THE RISE OF NANOTECHNOLOGY - FOOD PROCESSING AND PACKAGING

ABSTARCT

The main concern of food processing is to satisfy the demand of excellent quality product and safety concerns related to product. Nanotechnology has contributed a lot, in the area of eatable production, preservation and wrapping by increasing the product shelf life. The applications are not limited up to fresh foods, novel food products are also being designed through nano-delivery systems which act as food supplement carriers in the process. Packaging materials based on nanotechnology provides better barrier and mechanical properties with an opportunity of preservation, achieved by controlled release of preservatives or antimicrobials. Here, an outline has been specified on nanotechnology applications in the areas of food production, preservation and packaging.

Keywords: Nanotechnology, Packaging materials, Shelf life

INTRODUCTION

Nano-technology has become a promising and attractive field to do research and expansion, ever since it was purposed by R. Feynman in 1969 [70].It is one of the fastest growing markets in world. This technology uses the materials, whose external dimensions ranges in between 1nm to 100 nm. Therefore, these materials are known as nano-materials. These materials possess more attractive properties than their macro-scale molecules such as elevated physical strength, ductility, finer particle sizes and larger surface areas. These properties are the reason of their wider use in industrial field. Nano-materials are further classified into 5 categories, known to be zero-dimensional in structures (i.e., nano-particles, nano-clusters), single dimensional (i.e. nano-tubes, nano-rods), double dimensional (i.e. thin films) and triple dimensional (i.e. nano-composites and nano-fibers) nano-materials [56]. Nano-technology put forward a broad spectrum of opportunities for research and development of materials and systems with modified and better characteristics in almost all possible fields we are aware of. Nano-technology has brought forth a sound and swift advancement in the agri-food processing area.

In the precedent times, the distinctive characteristics of nano-materials except their respective massive counterparts includes physical, chemical and biological characteristics, studies on the amalgamation, categorization, functioning and analysis of these products to boost the technical development to produce along with improving the whole agri-food sector [9,57].The rising consciousness of customer and concerning for nutritional quality of food, microbial quality and their wellbeing associated with the food, are encouraging the scientists to rationalize various methods and techniques to enhance the quality of food with least consequences on the dietary profile of the agri-food product. Food safety in addition to food quality is the two major parameters of immense concern and always counted into the sum since living lies there. The introduction of nano-science in the area of food and nourishment has lead to the characterization and designing of newer food products along with improved properties such as thermal stability, oral bioavailability and better solubility [23]. Earlier mentioned fundamentals are means towards achieving a superior and healthy life, the sole motivation why we consume food. Adding together of purposeful essentials in the foods has been a field of analysis from a extended period and nanotechnology proved itself with the development of nano-composites and nano-emulsions.

Comment [G1]: This sentence could be improved.

Comment [G2]: Delete this comma!

Comment [G3]: The correct year is 1959 (Feynman RP. There's plenty of room at the bottom. *Caltech Engineering and Science* 1959; 23(5): 149–160); "The concept was first mentioned in a speech by Richard Feynman given in December 1959 at the annual meeting of the American Physical Society", quoted by Wyser et al., 2016.

Comment [G4]: Bibliographic references usually start with number 1 and continue, in a chronological succession, until the last citation. In this manuscript there is no logical order of numbers related to citations. Please renumber the citations in the text according to the order of their appearance. In this case use [1] instead [70].

Comment [G5]: There is more than one space between some words. Please check the entire manuscript.

Comment [G6]: You can delete this word because you referred .to it at the beginning of the sentence

Comment [G7]: [2] not [56]! Check all references and number them in the order they appear in the text!

Comment [G8]: are

Nano-technology has been actively engaged in the area of food technology and processing commencing better stability, enhanced shelf life and contaminants identification towards the addition of wellbeing supplement or else food additives in food, nano-technology has been contributing in the up- gradation of the food processing sector.

The increasing rate of human population all over the world has arrive along with rising numbers of mouth which need to be fed. Food processing industries are under pressure to satisfy the consumer demand of healthy, fresh and nutritious diet alongside with the responsibility of satisfying all the concerned regulations and standards. The steady demand of nano-materials in the food processing is because of its non- toxic nature and stability at higher temperature and pressure. Nano-technology provides wide spectrum of applications commencing from processing of food , preservation and in the direction of food packaging. Food processing is the division of food science, which treaties with the methods and techniques of preserving used for the transformation of food into more consumable form. The food is processed to convey them to far places without degrading its quality. Packaging of food is one of the major operations of every phase in the food industry. Packaging is done to the processed food to make sure that quality of food do not get deteriorate with time. Packaging provides the physical protection. Packaging material should be of biodegradable materials and led to the reduction in environmental pollution.

