IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

A Review On: Recent Advances In Nanoparticles In Drug Delivery System

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Abstract: Nanotechnology has accelerated over the past forty years and shows no signs of slowing down. Nanotechnology-related innovations and products have transformed every facet of daily life, from the food sector to medical uses. Nanoparticles have improved the intracellular delivery of hydrophobic medications, greatly increased the shelf life of food products, and increased the effectiveness of some treatments like anticancer medicines. As a result, nanotechnology has affected both the global economy and the standard of living. This review discusses the properties of nanoparticles that give them appropriate and potentially harmful biological effects, as well as their uses in various biological domains and nanoparticle-based medications and delivery systems in biomedicine, including nano-based medications that are currently FDA-approved in the United States. The potential effects of ongoing nanoparticle exposure brought on by the growing usage of nanotechnology are also emphasized, along with potential remedies.

Key words- nanotechnology, nanoparticles, drug delivery systems, nanomedicine

I. INTRODUCTION:

Drug delivery is essential to therapeutic success since a drug's efficacy depends on both its pharmacological activity and its capacity to safely and carefully reach the intended location of action. Poor solubility, limited bioavailability, quick clearance, and non-specific distribution are common problems with conventional drug delivery methods such tablets, capsules, and injections. These shortcomings could result in decreased therapeutic efficacy and undesirable side effects, which calls for the creation of sophisticated systems with adjustable surface chemistry, a surface area-to-volume ratio, and the capacity to encapsulate a broad range of medications. They are perfect transporters for both hydrophilic and hydrophobic medicinal drugs because of their characteristics. Nanoparticles can be designed for targeted medication delivery, prolonged release, and decreased toxicity by altering their surface functions. In order to overcome these obstacles, a lot of research has been done during the past ten years on various nanoparticle kinds, including polymeric nanoparticles. In the field of pharmaceutical sciences, nanotechnology has become a ground-breaking platform that offers creative answers to the drawbacks of conventional drug delivery techniques. High lipid-based systems

(liposomes, solid lipid nanoparticles, nanostructured lipid carriers), dendrimers, metallic nanoparticles, and hybrid nanostructures are examples of the distinctive physicochemical characteristics of nanoparticles, which are usually between 1 and 100 nanometers in size. Improved drug stability, regulated pharmacokinetics, and increased patient compliance are just a few of the unique benefits that each of these systems provides. The distribution of biomolecules like proteins, peptides, and nucleic acids as well as the treatment of cancer, infectious diseases, cardiovascular disorders, and neurological conditions have all shown great promise with nanoparticle-based delivery methods. For instance, nanoparticles have made it possible to deliver chemotherapeutics to tumor tissues precisely in oncology, therefore lowering systemic toxicity. Similar to this, nanoparticles serve as non-viral vectors for safer and more effective nucleic acid delivery in gene therapy. The full-scale clinical translation of nanoparticle-based medication delivery is hampered by a number of issues despite these impressive developments. Large-scale production, repeatability, long-term stability, possible toxicity, regulatory obstacles, and cost-effectiveness are some of these concerns. Innovative research and strong regulatory frameworks are necessary to address these issues in order to transition from experimental success to Over the past few decades, the science of drug administration has undergone a significant transformation, moving from straightforward dose forms to complex platforms intended to enhance therapeutic efficacy and reduce side effects. Despite being widely utilized, conventional administration methods frequently have drawbacks such non-specific biodistribution, fast systemic clearance, and inadequate penetration into biological barriers. Nanoparticle-based drug delivery systems (NDDS) are the result of nanotechnology's revolutionary response to these problems. Because of their nanoscale size, nanoparticles have special qualities like increased permeability and better solubility of medications that are poorly soluble in water. as well as the capacity to pass across biological obstacles like the blood–brain barrier. Additionally, their surfaces can be modified with polymers, ligands, or antibodies to accomplish active targeting, which allows the therapeutic payload to be delivered precisely to diseased tissues while avoiding healthy ones. The capacity of NDDS to deliver regulated and prolonged medication release is a major benefit. Researchers can create carriers that release medications in response to particular physiological cues, such as pH gradients in tumors or enzymatic activity in diseased tissues, by adjusting particle size, surface charge, and composition. Because of their versatility, nanoparticles can be used in a wide range of therapeutic applications. From conventional liposomes and polymeric carriers to sophisticated systems like dendrimers, solid lipid nanoparticles, metallic nanocarriers (such as gold and silver nanoparticles), and hybrid systems that blend organic and inorganic components, recent research has broadened the scope of nanoparticles. In fields like immunotherapy, gene delivery, and vaccine development, these innovative technologies have demonstrated tremendous potential. For instance, the effectiveness of lipid nanoparticles (LNPs) in delivering mRNA vaccines against COVID-19 has shown the scalability and therapeutic usefulness of nanoparticle technology globally.

