MEDDOCS Open Access Publisher

ISSN: 2637-7721

Journal of Plant Biology and Crop Research

Open Access | Review Article

# Effects of Nanoparticles on Improvement in Quality and Shelf Life of Fruits and Vegetables

***Abdulraheem Mukhtar Iderawumi[1]*; Moshood Abiodun Yusuff[2]***

*[1]Department of Agricultural Science Education, Oyo State College of Education, Nigeria.*

*[2]University of Ilorin, Nigeria.*

***Corresponding Author(s): Abdulraheem Mukhtar Iderawumi**

Department of Agricultural Science Education, Oyo State College of Education, Nigeria.

Email: m.iderawumi@gmail.com

Received: Aug 02, 2021

Accepted: Sep 17, 2021

Published Online: Sep 20, 2021

Journal: Journal of Plant Biology and Crop Research

Publisher: MedDocs Publishers LLC

Online edition: http://meddocsonline.org/



**Keywords:** Nanoparticles; Fruits; Vegetables; Nanotechnology; Shelf-life.

**Abstract**

Presently, the agricultural sector is facing wide spectrum of local as well as global challenges viz., climate change, low productivity, declining soil organic matter, low nutrient-use-efficiency, deficiency of both macro and micro nutrients, reduction in agriculture lands and water availability, issues related to environment such as increase of pesticides residues and shortage of skilled labour besides lack of interest amongst farmers for cultivation. These constraints are further exacerbated by the growing food demand at the rate of 4%, which is required to endure world population of 9 billion by 2050. The recent coronavirus pandemic has highlighted the great important role the agriculture and food sector can plays in the society. To enhance the productivity of the agricultural and food sector, applications of the nanomaterials and nanotechnology have been adopted. Nanotechnology has proven its competence in almost all possible fields. However, today nanotechnology has evolved in true sense by contributing to a very large extent to the food industry. With the growing number of mouths to feed, production of food is not adequate. It has to be preserved in order to reach to the masses on a global scale. Nanotechnology made the idea a reality by increasing the shelf life of different kinds of food materials. Today, there has been a growing tendency for foods with low levels of chemicals. Thus, various edible formulations are considered as an environmentally favorable technique to extend the shelf life of fruits and vegetables by establish a modified atmosphere, which results to improving crop quality by reduction in respiration rate and loss of moisture.

**Cite this article:** Abdulraheem MI, Moshood AY. Effects of Nanoparticles on Improvement in Quality and Shelf Life of Fruits and Vegetables. Plant Biol Crop Res. 2021; 4(2): 1042.

## Introduction

Nanotechnology is a useful tool in modern agriculture to face emerging agricultural and environmental challenges principally related to the needs for increased productivity, sustainability, and security of agriculturally produced foods. The beneficial expectations from applied nanotechnology in agriculture may be helpful to implement delivery systems for agrochemicals, improve plant breeding, and reduce the impact of modern agriculture on the environment and input costs while improving the quality and quantity of yields [1]. Applications of nanotechnology in agriculture can improve crop production and protection with an emphasis on Nano fertilizers, Nano pesticides, Nano biosensors, and Nano enabled remediation strategies for the management of contaminated soils, with the main objective to obtain their fully-fledged biological efficacy without over dosage [2]. The technology involved in getting fresh produce from the field to the consumer has been the subject of detailed research for over a century. It is enormously complicated because many of the crops are highly perishable and variable. This variability militates against simple solutions.

Most of our food consists of agricultural products, which are usually seasonal and spoil quickly. To make food available throughout the year, humans have developed methods to prolong the storage life of products to preserve them [3]. Fruits and vegetables can also become contaminated with microorganisms capable of causing human diseases while still on the plant in fields or orchards, or during harvesting, transport, processing, distribution and marketing, or in the home [4]. Vegetables and fruits loss reaches more than 40% globally [5]. After harvesting crops, oxygen boosts the environment of microbial growth especially aerobic bacteria which is the first responsible for the corruption of vegetables and fruits. The production of fruit and vegetables is one of the most important economic activities around the world. They are a source of vitamins, minerals and nutrients beneficial to human health. Among fruit, the health benefits and nutritional value of avocados have been well-documented [6]. Deterioration of fruits and vegetables during storage depends largely on temperature and one of the ways to slow down this change and increase the length of time fruits and vegetables that can be stored is by lowering the temperature to an appropriate level. It must be remembered that if the temperature is too low the produce will be damaged and also that as soon as the produce leaves the cold store, deterioration starts again and often at a faster rate. Reduction of water loss by packaging has a marked influence on storability [7]. Fresh fruits and vegetables therefore remain the healthiest foods for men against metabolic diseases (diabetes, overweight and obesity, cardiovascular) their daily intake is usually much lower than the quantities recommended by the WHO. In developing countries, postharvest losses reported mostly occur during transportation, handling, storage and processing [8].