Comment [G9]: All four of these sentences begin with the word "packaging". I suggest you reorganize them in such a way as to avoid this repetition.

With the developments in the ground of nano-technology, shelf life of the food can be enhanced by reducing food spoilage, so that population can consume healthy food and help in producing adequate food supply. Nano-technology solves the problems related to food spoilage and food shortage. Major nano-systems such as solid nano-particles, nano-fibers, nano-capsules, nano-tubes, nano-composites, nano-sensors, nano-barcodes are largely employed in the food processing, food preservation and packaging sector [67].

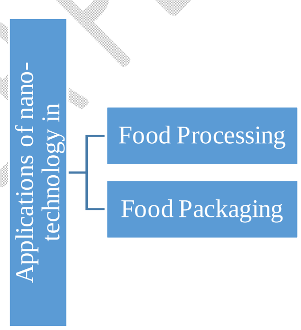

Figure (1) Nano-technology Relevance in Agri-food sector

Comment [G10]: Use only lowercase letters.

FOOD PROCESSING SECTOR

Is an exciting application of enhancing shelf life of food with the assistance of method and technique in order to renovate food into a more palatable state The primary objective of these techniques is to preserve the real essence and superiority of the food product for extended period. The secondary objective is to prevent microbial infestation and to protect the food from food spoilage and losses. Some of the traditional ways employed for processing of food are

Comment [G11]: I consider this word is not being used correctly and I suppose innovate/prepare/convert or other synonyms might be more appropriate.

Comment [G12]: I think it's better to use contamination instead of infestation. Thus, you will refer to the general contamination and not just talk about the microbial one.

irradiation, high hydrostatic pressure processing and ohmic heating [29]. Applications of the nano-materials in food processing are amalgamation of nutraceutical, nutrient delivery systems, fortification of minerals and vitamins, nano-emulsions and nano-encapsulation of unstable components. Lyposomes, nanoparticles, nano-capsules are widely used in food processing for enhanced stability of product, and retention of volatile ingredients [12].

Liposomes are small spherical synthetic cavity composed of lipid bilayers. The size of liposome particles ranges in between 100 to 400nm.Nano-lyposomes are used for the delivery of enzymes, additives, vitamins in food product. Nano-particles range in between 20 to 200nm in size and are composed of ecological or eco-friendly polymers for constant antioxidant or nutrient discharge. Number of drugs and nutrients can encapsulate in nano-capsules ranges in size 10 to 1000nm. Micelles ranges in size 10 to 100nm are amphiphilic in nature which are capable of encapsulating, lipophilic as well as lipophobic drugs stabilized by surfactants. Another macromolecule largely used for this purpose is dendrimers, ranges in size between 3 to 20nm. Nano-conjugates are polymers formed by nano-conjugation [47].The major goal of food processing is to preserve the nutrient balance and also to enhance shelf life. Food processing performs a significant function in the transportation of edible product over long distances without spoilage and minimal losses of food. Major contribution of food processing is to make availability of seasonal foodssuch as peas, corns whole yearly, by minimal processing. Another concern of food processing industry is to contribute a healthier food product with a better taste and flavor such as fortified foods. Table 1 provide various nano-techniques used in food processing with their advantages over conventional methods.

Comment [G13]: with

Comment [G14]: Use “fortification with” instead “fortification of”

Comment [G15]: Missing space between words. Please check the entire manuscript.

Comment [G16]: Put space between number and nm.

Comment [G17]: Delete this comma

Comment [G18]: These two words appear stuck together, probably because of the difference from Office. However, please check the entire manuscript so that there are no typos.

TABLE (1) Selected techniques used in food processing

TECHNIQUES	EXAMPLE	ADVANTAGES

Nano-encapsulation	Nano-capsules	• Enhanced stability, • Act as an antioxidant , volatile ingredients retention • Controlled release (triggered by moisture or pH)
	Nano-liposomes	• Odour entrapment • Delivery of enzymes, additives, vitamins
	Colloidosomes	• Enhancing the nutrient availability by delivery of vitamin and minerals in the food
	Nano-cochleates	• Improves the superiority of the processed food
	Archaeosomes	• Antioxidant delivery system
	Nano-ceuticals	• Employed to encapsulate nano-clusters, Enhances the flavor
Nano-emulsions	Nano-emulsions	• Texture improvement, maintaining uniformity • Enhancing nutrient Distribution and availability

Comment [G19]: Use a comma after each enumeration or don't use it at all, but not sometimes yes and sometimes no.

Comment [G20]: Delete space!