II. Types of Nanoparticles in Drug Delivery:

There are several types of nanoparticles commonly employed in NDDS, each offering unique advantages:

• **Polymeric Nanoparticles**: Made from biodegradable polymers like polycaprolactone (PCL) and poly(lactic-co-glycolic acid) (PLGA), polymeric nanoparticles are widely employed for targeted distribution and controlled medication release (Danhier et al., 2012). They are especially well suited for long-term drug delivery applications in cancer therapy due to their biodegradability and biocompatibility (Kumar et al., 2015).

• **Liposomes**: Phospholipid bilayers make up these spherical vesicles, which can contain both hydrophilic and hydrophobic medications. Through enhanced permeability and retention (EPR) effects, liposomes have been employed extensively to encapsulate chemotherapeutic drugs and improve drug accumulation in tumor tissues (Allen & Cullis, 2013). PEGylated liposomes, which have a longer bloodstream circulation period, are one example of recent advancements (Torchilin, 2005).

• **Solid Lipid Nanoparticles (SLNs)**: Solid lipids make up these sub-micron colloidal carriers. SLNs provide stability, biocompatibility, and controlled drug release by combining the advantages of polymeric nanoparticles and liposomes (Ekambaram et al., 2012). They have been used in anti-inflammatory and anti-cancer treatments, among other drug delivery applications (Müller et al., 2011).

Dendrimers: Dendrimers are highly branching, tree-like molecules with fine structural control that offer several functional groups for drug loading and targeting (Patri et al., 2005). Due to its capacity to improve medication solubility and bioavailability, dendrimers have been investigated in gene delivery and as anticancer drug carriers (Malik et al., 2000).

• **Nanocrystals:** These are pure drug nanoparticles stabilized by polymers or surfactants that increase the pace at which pharmaceuticals that are poorly soluble in water dissolve (Junghanns & Müller, 2008). Particularly useful for increasing the bioavailability of hydrophobic medications are nanocrystal formulations.

• **Size:** Since this size range promotes cellular absorption and avoids the reticuloendothelial system's (RES) quick clearance, nanoparticles between 10 and 200 nm are typically thought to be ideal for drug administration (Danhier et al., 2012). The EPR effect allows small nanoparticles to more successfully enter tumor tissues (Barua & Mitragotri, 2014).

• **Surface Charge:** The surface charge (often measured as zeta potential) affects the stability and interaction of nanoparticles with cellular membranes. Positively charged nanoparticles tend to have better cellular uptake but may increase toxicity due to interactions with cell membranes, while neutral or negatively charged particles generally exhibit longer circulation times and lower toxicity (Owens & Peppas, 2006)

1. Size and Shape: The size and shape of the iron/silica nanoparticles must be carefully controlled to optimize their performance and minimize any potential toxicity.
2. Surface functionalization: The surface of the nanoparticles can be functionalized with various moieties, such as polymers, antibodies, or small molecules, to target specific cells or tissues. It is

important to consider the stability, specificity, and efficiency of these functionalisation in the design of the nanoplatform.