Today, there has been a growing tendency for foods with low levels of chemicals. Thus, various edible formulations are considered as an environmentally favorable technique to extend the shelf life of fruits and vegetables by establish a modified atmosphere [9], which results to improving crop quality by reduction in respiration rate and loss of moisture [10]. Nanotechnology is a new emerging and fascinating field of science. Nanotechnology permits advanced research in many areas and Nano technological discoveries could open up novel applications in the field of biotechnology and agriculture [11].

Continuous agricultural innovations are crucial to meet the increasing food demand of exploding global population through the uses of natural and synthetic resources. In particular, nanotechnology has potential to provide effective solutions to the multiple agriculture-related problems. Nanotechnology provides a unique position in transforming agriculture by developing existing crop management techniques and food production experiences [12], especially the production of Nano pesticides and Nano fertilizers. The use of nanotechnology as a plant nutritional mediator and as modern Nano fertilizers are coined as controlled release fertilizers, which prepared for governing nutrient liberation behaviors that depend upon thermal post-treatment criteria can mitigate the nutrient use efficiency of crops [13]. For example, Wade and Jason [14] investigated whether foliar sprays of micronutrient NP could affect plant health in disease-infested soils and reported that NP of CuO, MnO, or ZnO reduced disease estimates by 31%, 28%, or 28%, respectively when compared to untreated controls. The authors also found that NP of CuO increased fresh weights by 64%, reduced the Area under the Disease Progress Curve (AUDPC) values by 69%, and had 32% more Cu in the roots compared to untreated eggplants held in the greenhouse in soilless medium infested with the Verticillium wilt fungus [14].

Quality of fruits and vegetables has huge impact of surrounding during storage, we can only maintained the quality of fruits and vegetables after harvesting; therefore it is important to store it in proper ecosystem. Quality is a complex perception of many attributes that are simultaneously evaluated by the consumer either objectively or subjectively [3].

### Applications of NPs in Agriculture

Nanotechnology has paved the way for addressing several obstacles in the agriculture sector by providing unique and marked improvements over traditional methods. ENMs have been used to improve plant growth and development with specific goals to increasing crop production and combatting plant diseases. The global scientific community has been inspired to explore the potential impacts of ENMs at various plant stages (Figure 1).

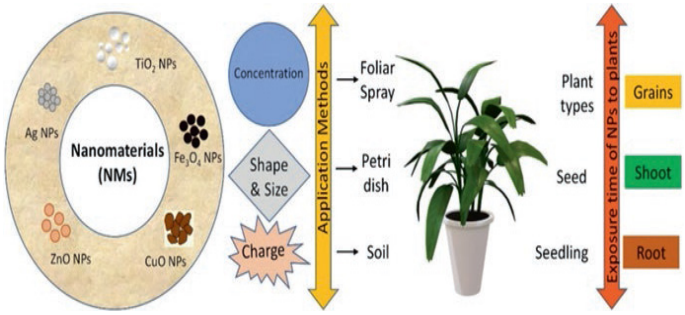


**Figure 1:** Overview of ENM properties and their potential applications for plants.

The major contribution of nanotechnology in agriculture sector can be broadly classified into, (a) delivery of nanocide-pesticide, (b) stabilization of green pesticides and biopesticides using nanomaterials (NMs), (c) slow and controlled release of NMs assisted micronutrients, fertilizers and biofertilizers, (d) NMs assisted transport of genetic materials for crop development, (e) nanobiosensors for rapid and selective plant pathogen and pesticide detection etc [15,16].