Comment [G21]: Being another advantage, you can put it as a new paragraph/list

Comment [G22]: Use small letters

NANO-ENCAPSULATION

Involves the use of nano-capsules. These capsules have several advantages such as easy handling,prevent oxidation, increases stability, intact the volatile ingredients, provides taste, controlled release of target components triggered by moisture or pH, multiple active ingredients can be consistently delivered , long lasting perception of flavors, better bioavailability[46]. Nano-capsules are basically bio-phasic in structures (core + shell) where desired composite is compact to a basin and coated with polymer membrane [12]. The compound may be present in solid or liquor form or in the form of dispersion at molecular levels. Nanotechnology based capsules are employed for the liberation of target compounds and for the food preservation. Nano-capsules are also employed for increasing the bioavailability of the desired compounds such as vitamins, minerals, fatty acid, growth hormones etc. Food supplements are carried by nano-capsules through the gastrointestinal track in the human body. Nano based capsules can be prepared by six ways, which are nano-precipitation, emulsion-coacervation, polymer coating, emulsion-diffusion, layer by layer and double emulsification. The main advantage of nano-emulsions over conventional emulsions is that, when added to food, it do not affect the physical properties of the food item. The pesticides, fertilizers and vaccines delivery system of the plant, nano-capsules were widely used. These nano based capsules has discover their usage in the liberation of lipophilic health supplements and in the up-gradation of nutritional profile of food items. Even in an unfavorable environment, nano-capsules are capable of delivering the hidden compound to the target which is the main benefit of encapsulation.

Comment [G23]: Unclear sentence. Probably, you want to say: "In delivery of pesticides, fertilizers and vaccines to plants, nano-capsules are widely used" or "The nano-capsules are widely used as delivery system of pesticides, fertilizers and vaccines to plants"

Comment [G24]: nano-based

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Most widely used nano-based carries for encapsulation is liposome because they are capable of delivering controlled and specific amount of several compounds in a system. They are used for the delivery of nutraceutical, nutrients, enzymes, vitamins, preservatives and additives. Emerging techniques of encapsulation uses electro-spinning area in which gallic acid is loaded with zein fiber. Zein fibers provide resistance against unfavorable conditions inside the organization prior reaching the intended delivery. Above described way is well employed via the packaging ector of food industries. Fats derived organization of encapsulation has improved properties o solubility and specificity of compounds encapsulated. They do not allow the desired compound to interact with other food materials and in such a manner the food profile is reserved and desired compound remains undisturbed. Identically, colloidosomes are small trough shell-like structures or capsules. Food supplement and drugs are infused in the cavities and used for delivery purpose.

Similarly, nano-cochleates are minute coils that enclose the micronutrients and stabilizes them. They are made up of phospholipids derived from soy moreover that can be, phosphatidic acid, , phosphatidyl glycerol, phosphatidyl choline, phosphatidyl ethanol amine, diphosphatidyl glycerol, phosphatidyl inositol, dioleoyl phosphatidic acid, distearoyl phosphatidyl serine, dimyristoyl phosphatidyl serine , dioleoylphosphatidyl serine, phosphatidyl serine and dipalmitoyl phosphatidyl glycerol and have the efficiency to improve the quality of processed food. Nano-technology has achieved a huge success in the encapsulation of probiotics, as they are soundly conserved and liberated successfully in the gastrointestinal tract. It is an attempt to design vaccines, which will modulate immune response within the system. Nano-particles derived from starch are more efficient in preservation of lipid bodies and also capable of delivering to the target site [27].Antioxidants are encapsulated in systems derived from lipid of archaeobacterial membrane and known as *Archaeosomes*. They are thermostable and resistant to stress. Milk can be preserved by encapsulating fat droplets with α tocopherol, according to several reports [46].

Comment [G26]: Do not put space before comma!

NANO-EMULSIONS

Nano emulsions are employed for the production of salad-dressings, sweeteners, and other modified food products. Nano based emulsions are capable of flavor release with the stimulation of high temperature, Hydrogen ion concentration and ultrasonic waves. They are capable to hold flavor and prevent oxidation as well as catalytic reactions. Nano based emulsions can be prepared by different ways; approach with high energy and low energy approach. Approaches with high energy involve homogenization at high pressure, ultrasound method and liquid coaxial jets at high-speed. In a same manner, approaches with low energy involve phase inversion point membrane emulsification, emulsion inversion point and solvent displacement. Nano-emulsions are prepared by dispersing liquor phase in continuous aqueous phase. Nano-emulsions are lipophilic in nature in which lypophilic constituents assorted completely with the oil phase. In nano-emulsions