3. Core stability: Some of these nanoparticles such as iron oxide are known to be highly reactive, so it is important to ensure that the iron oxide core of the nanoparticles is stable and does not degrade or aggregate in biological systems.
4. Biocompatibility: The nanoplatform must be biocompatible, meaning that it should not elicit an adverse reaction in biological systems, such as inflammation, toxicity, or immune response.
5. Release kinetics: For therapeutic applications, it is important to consider the release kinetics of the payload from the nanoplatform. The release rate should be carefully controlled to ensure that the payload is delivered in a manner that is effective and safe.
6. Targeting and accumulation: For therapeutic applications, it is also important to consider the targeting and accumulation of the nanoplatform in the desired tissue or organ. The nanoplatform must be able to selectively target and accumulate in the desired location in order to maximize its therapeutic efficacy.

Size and Surface Area

As mentioned, nanoparticles have a high surface area to volume ratio since they are tiny particles with diameters ranging from 1 nm to 100 nm. This characteristic makes some usually inert particles, like gold, reactive in the nanoscale range because nanoparticles have a higher surface area of contact per mass unit than more bulky particles. Because of their very small size, nanoparticles may readily penetrate bodily fluids and tissues, which would otherwise be difficult for them to do in quantity. Essentially, the pace at which these nanoparticles are endocytosed, dispersed, and maintained depends on their size and surface area, and removed from biological systems. For instance, liposomes of particular sizes that are easier for mammalian cells to internalize can be prepared using various lipid formulations. Extrusion techniques, for example, have been employed in some research to create liposomes of appropriate sizes that are easily internalized by mammalian cells using a polycarbonate membrane of preset size. It has been demonstrated that these liposome manufacturing techniques increase the effectiveness of chemotherapy medications by improving cell absorption.

are compatible, the liposome can be adsorbed to the cell membrane and internalized either by fusion with the plasma membrane, which causes membrane invagination and internalization, or by receptor-mediated endocytosis.

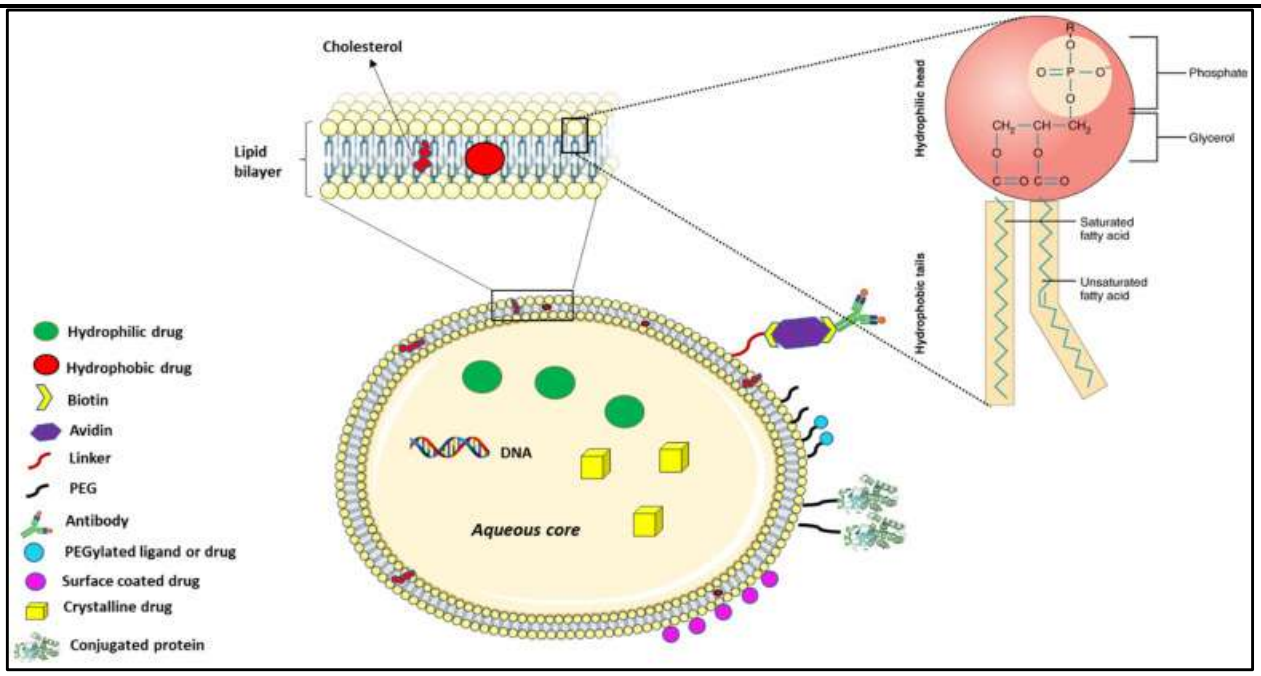

Fig1. Liposomal modification for drug delivery.