### Nanoparticles for sustainable agriculture

Today several techniques have made it possible to isolate the soluble fibers of many foods, for the good state of our micro-

biota, they are in form of powder, easy to consume since they are soluble in water. However the intake of insoluble fiber that regulates the transit, is contained in leeks, salads, as well as other green vegetables, fruits, it should not be neglected. Eating a good fruit or a good vegetable is a pleasure! Every day, new research makes us discover vital essential elements for health and well-being. Until this day, fruits and vegetables have not disclosed all their secrets, the mystery continues. Nanoparticles serve several purposes in the processing of food. They help in improving the food's flow property, colour, and stability. The effectiveness of the nanoparticles in the food depends on its bioavailability in a system [17]. Nanoparticles may be created using several methods. Some of them may occur in nature as well. The methods of creation include attrition and pyrolysis. While some methods are bottoms up, some are called top down. Top down methods involve braking the larger materials into nanoparticles [18]. Combining antimicrobial and antifouling properties, thermal and mechanical protection, oxygen and moisture barrier, as well as to verify the actual quality of food, e.g., sensors to detect spoilage, bacterial growth, and to monitor incorrect storage conditions, or ant counterfeiting devices in food packages may extend the products shelf life and ensure higher quality of foods.

The research and development of nanotechnology in the sector of agriculture and food industries has been extensively focused on in recent decades. The reports have shown a positive output regarding sustainability along with improved productivity [19]. Currently, there are applications of NPs in the development of products including nanosized nutrients, bionanocomposites, Nano coated fertilizers together with nanobiopesticide and nanoinsecticides for eco-friendly protection against phytopathogens [20].

Nanotechnology offers a new agrochemical tool that assists in high crop productivity reduction of toxic chemicals, plant-pathogen controls, and plant adaptation, which confers crop protection (Figure 2). Nanotechnology has proven its competence in almost all possible fields. However, today nanotechnology has evolved in true sense by contributing to a very large extent to the food industry. With the growing number of mouths to feed, production of food is not adequate. It has to be preserved in order to reach to the masses on a global scale. Nanotechnology made the idea a reality by increasing the shelf life of different kinds of food materials [21].

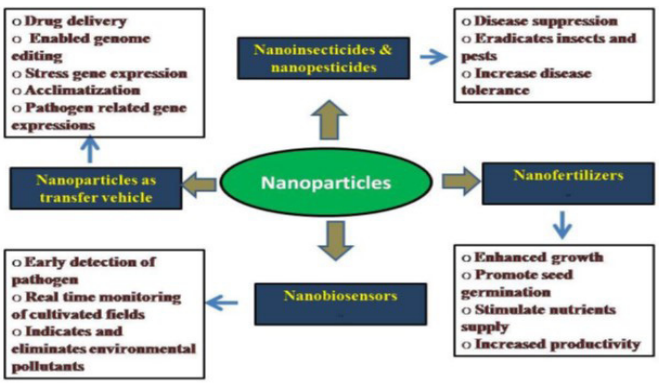


**Figure 2:** Different application of nanoparticles in crop protection [22].

Sustainable agriculture relies on practices that help to maintain ecological equilibrium and encourage natural regenerative processes such as nitrogen fixation, nutrient cycling, soil regeneration, and the protection of natural enemies of pest and diseases as well as the targeted use of inputs. Agricultural systems relying on such approaches not only support high productivity, but also preserve biodiversity and safeguard the environment [23]. Plants offer a prospective route for NP transfer to the ecosystem and serve as an important factor in the food chain for assessing possible bioaccumulation. Various microscopic and spectrometric techniques are now available to investigate NP effects on different parts of plants and their possible mechanisms of transfer.

Outburst of world population in past decade has forced the agricultural sector to extend crop productivity to satisfy the needs of billions of people particularly in developing countries. Since green revolution, chemical fertilizers are deemed as an indispensable input of modern crop production systems, however these are associated with environmental and ecological consequences. Researchers have synthesized different kinds of nanomaterials with different research materials for agricultural development but the challenge is in the scaling up of this research to the direct benefits of farmers and agro-processors [24].

During the last few decades, nanotechnology in the field of agriculture changed the whole agricultural practice forever. Rapid disease detection, disease diagnosis, nutrients enrichment, disease suppression, real-time monitoring of the cultivated fields and environmental waste reduction are some of the aspects that are achieved by using nanoparticles in the agricultural fields. The main purposes of sustainable agriculture are reducing environmental pollutants and the increase in crop yield. In particular, nanotechnology is the best tool that triggers conventional farming towards sustainable agriculture. Advancement in nanotechnology offers a new green revolution in the future. The benefits and application of nanoparticles are vast.