Comment [G27]: Use Nano-based

Comment [G28]: Nano-based

the position of lypophilic components depends upon physiochemical and molecular properties. Physiochemical relevance such as oil water partition coefficient, surface activity, hydrophobicity, solubility and melting point. Encapsulation of various lypophilic components are carried out by nano-emulsions such as β-carotene, coenzyme Q, flaxseed oil, capsaicin and several oil soluble vitamins. Nano-emulsions are thermally stable as well as gravitationally stable as compare to conventional emulsions. Nano-emulsions are widely employed because of their tiny droplet size, larger surface areas, and smooth digestion and can absorb easily. Nano-emulsions can easily penetrate through the epithelial layer and mucous layer of the small intestine. Therefore help in better absorption of components. The smaller is the size of lyophilic component, better will be the solubility. Nano-emulsions derived from proteins or carbohydrate are used for texture improvement and in maintaining the uniformity in the ice creams and frozen yogurts., sucrose-acetateisobutyrate, ester gum, and Brominated vegetable oil are employed as bulking agent [55]. For reducing creaming and sedimentation in ice cream weighting agents are used. They are also employed for the purpose of nutrient dispersion and availability in food. With the encapsulation, biological fragments like milk protein and carbohydrate namely dextrin proved to be potential carriers of nutrients [1]. α-lactalbumin, which is hydrolyzed milk protein has proved to be potential nutrient and supplement carrier [50]. Hydrophobic nutraceuticalare best delivered by casein micelles [50]. Nano-emulsions prevents the microbial growth and are majorly effective against Gram-positive organisms than Gram negative-organisms [72]. That's why, nano-emulsions are employed for decontaminating purpose in food packaging materials. Nano-emulsions derived from surfactants which are non ionic in nature such as tributyl phosphate and soybean oil helps in avoiding the microbial growth [45]. Self-designed nano-emulsions are accountable for protecting the flavor of volatile compounds fromenzymatic degradation, hydrolysis, oxidation and environmental conditions such as temperature, and pH[53]. The active components such as β-carotene, isoflavones, lycopene, lutein, vitamins A, D, E3, and Q10 are entrapped by the nano-emulsions which can be self assembled [3]. Nano-emulsions are employed for the liberation of phytochemical such as carotenoids and polyphenols. The low bioavailability of these psychochemical's was the major difficulty faced by the scientists while manufacturing

Nano-emulsions solves this problem by means of enhancing the phytochemicals bioavailability through proficient liberation scheme. The compact size of lipid, the better is its bioavailability [43]. Nano-emulsions comprises an upper hand on the traditional available emulsions because of their smaller structure. Compact dimensions have larger surface area which increases their adsorption rate. The development of efficient nano-emulsions is based on this principle.

FOOD PRESERVATION AND PACKAGING

Food packaging techniques are used to ensure that the satisfactory of the meals is saved intact however; they're packaged in this sort of way that remains safe for intake. Packaging is carried out to offer physical safety to be able to save you the meals losses from outside shocks and vibration, microbial infestation, and temperature in offering barrier protection by way of scavenging oxygen and different spoilage causing gases. The packaging materials are preferably made of biodegradable substances in an effort to reduce environmental pollutants. This concept has been became fact because of the introduction of nanotechnology in meals packaging

Comment [G29]: Incomplete sentence

Comment [G30]: check the point and comma

Comment [G31]: nutraceutical are

Comment [G32]: prevent

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Comment [G34]: Split the words!

Comment [G35]: Put space after pH

Comment [G36]: Use phytochemicals not psychochemical's

Comment [G37]: Incomplete sentence!

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Comment [G39]: Incomplete sentence!

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industry. High barrier plastics, introducing antimicrobials, and detection measures for contaminants are few of the techniques that require being paid attention to even as food is being packaged. A summary of the distinct type of nano-techniques used for the maintenance and packaging of food is given in Table 2. Whereas treating and dealing with of food for you to gradual down the spoilage, resulting in the prevention of loss of food fine, edibility, or nutritive price by the microorganisms, are termed as food protection. Conventional strategies such as drying, canning, and freezing have observed their usage in food preservation. Food is controlled in several distinctive steps which involve processing, packaging and maintenance approach at the same time.

Comment [G41]: Unclear sentence!

TABLE (II) Selected techniques used in food packaging

Comment [G42]: I suggest you draw the table using one line for each "example" instead of delimiting it with a new paragraph. I've created a table model that will help you to prevent the "advantage" moving below the "example".