Carrageenan oligosaccharide-capped AuNP, for instance, has recently been demonstrated to significantly release epirubicin in an acidic pH, inducing cell death in HCT-116 colorectal cancer cells. This phenomenon has been used to trigger drug release in the tumor microenvironment, which is characterized by an acidic pH. Nanoparticles' surface can change how they travel in aqueous biological systems, which can therefore have an impact on their delivery or reactivity. These surface characteristics make them useful in a number of applications, including drug delivery systems, medical implant coatings, and biomedical sensors. For instance, because of the antibacterial qualities of AgNPs, an AgNP-functionalized titanium implant surface was created to avoid postoperative infection caused by resistant strains of Staphylococcus aureus and Liposomes are composed of an outer aqueous core and a lipid bilayer, both of which can be utilized for drug delivery in the treatment of illness. In order to limit the phospholipid's fluidity, similar to that of the plasma membrane, cholesterol is frequently included to the liposome preparation recipe.

Shape

As mentioned earlier, the size of nanomaterials can be adjusted, and during their production, their shape can also be controlled. During the last stage of synthesis, which usually entails nucleating the nanoparticles from seed, the morphologies of the particles can be changed. In order to create a template for the growth of nanoparticle crystals, the nucleation process entails the fusion of nanoparticle nuclei known as seeds. Similar to size, a nanoparticle's form is crucial to its biological activity and reactivity. In general, round or round nanoparticles are more easily endocytosed than rod or tube-shaped ones [97]. This is due to the shape's impact on endocytosis, which hinders the membrane's ability to cover the nano-construct upon contact. Therefore, the incapacity of the cell to start the actin-dependent membrane dynamics required for endocytosis is probably the cause of the decreased endocytosis of nano-rods or other forms.

The endocytosis of a nanoparticle can be significantly influenced by its form. Both clathrin-mediated and clathrin-independent mechanisms can result in endocytosis. The nanoparticle's form can influence the endocytic pathway it uses and, consequently, how the cell internalizes it. Particle size and charge are two

examples of the variables that can affect this less selective process. Furthermore, some shapes—like rod-like or bristle-like nanoparticles—can get stuck in the cell

III.Mechanisms Nanomaterials: Drug Delivery Using Nanoparticles act as versatile carriers that transport therapeutic agents to the site of action with high precision. Their drug delivery mechanisms can be broadly categorized into passive targeting, active targeting, and stimuli-responsive release, each governed by unique physicochemical and biological interactions.

1)Passive Targeting: Based on the Enhanced Permeability and Retention (EPR) effect, commonly seen in tumors and inflamed tissues.

2)Active Targeting: Involves surface modification of nanoparticles with ligands (antibodies, peptides, aptamers, sugars) that recognize and bind to specific receptors on target cells. This receptor-mediated binding promotes cellular uptake via endocytosis and ensures site specific delivery. Example: Folic acid–conjugated nanoparticles selectively target folate receptors, which are overexpressed in many cancer cells.

3) **Cellular Uptake Mechanisms**: Nanoparticles enter cells through multiple endocytic pathways: • Clathrin-mediated endocytosis → uptake into clathrin-coated vesicles.Caveolae-mediated endocytosis → uptake through lipid raft–associated invaginations. Macropinocytosis → engulfment of extracellular fluid and nanoparticles. Once inside, nanoparticles release drugs into the cytoplasm or bypass lysosomal degradation to deliver biomolecules like DNA and RNA.

