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Nanotechnology in Management of Post-Harvest

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INTRODUCTION

Fruits and vegetables are rich in various types of vitamins, minerals, carbohydrates, flavonoids, organic acids, and so on that are important for human health. Fruits and vegetables, however, are highly perishable in nature so they cannot be stored for a long time without proper management. After harvesting, they continue their metabolic activity, in which breathing and transpiration from living cells are the most common. Environmental factors and handling after harvest also affect the quality of the fruits. As a result, the shelf life of fruits and vegetables is affected, which after harvesting from plants causes deterioration in quality, off-flavor, browning, softening, etc. As per the FAO report, there is 20 to 44 percent of fruits and vegetables are losses in the world every year because of insufficient post-harvest management practices. Nano-technology is currently being used in most of the agricultural sector and its growth is continuously increasing day by day. Nano-technology is used in agriculture in various stages such as nano-fertilizer, weed management, plant protection (fungicide, pesticide), crop improvement, nano sensor, post-harvest technology, nano-biotechnology, seed technology, water management, soil management, plant growth regulators, food technology, agricultural engineering aspects, etc. Nano-technology has recently been introduced as a new word in post-harvest technology that is considered one of 21st century technologies. Nanomaterial, which is prepared by crushed the material in very small pieces by different chemical and physical methods or rebuild the structure of the material on the Nanoscale size about less than 100nm. In nanomaterial, use different kinds of natural biodegradable materials like-Nano-zinc dioxide, silver Nanoparticles, Nano-$CaCO_3$, chitosan, and Nano silica, etc. are used mostly as a coating material.

Nowadays, it's widely used in agriculture both production and processing purposes. Nanomaterial has very unique attributes like a barrier, mechanical, anti-bacterial, photocatalytic, thermal properties, etc. are found to be beneficial for increasing the shelf life of fresh fruits and vegetables.

Principle of Nano-technology in the improvement of shelf life:

Mostly, conventional post-harvest methods based on physical (cold storage, irradiation), chemical (different concentration of chemicals such as chlorine, CMC, BA, etc.) and biological (nisin-incorporated cellulose films) methods to increase fresh fruit and vegetable shelf life. It follows that there are three main factors that play an important role in quality preservation: (1) control of senescence; (2) control of micro-organisms; and (3) control of internal water evaporation. In a structure that is used as coating material and packaging film in fresh fruits and vegetables, the nanomaterial is natural biodegradable material has less than 100 nm in it. In fresh fruits and vegetables, the nanomaterial is used as a barrier for controlling moisture and gas exchange for increasing self-life. The thickness of the coating layer mainly depended on the variety of treatments and the type of coating emulsion attach to the surface of fruit and vegetable. There are some basic principles which are followed by nano-preservation for self-life increases in fruits and vegetables had details given in the below section.

Synthesis of Nanomaterials:

In nanomaterial synthesis, the "Bottom-up" and "Top-down" methods are mainly used. In "Bottom-up" technique nanoparticles are synthesis from the smaller unit (atoms, molecules, clusters) to further synthesis of nanomaterials with its outstanding natural self-assembly property. In this process, molecules are changes into either gas-phase or liquid-phase which condensed by the Inert gas method (vacuum arc deposition, inert gas aggregation and vapor condensation) and liquid phase method (ultrasonic dispersion, sol-gel methods) for 0D nanomaterials. On the other hand, for the synthesis of 1D and 2D materials used a different type of methods like CVD methods (rod-like nanomaterials), VLS methods (nanowires), molecular beam epitaxy (MBE), Metal-organic Chemical Vapor Deposition (MOCVD) and Electrodeposition (commonly used for 3D nanomaterials like multilayer). Silver nanoparticle one of the examples which is made "Bottom-up" technique.

In "Top-down" technique nanoparticles are synthesis from grinding and slicing of bulk material (macroscopic) into nanomaterials. There are several techniques like specialized ablations, sputtering, thermal decomposition, mechanical grinding, etching and cutting used in the "Top-down" method. There are two methods commonly following in the synthesis of nanomaterials such as Photolithography, Lithography (Electron-beam lithography, X-ray lithography, soft lithography) and Micromachining methods. It's a slow and expansive method in which the efficiency of nanomaterials is low compared to the Bottom-up technique due to surface structural defects. "Bottom-up" technique is a more efficient, cheap and commonly useful technique in comparison to the "Top-down" technique which is expensive and complex for application on a larger scale.