NANO-TECHNIQUES	**EXAMPLES**	**ADVANATGES**
Nano-sensors	Metal based Nano-sensors	• Detect color change in food • Detect gases release • Detect physical and chemical changes into digital signals • Toxin identification
	Carbon nanotubes	• Monitoring soil condition for crop growth • Pesticides residue detection on the surface of fruits and vegetables
	Carbon black and polyaniline	• Determination of carcinogenic compounds • Detect food-borne pathogens Detect spoilage organisms
	Electronic noses	• In case of food spoilage, shows colour change • ???
	Nano-smart dust	• ???
	Nano-barcodes	• ???
	Nano-biosensors	• ???
	Bio-mimetic-sensors	• ???
	Carbon nanotubes & silicon nanowire transistors	• Detect staphylococcal enterotoxin B
Nano-composites		

Nanoparticles	Silicon-dioxide	• Reduces moisture leakage Anti caking agent • Shows hygroscopic application
	Titanium dioxide	• Used as a food colorant Photo-catalytic disinfecting agent • Used as whitening agent in dairy products
	Zinc oxide	• Reduce the oxygen transmissions in the packaged products
	Silver nanoparticles	• Antibacterial in nature • Able to absorb and decompose ethylene
	Inorganic nanoceramic	• Used in edible oils
	Polymeric nanoparticles	• Bactericidal in nature with proficient liberation systems

NANO-TECHNIQUES	**EXAMPLES**	**ADVANATGES**
	Metal based Nano-sensors	• Detect color change in food Detect gases release • Detect physical and chemical changes into digital signals • Toxin identification
	carbon Nano tubes	• Monitoring soil condition for crop growth • Pesticides residue detection on the surface of fruits and vegetables
Nano-sensors	Carbon black and polyaniline	• Determination of carcinogenic compounds • Detect food-borne pathogens Detect spoilage organisms
	Electronic noses	• In case of food spoilage, shows

Comment [G43]: Add references

Comment [G48]: Here are three spaces!

Comment [G49]:

Comment [G45]: Use Carbon nanotubes

Comment [G44]: If you use the Aldin/Bold format for this nano-technique, use it for the following examples as well.

		colour change
	Nano-smart dust	• Changes colour on coming in touch with any signal of spoilage inside the food
	Nano barcodes	• Changes color on coming in contact with any sign of spoilage in the food material
	Nano-biosensors	• Determination of environmental pollutants • Detect quality agricultural commodities
	Bio-mimetic-sensors	• Detect viruses and bacteria
	Carbon nanotubes & silicon nano wire transistors	• Determination of mycotoxins and several different toxins • Perform as pseudo cell surfaces which help in the detection and elimination of the pathogens • Detect staphylococcalenterotoxin B

Comment [G46]: Use Nano-barcodes

Comment [G50]: These advantages are difficult to attribute to appropriate examples

Comment [G47]: Use nanowire

Comment [G51]: Use staphylococcal enterotoxins B

Nano-composites	Nano-clay	• Used as a gas obstacles that prevent the getaway of carbon dioxide from the bottles
	Aegis	• Oxygen scavengers in nature, retains the carbon dioxide gas in the bottles
	Durethan	• Makes the paper board containers stiff
	Imperm(nylon)	• Act as scavenger of oxygen
	Nano-core	• Used for the manufacturing of plastic beer bottles
	Nano-encapsulation	• Coating for meats, cheese and baked goods
	Nano-composites	• Antimicrobial agent against lipo-polysaccharide • Ruptures the DNA of bacteria
	Bio-nano-composites (cellulose&starch)	• Efficient wrapping material for food products
	Enzyme immobilization	• Increases the surface area and enhances the rates of transfer

Nanoparticles	Silicon-dioxide	• Reduces moisture leakage Anti caking agent • Shows hygroscopic application
	Titanium dioxide	• Used as a food colorant Photo-catalytic disinfecting agent • Used as whitening agent in dairy products
	Zinc oxide	• Reduce the oxygen transmissions in the packaged products
	Silver nanoparticles	• Antibacterial in nature • Able to absorb and decompose ethylene
	Inorganic nanoceramic	• Used in edible oils
	Polymeric nanoparticles	• Bactericidal in nature with proficient liberation systems

NANO-SENSORS

Nano-sensors are hired for detecting any sort of color change in the food item and additionally enables inside the detection of any gases launch because of spoilage. The sensors are fantastically sensitive towards gases such as hydrogen, hydrogen sulphide, nitrogen oxides, sulphur dioxide and ammonia [58]. Nano-sensors is composed of two important components which are, an digital data processing part and sensing part which detect any varianceinlight,warmness,humidity,gas,andchemicalsintoelectrical alerts [4].