4**) Stimuli-Responsive Release**: Nanomaterials can be engineered to release drugs in response to specific triggers: • pH-sensitive systems → release drugs in acidic tumor endosomes. microenvironments or • Enzyme-sensitive systems → degrade in the presence of disease-specific enzymes. • Temperature-sensitive nanoparticles → release drugs when exposed to hyperthermia at diseased sites. • Redox-responsive systems → triggered by high intracellular glutathione levels. • Example: pH-sensitive polymeric nanoparticles carrying doxorubicin release the drug specifically in tumor tissues.

5) **Controlled and Sustained Release:** Nanoparticles provide a reservoir effect, slowly releasing drugs over time. • Mechanisms include diffusion through the matrix, erosion of biodegradable polymers, or swelling-controlled release. • Example: Poly (lactic-co-glycolic acid) (PLGA) nanoparticles provide sustained delivery of hydrophobic drugs.

6) **Transcytosis Across Biological Barriers**: Certain nanocarriers (e.g., lipid nanoparticles, polymeric micelles) can cross difficult barriers like the blood–brain barrier (BBB) via receptor-mediated or adsorptive-mediated transcytosis. This property expands therapeutic possibilities for central nervous system (CNS) disorders.

7) **Co-Delivery and Combination Therapy**: Nanoparticles can encapsulate multiple drugs or drug gene combinations, releasing simultaneously or sequentially.

