antibacterial agent of edible coating and films by incorporating it with green metallic nanoparticles using Luria mobiles leaves 2020;8:80-97.
15. Eshghi S, Hashemi M, Mohammadi A, Badii F, Mohammadhoseini Z, Ahmadi K. Effect of Nanochitosan-Based Coating With and Without Copper Loaded on Physicochemical and Bioactive Components of Fresh Strawberry Fruit (*Fragaria x ananassa* Duchesne) During Storage. Food and Bioprocess Technology, 2014;7:2397–2409.
16. Esyanti, R.R., Zaskia, H., Amalia, A. & Nugrahapraja, D.H. (2019). Chitosan Nanoparticle-Based Coating as Post-harvest Technology in Banana. Journal of Physics: Conference Series 1204.
17. Fathi Achachlouei B, Zahedi Y. Fabrication and characterization of CMC-based nanocomposites reinforced with sodium montmorillonite and TiO2 nanomaterials. Carbohydrate Polymers 2018;199:415-425.
18. Fathi N, Almasi H, Pirouzifard MK. Sesame protein isolate based bionanocomposite films incorporated with TiO2 nanoparticles: Study on morphological, physical and photocatalytic properties. Polymer Testing 2019;77:105-919.
19. Godbole SS. Comparative Study on Purification of Drinking Water Stored in Copper and Brass Vessels to Prevent Waterborne Diseases 2018, 39-43.
20. Guhan Nath S, Sam Aaron I, Raj AAS, Ranganathan TV. Recent innovations in nanotechnology in food processing and its various applications - A review. International Journal of Pharmaceutical Sciences Review and Research 2014;29:116-124.
21. Hamelian M, Zangeneh MM, Amisama A, Varmira K, Veisi H. Green synthesis of silver nanoparticles using Thymus kotschyanus extract and evaluation of their antioxidant, antibacterial and cytotoxic effects. Applied Organometallic Chemistry 2018;32:1-8.
22. Han JH. Edible Films and Coatings: A Review. Innovations in Food Packaging: Second Edition. Elsevier Ltd 2013.
23. Hazirah SMF, Armylisas NAH. Nanomaterials – Recent Advancements in Edible Coating Technology. *Palm Oil* Developments 2016;66:1-4.
24. Jayakumar AKV, HTSS, Joseph M, Mathew SGP, Nair IC, EKR. Starch-PVA composite films with zinc-oxide nanoparticles and phytochemicals as intelligent pH sensing wraps for food packaging application. International Journal of Biological Macromolecules, 2019;136:395-403.
25. Joshy KS, Jose J, Li T, Thomas M, Shankregowda AM,

Sreekumaran S *et al*. Application of novel zinc oxide reinforced xanthan gum hybrid system for edible coatings. International Journal of Biological Macromolecules 2020;151:806-813.
26. Kraśniewska K, Galus S, Gniewosz M. Biopolymers-based materials containing silver nanoparticles as active packaging for food applications–A review. International Journal of Molecular Sciences 2020, 21.
27. Kumar A, Gupta M. Synthesis and surface engineering of iron oxide nanoparticles for biomedical applications 2005;26:3995-4021.
28. Marchiore NG, Manso IJ, Kaufmann KC, Lemes GF, Pizolli AP, de O *et al*. Migration evaluation of silver nanoparticles from antimicrobial edible coating to sausages. LWT - Food Science and Technology 2017;76:203-208.
29. Nile SH, Baskar V, Selvaraj D, Nile A, Xiao J, Kai G. Nanotechnologies in Food Science: Applications, Recent Trends, and Future Perspectives. Nano-Micro Letters. Springer Singapore 2020.
30. Nisha V, Monisha C, Ragunathan R, Johney J. Use of Chitosan as Edible Coating on Fruits and in Micro biological Activity-An Ecofriendly Approach. International Journal of Pharmaceutical Science Invention 2016;5:7-14.