Nano-sensors have an advantage over conventional sensors that, they are more efficient and sensitive. Palladium, platinum and gold metals are used for the manufacturing of gas sensor [60]. Toxins consisting of aflatoxin B1 in milk may be decided using gold primarily based nanoparticles[37]. Sometimes, DNA and carbon nano tubes (single walled) can be employed for the manufacturing, which will increase the sensitivity of the sensors. In the field of agriculture, nano-sensors are employed for monitoring the quality of soil, requisite for the growth of crop. They also are used for the detection of insecticides residues on the fruits and vegetables. There also are nano-sensors which have been developed for the detection of cancer agents in food stuffs [18]. Conducting polymers are also employed for the manufacturing of gas sensors. The conducting particles are implanted with in an insulated polymer matrix in sensors based on electro-active conjugated polymer [28]. The accomplishing polymers are used particularly due to their electric, optical, and magnetic houses and they have conjugated π electron backbones. If

Comment [G52]: nanotubes

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there is any launch of gases take vicinity, resonance changes and effects into a response sample on the undertaking polymer based totally sensors [28]. These sensors are also employed for detecting food borne pathogens. When carbon black and polyaniline were embedded with nano-sensors [40].

Nano-sensors can also be installed in the packaging flora for the detection of spoilage microorganisms. These sensors reduces the weight of sampling of packaging cloth in the laboratory. Nano-sensors aware the consumers approximately the color change and satisfactory of the food product. In the meals packaging industries time-temperature integrator and fuel detectors are extensively used. Various different sorts of nano-sensors used are array biosensors, nanoparticle in answer, nanoparticle based totally sensors, electronic noses, nano-check strips and nano-cantilevers [20]. Electronic noses consist diverse chemical sensors that is connected to a data processing system[49]. These sensor behaves like a human nostril, that’s why they're known as electronic nose. Similarly there is an electronic tongue sensors primarily based on identical precept as that of an digital nose. It indicates a alternate in color, whilst came in contact with any signal of spoilage inside the meals fabric and broadcasts the meals undeserving for intake [73]. Determination of the adulterants in meals and drinks along with meals dyes are detected with the assist of carbon ceramic electrode that is customized with multiwalled carbon nanotubes ionic nano-composites [36]. Biosensors are more recent field to be explored which is proving itself correctly. Nano-sensors such as nano-gasoline sensors, nano-smart dirt may be used for the detection of any sort of environmental pollution [59].These sensors consists of tiny wi-fi sensors and transponders. Quality of the rural produce may be correctly decided through nano-barcodes [64].

Nano-biosensors have proved to be quite effective and handy for the detection of viruses and bacteria. Bio mimetic sensors and clever biosensors are correctly used for the dedication of mycotoxins and several other toxic compounds [16]. The biomimetic sensors are composed of protein and biomimetic membranes. These sensors behaves as pseudo cellular surfaces which is used for willpower of the pathogens[65]. Due to the improved level of selectivity and sensitivity of nano-sensors reduced the detection limits. There are quantity of immune sensors evolved for the detection of numerous toxins like Ochre toxin A that's decided by way of cerium oxide immunosensors and chitosan primarily based nano-composite. Cholera toxin and Staphylococcal enterotoxin B and may be detected via carbon nanotubes and silicon nanowire transistors [69].

NANO-COMPOSITES

Are produced by fusing the nanoparticles with the traditional food packaging materials. They have achieved an active interest of food packaging section. Nano-composites are made up of polymer medium in a discontinuous and continuous phase [5]. Nano-composites possess a extremely adaptable chemical functionality and so designed for the manufacturing of tough resistant packaging materials. They maintain freshness of food products, preventing several biological invasion for a desired period of time. Nano-composites acts as a brilliant gas barrier and from carbonated beverages, prevents the escape of carbon dioxide [62]. In such a manner, it enhances the stability of the product. Packaging industries can employ nano-composities to shield their bottles to prevent leakage, as an alternative of costly cans and bulky glass bottles. It is produced by the process of matrix amalgamation (in continuous phase) with a nano-dimensional materials (in discontinuous phase), therefore known as multiphase material. On the basis of material employed, nano-dimensional phase are classified into nano-spheres, nano-

Comment [G54]: This sentence is incomplete or must be included in the previous one.