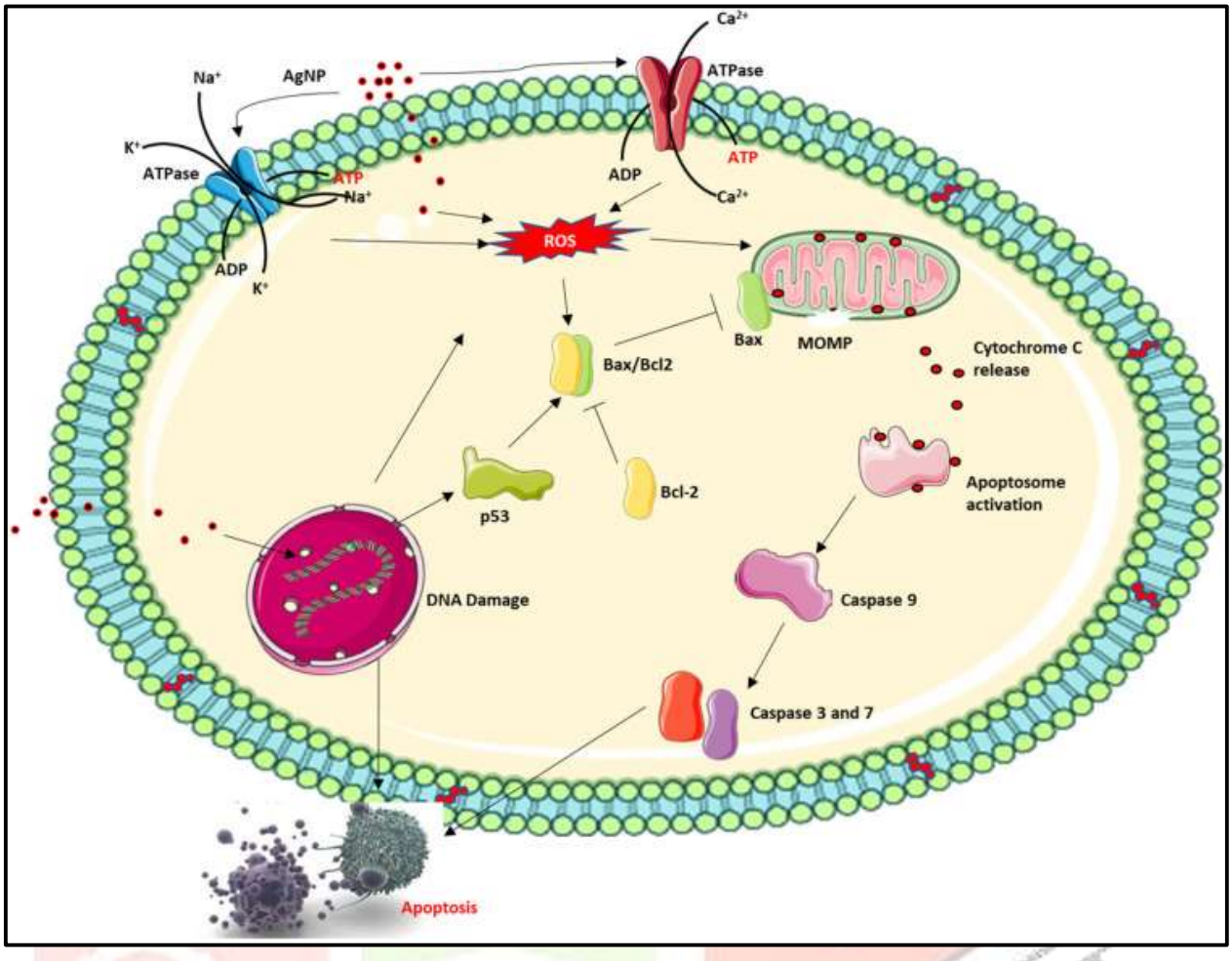

Fig 2. Proposed mechanism of action of AgNPs.

IV. Future Perspectives of Nanoparticle-Based Drug Delivery Systems:

Nanoparticle-based drug delivery systems (NDDS) represent one of the most transformative innovations in modern medicine, yet their full potential is still unfolding. With ongoing advances in nanotechnology, material science, and molecular biology, NDDS are expected to become more precise, intelligent, and patient-centered in the future.

1) Precision and Personalized Nanomedicine: Integration of genomics, proteomics, and AI driven predictive models will allow nanoparticles to be tailored for individual patients. Patient-specific nanocarriers could optimize drug dose, release profile, and targeting, reducing adverse effects and improving therapeutic outcomes.

2**) Smart and Stimuli-Responsive Nanoparticles**: Development of next-generation intelligent nanocarriers that respond to multiple stimuli (pH, redox, enzymes, light, ultrasound, magnetic fields). These "on-demand" systems will enable site specific and time-controlled drug release, particularly in cancer, neurodegenerative, and inflammatory diseases.

3) Theranostic Nanoplatforms: Combining therapy and diagnostics in a single nanoparticle platform. Future systems will integrate imaging (MRI, PET, fluorescence) with therapeutic agents, enabling real-time monitoring of treatment efficacy. This will improve early detection, personalized dosing, and adaptive treatment strategies.

4) Nanoparticles in Gene and Nucleic Acid Therapy: Expansion beyond mRNA vaccines to siRNA, CRISPR-Cas9, and DNA-based therapies. Nanoparticles will serve as safe, non-viral carriers for genome editing and regenerative medicine. Could revolutionize treatments for genetic disorders, cancers, and neurological diseases.

V. CONCLUSION: Recent years have seen rapid, practical progress in nanoparticle (NP)-based drug delivery: lipid nanoparticles (LNPs) have matured into clinically validated carriers for nucleic-acid therapeutics, enabling safe and efficient mRNA delivery; surface engineering strategies (targeting ligands, stealth coatings and stimuli-responsive moieties) have greatly improved targeting, circulation time and cellular uptake; and nanoparticle platforms are now being actively integrated with immunotherapy and gene-editing approaches to boost efficacy while lowering off-target toxicity.

These advances have expanded applications beyond oncology into vaccines, CNS disorders (new work shows promising approaches to cross the blood–brain barrier), localized sustained-release formulations and organ-specific targeting—demonstrating both therapeutic breadth and precision.Despite strong preclinical and early clinical results, translation challenges remain: long-term safety and immunogenicity of novel materials, scalable manufacturing and reproducible characterization, regulatory harmonization, and gaps between animal models and human outcomes are still major hurdles to broad clinical adoption.Looking ahead, the field is shifting from single-purpose carriers toward multifunctional, biomimetic systems that combine targeted delivery, controlled release, and sensing/diagnostic capabilities — promising truly personalized, lower-toxicity therapies if regulatory and manufacturing challenges are solved. Continued interdisciplinary work (materials chemistry, biology, engineering, and clinical trials) will be essential to convert these promising advances into widely available treatments.