**Postharvest losses in fruits and vegetables**

Postharvest and economic losses suffered by horticultural industry annually due to mechanical damages of fresh produce from harvest to postharvest handling are considerably huge [25,26]. Most of our food consists of agricultural products, which are usually seasonal and spoil quickly. To make food available throughout the year, humans have developed methods to prolong the storage life of products to preserve them. Fruits and vegetables can also become contaminated with microorganisms capable of causing human diseases while still on the plant in fields or orchards, or during harvesting, transport, processing, distribution and marketing, or in the home [27].

The process of distasteful change of vegetables and fruits from its normal condition that make it unaccepted by the consumer is known as vegetable spoilage; this economic issue was an obstacle in facing food insecure for many countries in the world, vegetable spoilage has negative effect for both [28]. High fruits and vegetable intake is also linked to healthy skin and hair, increased energy and lower weight. Increasing the consumption of fruits and vegetables significantly decreases the risk of obesity and overall mortality [4].

The food industry uses a variety of preservation, or processing, methods to extend the shelf life of fruits and vegetables such that they can be consumed year round, and transported safely to consumers all over the world – not only those located near the growing region. Refrigeration is very popular method of storage. Apart from this, the epileptic power supply and low income of farmers in the rural communities makes refrigeration expensive. The quality of a crop at harvest can have a major effect on its postharvest life. There are numerous factors involved and these factors frequently interact, giving complex interrelationships. In tree crops, fruit produced on the same tree and harvested at the same time may behave differently during marketing or when stored. In addition to the effects of preservation techniques, which will be discussed later, there are many other factors that affect the nutritional quality of fruits and vegetables. Most consumers do not have home gardens capable of providing the recommended 5–13 daily servings year round. In the USA, fruits and vegetables grown in North America may spend up to 5 days in transit postharvest, before arriving at a distribution center. For produce grown in the Southern Hemisphere for winter and spring consumption in the USA, transit may be a matter of days if transported by airfreight, to several weeks if fruits and vegetables are sent by refrigerated ship. Once arriving at the retail store, fruits and vegetables may spend 1–3 days on display prior to being purchased and brought to the consumer's home, where they may be stored up to 7 days at room or refrigerated temperatures prior to consumption During this postharvest period, significant changes in moisture and nutrient content will occur.

In addition to the effects of transport and storage on fruit and vegetables, the variety and stage of ripeness all have an impact on the levels of vitamins, minerals and phytochemicals within fruit and vegetables. Most varieties of fruits and vegetables found in the supermarkets are not chosen for their nutritional content and instead varieties are chosen for their appearance, yield and their ability to withstand long-distance transport. The stage of ripeness may also have a significant impact on the nutritional quality of fruit and vegetables. For example, many fruits and vegetables are harvested before they reach full maturity in order to extend their shelf life. Fruits such as tomatoes, apples, melons and peaches, which are known as climacteric, will continue to ripen and reach their peak color after being detached from the mother plant. There are considerable losses of vitamin C compared to that found if the product had been freshly picked at its peak of maturity.

New alternatives for food conservation and preservation are now emerging, as many studies have shown that the use of synthetic preservatives and chemical additives is leading to intoxication, cancer and other degenerative diseases. This has led to a growing consumer concern and the desire to consume healthier products containing natural preservatives and additives instead of synthetic ones [29]. The food industry uses a variety of preservation, or processing, methods to extend the shelf life of fruits and vegetables such that they can be consumed year round, and transported safely to consumers all over the world – not only those located near the growing region [30].

### Types of nanoparticles

NPs can be grouped into various forms based on size, morphology, and physical, chemical, and biological properties. Based on shape, they can be classified into quantum dots, nanotubes, nanofibers, Nano rods, Nano sheets, aerogel, and nanoballs [31] and can also be classified as either magnetic or nonmagnetic NPs. Alternatively, NPs may be classified into organic, inorganic, and carbon-based NMs with improved properties compared with larger sizes of bulk materials [32]. Some of them are carbon-based NPs, ceramic NPs, metal NPs, semiconductor-based NPs, polymeric NPs, and lipid-based NPs. Zinc oxide and pediocin incorporated nanoparticles in the nanocomposite films also have antimicrobial activity [33]. Silver coated nanocomposites also act as an antimicrobial agent. Silver attaches to the cell surface and degrades the lipopolysaccharide and hence results into increased permeability, causing irreversible damage to the bacterial DNA [21].