Comment [G55]: reduce

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Comment [G57]: sensors behave

Comment [G58]: Insert space

Comment [G59]: Delete “and”

whiskers, nanotubes and nano-sheets[11]. Nano-composite has been identified as a gold fashionable for improvising the mechanical and barrier traits of polymers [41]. Instead of improved properties, nanoparticles includes active and smart properties to the packaging material [21]. In the field of polymer science, introduction of nanotechnology has open new avenues for improved properties with minimum price competence among packaging materials [35]. Nano-composites based on polymers have been recently introduced as novel packaging material, produced by mixing polymers with organic or in organic fillers of significant geometry(fibers, flakes, spheres, particulates)[44]. There are number of nano-materials available such as silica[10],clay[54],organo-clay [26], grapheme [32], polysaccharide nano-crystals, carbon nanotubes[66], , chitosan[14], cellulose-based [52], and other metal nanoparticles, such as, ZnO2 [24] are widely used as fillers. Nano-clays are widely employed for manufacturing of high resistant gas barriers.). The relevance of 5% (w/w) of clays in thermoplastic starch (TPS)/clay nano-composites, improves the mechanical properties with decreased water vapor permeability of starch biopolymer [39].

Comment [G60]: These sentences must be corrected.

Nano-clays are ecofriendly and stable in nature, as they occur naturally in the environment in the form of aluminum silicate, also known as Phyllosilicates [17]. On the basis of composition, Phyllosilicates are montmorillonite, kaolinite, hectorite, and saponite. Nano-composites are broadly classified into two segments, namely, intercalated nano-composites and exfoliated nano-composites [17]. Multiple polymeric structures are sequentially arranged and polymerchains go through into the internal layers of the clay thus forming alternative polymeric layers in the intercalated nano-compoites [17]. Exfoliated nano-composites formed by extensive penetration of polymers. They consist of clay layers which are dispersed irregularly in the polymer matrix. Cellulose based nano-reinforcements are cheaper, light weight nano-composite [8].Usage of montmorillonite clay in the form nano-component in wide diversity of polymers such as, polyethylene, nylon, polyvinyl chloride, and starch dates lower back to Nineties [38]. Reinforcements of cellulose are produced in the structure of microfibrils in the plants, which are stabilized by hydrogen bonds. These reinforcement's produces flexible and semi permeable nano-composites. Silicon dioxide nanoparticles are polymerized with single walled nanotubes for producing excellent gas barriers [31]. Aegis, Imperm, and Durethan are some of the nano-clay available commercially [31]. The demand of these nano-clays over others is because of their recyclable nature, transparency, lower density and good surface properties. Plastic beer bottles are manufactured from nano-clay based polymers to prevent the release of carbon dioxide known as Nano-cor[63]. Nano-laminates are another type of nano-coatings used for coating meat, cheese, fruits, vegetables and baked product. A blueberry based packaging system has been urbanized, by adding blue berry extract between the silicate interlayers of clay. Blueberry is a rich source of anthocyanin which shows a colour change with pH and shifted among quinoidal and flavylium form. Addition of blueberry extract can upgrade these clays into active and intelligent nano-composites [25].

NANOPARTICLES

Are minute on nano-scale, but play several role in processing of food. They improve the properties of eatables including flow property, color and stability. The bioavailability of nanoparticles effects its functioning in a system [68]. Initially, nano-particles were employed in pharmaceuticals for the delivery of drugs but currently they have found their opportunities in food processing sector in an identical manner. The main concern regarding the packaging material is the transmission of gases. These nano-particles such as titanium oxide and zinc oxide are employed in the form of plastic based films to reduce the oxygen flow, moisture leakage and maintains the quality or freshness of product for longer time inside the packaging containers. There are nano-particles used for the removal of pathogens and chemicals because of their selective binding properties [15]. Nano-particles of silicon dioxide and titanium dioxide are widely used in food packaging. Silicate nano-particles are widely available in nature, simple processing and lower cost are the reason for usage as a potential nanoparticles. Nano-particles based on silicon are used as an anticaking agent and drying agent [51]. They possess hygroscopic properties, hence able to absorb water molecules in food. Another nano-particle which act as food colorant is titanium dioxide and known as photo-catalytic disinfecting agent. It is used as a whitening agent in the products like milk and cheese [22]. It is used as a hurdle against UV in food packaging. Silver nano-particles are used to prevent microbial infestation in products, hence act as an antimicrobial agent [51]. Silver based nanoparticles have smaller size and larger surface area due to which it can easily disperse in product and are chemically active in nature. Therefore known as antimicrobial agent with a lot potential. In the category of metallic nanoparticles, nano-sized silver particles are most promising antimicrobial agents and possess spectrum of other activities [51]. Silver is a stable element in nature and from various researches it is proved that it does not cause any threat to biological system, when incorporated within standards proposed by FDA (Food and Drug Association) [51]. The advantage possess by silver is its stability therefore act as an effective antimicrobial agent. Silver can easily penetrate through biofilms and its incorporation in packaging material is also quite feasible. Nowadays, silver is more desirable means of packaging material because of its lower propensity in making microbes resistant to it [51]. From various reports, it is proven that silver can disturb the ribosomal activity and responsible for hindrance in enzyme production [51]. Silver particles act as bactericide against Gram negative organisms because they can easily penetrate through the thinner cell wall of gram negative organisms [51]. Silver based nanoparticles have the potential to absorb and decompose ethylene, hence extends the shelf life of fruits and vegetables [51]. There are number of other nanoparticles such as zinc nanoparticles, titanium nanoparticles, carbon nanotubes which can be used for packaging of food. Polybutylene succinate in combination with zinc oxide shows antimicrobial activity against *E. coli* and *S. aureus* [42]. Carbon nanotubes are accessible either in single wall or multi-walled nanotubes. Single wall carbon nanotubes are usually one atom in thickness whereas multi-walled nanotubes consist of number of concentric tubes having high aspect ratios and elastic modules [37]. Carbon nanotubes when combine with allyl isothiocyanate can prevent the growth *Salmonella choleraesuis* during storagefor 40 days [19]. A report suggests that carbon nanotubes in combination with polyethylene films prevents the fungal growth for about 90 days and can be employed for the packaging of Mazafati dates [7]. The usage carbon tubes are limited because of their high toxicity level. Alginic acid, polylactic acid, coglycolic acid and chitosan are used in combination with polymers for producing polymeric nanoparticles. They are considered to be effective in delivery system [45]. Chitosan is widely used because of its biodegradability, biocompatibility and ability to form complex with metal ions. Chitosan is considered as antimicrobial agent because of their polycationic nature [6]. Chitosan nanoparticles are produced with the aid of ionic gelation [2]. Chitosan in aggregate with gold, silver and cinnamaldehyde constitutes antimicrobial action against E. Coli, S. Aureus and Candida albicans [48, 71]. Packaging with nanoparticles is considered as an active packaging because it incorporates components which have antimicrobial or antioxidant properties and can absorb gases or vapors from the product