V. ACKNOWLEDGEMENTS:

The authors are thankful to the management and principal of Kasturi Shikshan Sanstha College of Pharmacy, Shikrapur, Pune, for the encouragement.

VI. CONFLICT OF INTEREST:

The authors declare no conflict of interest.

VII.REFERENCES:

- 1.Nasrollahzadeh M., Sajadi S.M., Sajjadi M., Issaabadi Z. Interface Science and
- Technology. Volume 28. Elsevier; Amsterdam, The Netherlands: 2019. An introduction to nanotechnology; pp. 1–27. [Google Scholar]
- 2.Doran J., Ryan G. Does nanotechnology research generate an innovation premium over other types of research? Evidence from Ireland. Technol. Soc. 2019;59:101183. doi: 10.1016/j.techsoc.2019.101183. [DOI] [Google Scholar]
- 3.Cheng Y.J., Wolkenhauer M., Bumbu G.G., Gutmann J.S. A Facile Route to Reassemble Titania Nanoparticles into Ordered Chain-like Networks on Substrate. Macromol. Rapid Commun. 2012;33:218–224. doi: 10.1002/marc.201100638. [DOI] [PubMed] [Google Scholar]
- 4.Kango S., Kalia S., Celli A., Njuguna J., Habibi Y., Kumar R. Surface modification of inorganic nanoparticles for development of organic–inorganic nanocomposites—A review. Prog. Polym. Sci. 2013;38:1232–1261. doi: 10.1016/j.progpolymsci.2013.02.003. [DOI] [Google Scholar]
- 5.Roco M.C. Nanotechnology Commercialization: Manufacturing Processes and Products. Wiley; Hoboken, NJ, USA: 2017. Overview: Affirmation of Nanotechnology between 2000 and 2030; pp. 1–23. [DOI] [Google Scholar]
- 6.Huang Q., Yu H., Ru Q. Bioavailability and delivery of nutraceuticals using nanotechnology. J. Food Sci. 2010;75:R50–R57. doi: 10.1111/j.1750-3841.2009.01457.x. [DOI] [PubMed] [Google Scholar]
- 7.Bajpai V.K., Kamle M., Shukla S., Mahato D.K., Chandra P., Hwang S.K., Kumar P., Huh Y.S., Han Y.-K. Prospects of using nanotechnology for food preservation, safety, and security. J. Food Drug Anal. 2018;26:1201–1214. doi: 10.1016/j.jfda.2018.06.011. [DOI] [PMC free article] [PubMed] [Google Scholar]
- 8.Carbone M., Donia D.T., Sabbatella G., Antiochia R. Silver nanoparticles in polymeric matrices for fresh food packaging. J. King Saud Univ. Sci. 2016;28:273–279. doi: 10.1016/j.jksus.2016.05.004. [DOI] [Google Scholar]
- 9.An J., Zhang M., Wang S., Tang J. Physical, chemical and microbiological changes in stored green asparagus spears as affected by coating of silver nanoparticles-PVP. LWT Food Sci. Technol. 2008;41:1100–1107. doi: 10.1016/j.lwt.2007.06.019. [DOI] [Google Scholar]
- 10.Banach M., Tymczyna L., Chmielowiec-Korzeniowska A., Pulit-Prociak J. Nanosilver biocidal properties and their application in disinfection of hatchers in poultry processing plants. Bioinorg. Chem. Appl. 2016;2016:5214783. doi: 10.1155/2016/5214783. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 11.Emamifar A., Kadivar M., Shahedi M., Soleimanian-Zad S. Effect of nanocomposite packaging containing Ag and ZnO on inactivation of Lactobacillus plantarum in orange juice. Food Control. 2011;22:408–413. doi: 10.1016/j.foodcont.2010.09.011. [DOI] [Google Scholar]