### Quality and shelf life of tropical fruits and vegetables

Depending on the fruit or vegetable of interest, and the preservation conditions and specific nutrient(s), 'advanced' technologies may have a positive, neutral or negative effect on nutrient retention. Food packaging and preservation methods are used to make sure that the quality of the food is kept intact. However, they are preserved in a way so that it is safe for consumption. Preservation mainly aims at providing physical protection in order to prevent the food from external shocks and vibration, microbial infestation, and temperature in providing barrier protection by scavenging oxygen and other spoilage causing gases. The storage life of fresh fruit and vegetables varies with type, variety and pre-harvest conditions. There is scope to control storage life through postharvest management of the two most important determinants of storage life and quality — respiration and transpiration. Proper control of temperature and relative humidity is the key to maximizing storage life and marketable quality [3]. The quality of a crop at harvest can have a major effect on its postharvest life. There are numerous factors involved and these factors frequently interact, giving complex interrelationships. In tree crops, fruit produced on the same tree and harvested at the same time may behave differently during marketing or when stored. The issues that influence produce quality include obvious things, such as harvest maturity and cultivar or variety, but also the climate and soil in which it was grown, chemicals which have been applied to the crop and its water status. Many of these factors can also interact with time such as when fertilizers or irrigation is applied or the weather conditions near to the time of harvest. Fruits and vegetables play an important role in healthy nutrition and are high on the list of consumer priorities. However, the major obstacle of processing ready-to-eat fresh-cut fruits and vegetables is their short shelf life, leading to quick degeneration and decomposition of the product and undesirable look and negative palatability. Fruits and vegetables are living products undergoing a ripening and at the end an ageing process, in which the plant tissue is broken down. The product undergo various biological processes, which also continue after the products have been harvested. The processes cause gradual changes in the quality.

The main cause of postharvest losses was identified because of limited shelf life of tropical produce [34,35]. As a consequence, these losses have several adverse impacts on the sales of tropical produce farm, consumer prices, national income and nutritional quality [36].

## Conclusion

Nanotechnology is rapidly developing technology impacts every aspect of the food system from cultivation to food production to processing, packaging, transportation, shelf life, and bioavailability of nutrients. Fruits and vegetables are highly perishable and can be stored only for limited days under normal

tropical ambient condition. The complexity and variety impact factors such as temperature dependent respiration rate and different optimal storage temperatures affect the quality during postharvest storage. Nanoparticle engineering is one of the latest technological innovations that demonstrate unique targeted characteristics with elevated strength. So far "Organic" is likely the most commonly accepted standard for healthy food. Many public prefer traditional and "organic" food, especially when they compare it with genetically modified food. Sometimes public are even confused by genetically modified food with nano-engineered food. The main cause is the poor access to information and resources of food nanotechnology for the public. It is of utmost importance to explore innovative technologies like nanotechnology in the agricultural sector, for the cultivation of 'smart crops' that can grow and sustain in harsh climates, produce greater yields in shorter duration and with less agrochemicals inputs. The application of nanotechnology in the field of agriculture completely changed the present farming practices. One of the emerging challenges in the current agricultural system is developing disease resistance and increased productivity without accumulating environmental pollutants. Most of the applied conventional chemical fertilizers and pesticides have several side effects on both plants and the environment. Nanotechnology-based crop protection strategies have the potential to induce disease tolerance and enhancement of crop yield. Benefits of using nanoparticles in the agricultural fields include reducing environmental pollutants, rapid disease diagnosis, simple preparation process, less toxicity, and cost-effectiveness. As humanity faces major challenges involving energy, water, food, environment, poverty, diseases, education, democracy and population. Green nanotechnology could be a solution for providing sustainable energy, clean water and a better environment. Various nanomaterials can sustain the agricultural sectors. Here we review the effects of nanoparticles on improvement on fruits and vegetable.