31. Nusantara B. Received on 2018;22(42):49-58.
32. Oleyaei SA, Zahedi Y, Ghanbarzadeh B, Moayedi AA. Modification of physicochemical and thermal properties of starch films by incorporation of TiO2 nanoparticles. International Journal of Biological Macromolecules, 2016;89:256-264.
33. Paul SK, Sarkar S, Sethi LN, Ghosh SK. Application of Nanotechnology in Food Processing : A Promising Prospective with Considerable Risk, 2019, 75-82.
34. Pradhan N, Singh S, Ojha N, Shrivastava A, Barla A, Rai V, *et al*. Facets of nanotechnology as seen in food processing, packaging, and preservation industry. BioMed Research International 2015.
35. Ravichandran R. Nanotechnology Applications in Food and Food Processing: Innovative Green Approaches, Opportunities and Uncertainties for Global Market. International Journal of Green Nanotechnology: Physics and Chemistry, 2010;1:P72-P96.
36. Saravanakumar K, Hu X, Chelliah R, Oh DH, Kathiresan K, Wang MH. Biogenic silver nanoparticles-polyvinylpyrrolidone based glycerosomes coating to expand the shelf life of fresh-cut bell pepper (Capsicum annuum L. var. grossum (L.) Sendt). Postharvest Biology and Technology 2020;160:111039.
37. Shah SWA, Jahangir M, Qaisar M, Khan SA, Mahmood T, Saeed M *et al*. Storage stability of kinnow fruit (Citrus reticulata) as affected by CMC and guar gum-based silver nanoparticle coatings. *Molecules*, 2015;20:22645-22661.
38. Taheri A, Jafari SM. Gum-based nanocarriers for the protection and delivery of food bioactive compounds. Advances in Colloid and Interface Science 2019;269:277-295.
39. Thiruvengadam M, Rajakumar G, Chung IM. Nanotechnology: current uses and future applications in the food industry. *3 Biotech*, 2018;8:1-13.
40. Vijayakumar S, Divya M, Vaseeharan B, Chen J, Biruntha M, Silva LP *et al*. Biological Compound Capping of Silver Nanoparticle with the Seed Extracts of Blackcumin (Nigella sativa): A Potential Antibacterial, Antidiabetic, Anti-inflammatory, and Antioxidant. Journal of Inorganic and Organometallic Polymers and Materials 2020.
41. Wegari Dera M, Bogale Teseme W. Review on the Application of Food Nanotechnology in Food Processing. American Journal of Engineering and Technology Management 2020;5:41.
42. Xing Y, Li W, Wang Q, Li X, Xu Q, Guo X *et al*. Antimicrobial Nanoparticles Incorporated in Edible. Molecules 2019, 24.
43. Yu H, Park JY, Kwon CW, Hong SC, Park KM, Chang PS. An overview of nanotechnology in food science: Preparative methods, practical applications, and safety. Journal of Chemistry 2018.
44. Zambrano-Zaragoza ML, González-Reza R, Mendoza-Muñoz N, Miranda-Linares V, Bernal-Couoh TF, Mendoza-Elvira S, Quintanar-Guerrero D. Nanosystems in edible coatings: A novel strategy for food preservation. International Journal of Molecular Sciences 2018, 19.
45. Zambrano-Zaragoza ML, Quintanar-Guerrero D, Real A Del, González-Reza RM, Cornejo-Villegas MA, Gutiérrez-Corte E. Effect of nano-edible coating based on beeswax solid lipid nanoparticles on strawberry's preservation. Coatings 2020, 10.
46. Zhang W, Jiang W. Antioxidant and antibacterial chitosan film with tea polyphenols-mediated green synthesis silver nanoparticle via a novel one-pot method. International Journal of Biological Macromolecules 2020;155:1252-1261.
47. Zhang X, Liu Y, Yong H, Qin Y, Liu J, Liu J. Development of multifunctional food packaging films based on chitosan, TiO 2 nanoparticles and anthocyanin-rich black plum peel extract. Food Hydrocolloids 2019;94:80-92.