- 12.Zhang C., Li W., Zhu B., Chen H., Chi H., Li L., Qin Y., Xue J. The Quality Evaluation of Postharvest Strawberries Stored in Nano-Ag Packages at Refrigeration Temperature. Polymers. 2018;10:894. doi: 10.3390/polym10080894. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 13.Venkatasubbu G.D., Baskar R., Anusuya T., Seshan C.A., Chelliah R. Toxicity mechanism of titanium dioxide and zinc oxide nanoparticles against food pathogens. Colloids Surf. B Biointerfaces. 2016;148:600–606. doi: 10.1016/j.colsurfb.2016.09.042. [DOI] [PubMed] [Google Scholar]

- 14.Fathi M., Martín Á., McClements D.J. Nanoencapsulation of food ingredients using carbohydrate based delivery systems. Trends Food Sci. Technol. 2014;39:18–39. doi: 10.1016/j.tifs.2014.06.007. [DOI] [Google Scholar]

- 15.Davis J.L., Paris H.L., Beals J.W., Binns S.E., Giordano G.R., Scalzo R.L., Schweder M.M., Blair E., Bell C. Liposomal-encapsulated Ascorbic Acid: Influence on Vitamin C Bioavailability and Capacity to Protect Against Ischemia-Reperfusion Injury. Nutr. Metab. Insights. 2016;9:25–30. doi: 10.4137/NMI.S39764. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 16.Hallan S.S., Kaur V., Jain V., Mishra N. Development and characterization of polymer lipid hybrid nanoparticles for oral delivery of LMWH. Artif. Cells Nanomed. Biotechnol. 2017;45:1631–1639. doi: 10.1080/21691401.2016.1276920. [DOI] [PubMed] [Google Scholar]

- 17.Lu H., Zhang S., Wang J., Chen Q. A Review on Polymer and Lipid-Based Nanocarriers and Its Application to Nano-Pharmaceutical and Food-Based Systems. Front. Nutr. 2021;8:783831. doi: 10.3389/fnut.2021.783831. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 18.Singh T., Shukla S., Kumar P., Wahla V., Bajpai V.K. Application of Nanotechnology in Food Science: Perception and Overview. Front. Microbiol. 2017;8:1501. doi: 10.3389/fmicb.2017.01501. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 19.Frohlich E.E., Frohlich E. Cytotoxicity of Nanoparticles Contained in Food on Intestinal Cells and the Gut Microbiota. Int. J. Mol. Sci. 2016;17:509. doi: 10.3390/ijms17040509. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 20.Kim Y.S., Kim J.S., Cho H.S., Rha D.S., Kim J.M., Park J.D., Choi B.S., Lim R., Chang H.K., Chung Y.H., et al. Twenty-eight-day oral toxicity, genotoxicity, and gender-related tissue distribution of silver nanoparticles in Sprague-Dawley rats. Inhal. Toxicol. 2008;20:575–583. doi: 10.1080/08958370701874663. [DOI] [PubMed] [Google Scholar]

- 21.Shahare B., Yashpal M. Toxic effects of repeated oral exposure of silver nanoparticles on small intestine mucosa of mice. Toxicol. Mech. Methods. 2013;23:161–167. doi: 10.3109/15376516.2013.764950. [DOI] [PubMed] [Google Scholar]

- 22.Park E.J., Bae E., Yi J., Kim Y., Choi K., Lee S.H., Yoon J., Lee B.C., Park K. Repeated-dose toxicity and inflammatory responses in mice by oral administration of silver nanoparticles. Environ. Toxicol. Pharm. 2010;30:162–168. doi: 10.1016/j.etap.2010.05.004. [DOI] [PubMed] [Google Scholar]

- 23.Morganti P. Use and potential of nanotechnology in cosmetic dermatology. Clin. Cosmet. Investig. Dermatol. CCID. 2010;3:5. doi: 10.2147/CCID.S4506. [DOI] [PMC free article] [PubMed] [Google Scholar]

- 24.Verma P., Pathak K. Therapeutic and cosmeceutical potential of ethosomes: An overview. J. Adv. Pharm. Technol. Res. 2010;1:274–282. doi: 10.4103/0110-5558.72415. [DOI] [PMC free article] [PubMed] [Google Scholar]