## References


1. Bratovcic A, Hikal WM, Said-Al Ahl HAH, Tkachenko KG, Baeshen RS, et al. Nanopesticides and Nanofertilizers and Agricultural Development: Scopes, Advances and Applications. Open Journal of Ecology.2021; 11: 301-316.
2. Lavicolia L, Lesoa V, Donald HB, Shvedovab AA. Nanotechnology in agriculture: opportunities, toxicological implications, and occupational risks. Toxicol. Appl. Pharmacol.2017; 15: 96-111.
3. Abdulraheem MI. Quality of Fruits and Vegetables during storage: An Overview. Journal of Applied Sciences, Innovation and Technology, Lanlate (JASITLAN). 2021; 3: 145-154.
4. Abdulraheem MI. The Roles of Extension Agents in the Production and Marketing of Leafy Vegetable in Ibarapa Region in S.A. Developmental Issues in Ibarapa Region: A Multidisciplinary Approach. Lanlate. Department of Geography, Emmanuel Alayande College of Education, Lanlate. 2013: 20-25.
5. Imedpub.com. 2018.
6. Correa-Pacheco ZN, García-Paniagua KD, Bautista-Baños S, Corona-Rangel ML. Effect of chitosan-thyme essential oil nanocoatings on postharvest quality of tomato fruit. Revista Mexicana de Fitopatología. 2019; 37: 29-36.
7. Abdulraheem MI, Fudzagbo J, Iderawumi MA, Obene SA, Oluwaseun WA, et al. Innovation Techniques of Operating School Farm. Farming and Management Journal.2021; 6: 21-28.
8. Azizah O, Nazamid S, Rosli S, Jamilah B, Noor Diana Z, et al. Postharvest handling practices on selected local fruits and vegetables at different levels of the distribution Chain. Journal of Agribusiness Marketing.2009; 2: 39-53.
9. Ali A, Noh NM, Mustafa MA. Antimicrobial activity of chitosan enriched with lemongrass oil against anthracnose of bell pepper. Food Packag. Shelf Life. 2015; 3: 56-61.
10. Chitravathi K, Chauhan OP, Raju PS. Postharvest shelf-life extension of green chillies (Capsicum annuum L.) using shellac-based edible surface coatings. Postharvest Biol. Technol. 2014; 92: 146-148.
11. Siddiqui MH, Al-Whaibi MH, Mohammad F. Nanotechnology and plant sciences nanoparticles and their impact on plants. Springer International Publishing, Cham. 2015.
12. Elkady MF, Shokry HH. Equilibrium and dynamic profiles of azo dye sorption onto innovative nano-ZnO biocomposite. Curr. Nanosci.2015; 6: 805-814.
13. Younes NA, Shokry H, Elkady HMF, Hamed AM, Mona FA. Impact of synthesized metal oxide nanomaterials on seedlings production of three Solanaceae crops. Heliyon. 2020; 6: 1-10.
14. Wade HE, Jason CW. The use of metallic oxide nanoparticles to enhance growth of tomatoes and eggplants in disease infested soil or soilless medium. Environ. Sci.: Nano. 2016; 3: 1072-1079.
15. Salamanca-Buentello F, Daar AS. Dust of wonder, dust of doom: a landscape of nanotechnology, nanoethics, and sustainable development. Global bioethics: The impact of the UNESCO International Bioethics Committee, Advancing Global Bioethics, vol 5. Springer International Publishing, Cham. 2016: 101-123.
16. Subramanian KS, Manikandan A, Thirunavukkarasu M, Rahale CS. Nano-fertilizers for balanced crop nutrition. Nanotechnologies in Food and agriculture. Springer International Publishing, Cham. 2015; 69-80.
17. Coma V. Bioactive packaging technologies for extended shelflife ofmeat-based products, Meat Science. 2008; 78: 90-103.
18. Mandal A. Properties of Nanoparticles. News-Medical. 2018.
19. Shende S, Rajput V, Ingle AP, Gade A, Minkina T, et al. Synthesis of copper nanomaterials by microbes and their use in sustainable agriculture. Microbial Nanotechnology. CRC Press, Boca Raton. 2020: 1-34.
20. Shang Y, Hasan MK, Ahammed GJ, Li M, Yin H, et al. Applications of nanotechnology in plant growth and crop protection: a review. Molecules. 2019; 24: 2558.
21. Neha P, Surjit S, Nupur O, Anamika S, Anil B, et al. Facets of Nanotechnology as Seen in Food Processing, Packaging, and Preservation Industry. BioMed Research International.2015; 365672: 1-18.
22. Anuron B, Anik S, Krishnendu A, Nilanjan C. Nanotechnology: an Emerging Hope in Crop Improvement. Letters in Applied NanoBiosciences. 2021; 10: 2784-2803.
23. Farooq M, Siddique KHM. Conservation agriculture. Springer International Publishing, Cham. 2015.
24. Ndukwu MC, Ikechukwu-Edeh CE, Nwakuba NR, Okosa I, Horsefall IT, et al. Nanomaterials application in greenhouse structures, crop processing machinery, packaging materials and agro-biomass conversion. Materials Science for Energy Technologies. 2020; 3: 690-699.
25. Ahmadi E, Ghasemzadeh HR, Sadeghi M, Moghadam M, Zarifneshat S. The effect of impact and fruit properties on the bruising peach. Journal of Food Engineering. 2010; 97: 110-117.
26. Ghaffari H, Ghassemzadeh HR, Sadeghi M, Alijani S. Some physi-