Comment [G61]: maintain

Comment [G62]: This sentence should be improved

Comment [G63]: Split the words

Comment [G64]: *coli*

Comment [G65]: *aureus*

Comment [G66]: Use Latin name of the species in Italic font.

environment. Incorporation of nanoparticles with polymers improves the keeping quality and shelf life of products [5, 34].

FUTURE SCOPE

There are number of nano-systems, which are being designed to develop effective nano-components for food processing and packaging sector. The main concern is to develop more efficient and effective nano-carries. These carriers must have better bioavailability than conventional ones and do not influence the original physical and organoleptic properties of food. The research are still carried out to develop newsmart packaging systems such as antigen specific bio markers and newer combinations of nanoparticles with polymer. For the detection of spoilage organisms antigen specific biomarkers can be used. The pSivida of Australia has developed bio-silicon, employed in food packaging systems [30]. In India, the development of nanotechnology is not up to the mark as compare to other developed countries because of the inadequate collaboration between university-industry. However it is progressing slowly with the word scenario, developing newer systems and contributing in the field of nanotechnology. India has a huge potential and it can be properly used by significant interactions between scientists of university and industries [61].

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CONCLUSION

Nano based science has added a revolution in meals processing and packaging region. This revolution has provide promising effects by way of elevating the meals high-quality, prolonging shelf existence and via improving loss control. It helped in solving the major food processing problems such as food losses and crises by increasing shelf stability of product and reducing food wastage. Development of nano-delivery systems provide a new segment in the production food supplements and delivery of bioactive components to their targets. Nanotechnology has drawn advances in food packaging by proposing nano-composites, nanoparticles and nano-polymers. These developed packaging materials constitute better barrier properties, thermal stability, flexibility and strength. Incorporation of preservatives or antimicrobials in the packaging materials has solved the challenges previously seen by the processing and packaging industries. There are number of advantages of nanotechnology available but there are prominent drawbacks too present. This is one of the reason due to which emergence of nanotechnology is lagging behind.

Comment [G68]: Use Nano-based

Comment [G69]: provided

Comment [G70]: Use provides, because is in accord with development

Comment [G71]: This sentence is unclear

REFERENCE

Comment [G72]: According to the Author Guidelines (https://journaljeai.com/index.php/JEAI/about/submissions), this chapter should be rewritten. References must be listed at the end of the manuscript and numbered in the order that they appear in the text. Every reference referred in the text must also present in the reference list and vice versa. In the text, citations should be indicated by the reference number in brackets [3].

Comment [G73]: Use the family name first and then the initial of the first name.

Comment [G74]: The space before comma is missing.

Comment [G75]: Here there is no space between words/numbers. Please check entire references chapter!

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