Nanomaterial classification:

The nanomaterials are classified based on their chemical composition, the dimension of particles and mode of application in the following classes. Chemical composition: This is the most common classification based on the chemical composition of nanomaterials. Carbon-based materials like- hollow spheres, ellipsoids, or tubes formed from carbon. Nanomaterials like Spherical and ellipsoidal carbon are referred to as fullerenes. Metal-based materials in which nano-silica, nano gold, titanium dioxide, Cu, Co, Ni, Al and Fe metal oxide are used. Dendrimers have different types of simple, liquid, chiral, poly amido amine, micellar, polypropylene imine, amphiphilic, Metallo and dendrimers. The composite type has a combination of different

types of nanomaterials. There are other classifications also found in nanomaterials like Dimension of nanoparticles (0D, 1D, 2D, 3D). In one dimensional nanomaterial (nanotubes, nanorods and nanowires), two-dimensional nanomaterials (plate-like shape, graphene, nanofilms, nanolayers, and nanocoatings) and three-dimensional nanomaterials (bulk powders, bundles of nanowires, nanotubes and multi-nanolayers). Nanomaterials are commonly used as an edible coating materials and packaging films in fresh fruits and vegetables.

Properties of nanomaterials:

There has given brief discussion of nanomaterials which helps to improve the shelf life of fruits and vegetables.

Antibacterial properties: There are some antibacterial nanomaterials are used for suppressed different microorganism's growths or inhibited individual microorganisms for the increases shelf life of fruits and vegetables. The antibacterial materials are classified as metal ion and oxide photocatalytic type. Metal ionic particles which have antibacterial properties such as Zn, Ag, Cu, Co, Ni, Al and Fe are used as nanomaterials in a different kind of natural or synthetic metal ions. Nanomaterials are generally found in naturally chemically stable phosphate, silicate, multilayer clay minerals, larger surface area, porous, anti-toxic in nature and with better absorption properties, etc. Sometimes, it's also be divided into organic and inorganic antibacterial nanomaterials. Organic nano-materials are frequently less stable in nature at high temperature or high pressure in compare to metal ionic particles. Some common organic nano-materials examples are used in increases for the shelf life of fruits and vegetables like liposomes, dendrimers, polymeric micelles and carbon nanomaterials. Due to the instability of organic nanomaterial, most of the focused attracted by metal ionic particles which are used as widely in increases post-harvest shelf-life of the fresh commodity.

Barrier properties: Some nanomaterials have good barrier properties compared to traditional resources, if fruits and vegetables are used for self-life extension. There is a different type of nanomaterial with different barrier properties, such as reduction of gas transmission, reduction of moisture properties, etc., which are beneficial for increased storage life.

Mechanical properties: Nanomaterials mechanical properties depends on mainly two factors in which (1) stress transfer on the nanoparticles-matrix's interface and (2) positive hydrogen bonds and ionic interactions interactions between nanoparticles. Nanoparticales improves the mechanical property of coating and stabilizing the packaging unit of fruits and vegetables.

Thermal properties: In nanomaterial, interaction between nanoparticles and continuous dimensional phase or matrix rearranged the structure which is helps to increases thermal efficiency of the material. Due to changes in structure of nanomaterials melting point of nanomaterial are also increases. Thermal efficiency of nanomaterials having significant role in increases of self-life of fresh fruits and vegetables.

Nano-coating films: In agriculture recently many coating films developed with using of nanomaterial. They have different properties such as antimicrobial properties, anti-ethylene properties, antioxidant films, etc. based on purpose of coating. This coating having significant role in improvement of shelf life of fruits and vegetables.

Nanocomposites:

Nanocomposites is a new attractive strategy which help to elaborate in a more effective composition mixed with organic and inorganic type of nanoparticles. In nanocomposites, (composition of different kind of dimensional particles or phases) two types are found in which continuous phase which is known as "Matrix" and discontinuous phase are known as "Reinforcement or Reinforcing material". This kind of mixer used for improving barrier, mechanical, thermal, antibacterial, enzyme immobilization and photocatalytic properties in edible coatings. Nanocomposites materials are showing better performance compared to

nanoparticles because of their very large interfacial area. In general, synthesis of nanocomposite are mainly done by situ polymerization, melt homogenization and solvent-assisted methods. Dispersion and homogeneity are major problems in their synthesis. There are many kind of nanocomposites like Clay matterials, cellulose, Chitosan, Montmorillonite (MMT), nano-ZnO, nano-TiO2, nano-SiOx, CuO, AgNP, starch etc. are used for increases shelf life of fresh fruits and vegetables as a coating materials.

S.No.	**Crop Name**	**Nanomaterial**
1.	Apple	Nano-ZnO
2.	Kiwi	Nano-ZnO
3.	Cucumber	Chitosan
4.	Pomegranate	Nano-ZnO
5.	Carrot	Nano-ZnO
6.	Strawberry	Nano-ZnO
7.	Longan fruit	Nano-silica
8.	Chinese yam	Nano-$CaCO_3$