cal, mechanical and chemical properties of tomato fruit related to mechanical damage and bruising models. Biological Forum – An International Journal. 2015; 7: 712-718.

27. Kalaiselvi A, Roopan SM, Madhumitha G, Ramalingam C, Elango G. Synthesis and characterization of palladium nanoparticles using Catharanthus roseus leaf extract and its application in the photo-catalytic degradation, Spectrochim Acta A Mol Biomol Spectrosc. 2015; 135: 116-119.

28. Farah RS. Bacteriophage as Bio-Preserving to Enhance Shelf Life of Fruit and Vegetables. Plant Archives. 2020; 20: 359-362.

29. Laranjo M, Fernández-Léon AM, Potes ME, Agulheiro-Santos AC, Elias M. Use of essential oils in food preservation. Antimicrobial research: Novel bioknowledge and educational programs. 2017: 177-188.

30. Kalaivani R, Renuka C, Saravanan K, Elavarasi S. Preservation of Vegetable by Traditional and Natural Methods. National Seminar on Biodiversity and Conservation: Present Status and Future Perspectives. 2015.

31. Wang H, Zhao R, Li Y, Liu H, Li F, et al. Aspect ratios of gold nanoshell capsules mediated melanoma ablation by synergistic photothermal therapy and chemotherapy. Nanomed Nanotechnol Biol Med. 2016; 12: 439-448.

32. Ealias AM, Saravanakumar MP. A review on the classification, characterisation, synthesis of nanoparticles and their application. IOP Conf Ser Mater Sci Eng. 2017; 263: 032019.

33. Moraru CI, Panchapakesan CP, Huang Q, Takhistov P, Liu S, et al. Nanotechnology: a new frontier in food science, Food Technology. 2003; 57: 24-29.

34. Amin MN, Hossain MM. Reduction of post harvest loss and prolong the shelf life of banana through hot water treatment. Journal of Chemical Engineering. 2012; 27: 42-47.

35. Arah IK, Amaglo H, Kumah EK, Ofori H. Pre harvest and post harvest factors affecting the quality and shelf life of harvested tomatoes: a mini review. International Journal of Agronomy. 2015: 478041.

36. Wu CT. An overview of post harvest biology and technology of fruits and vegetables. In: Afro-Asian Rural Development Organization (AARDO) workshop on technology on reducing post harvest losses and maintaining quality of fruits and vegetables. 2010; 2-11.

37. Fazly AZ, Mozhiarhasi SS, Wan NWA, Ainun SG. Optimum postharvest handling-effect of temperature on quality and shelf life of tropical fruits and vegetables. J. Trop. Resour. Sustain. Sci. 2019; 7: 23-30.

38. Greenwood Michael. Nanoparticles in Food and Food Contact Materials. News-Medical. 2019.

39. Taheri A, Behnamian M, Dezhsetan S, Karimirad R. Shelf life extension of bell pepper by application of chitosan nanoparticles containing Heracleum persicum fruit essential oil. Postharvest Biology and Technology. 2020; 170: 111313.