Article: RT1127

Biotica Research Today
Vol 4:10
2022
722/724

How to cite this article?
Latha and Devaraju, 2022. Nanotechnology for Shelf Life Enhancement in Vegetable Crops. Biotica Research Today 4(10):722-724.

Nanotechnology for Shelf Life Enhancement in Vegetable Crops

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Abstract

Vegetables are highly perishable due to physical damage, moisture loss, biochemical changes, and post-harvest microbial activities, which reduce the quality and shelf-life of vegetables. Hence they cannot be stored for a long time without proper management. As per the FAO report, 20 to 44% loss of vegetables occurs in the world every year because of poor post-harvest management practices. Nanotechnology is one of the best solutions for overcoming these losses because it has not yet been linked to any adverse side effects; thus, it can be effectively used to extend the shelf life of fresh vegetables. Nano-materials are natural biodegradable materials of < 100 nm size that can be used for shelf life enhancement of fresh vegetables. These have unique attributes like a barrier against moisture loss, mechanical, anti-bacterial, photo-catalytic and thermal properties, which help to minimize the post-harvest loss in vegetables.

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Keywords
Nanotechnology, Post-harvest loss, Shelf life, Vegetables

Introduction

"Nanotechnology can be defined as the design, characterization, production and application of structures, devices and systems by controlling the shape and size at the nanometre scale." "Nano" is a Greek word that means "Dwarf." It is the ability to create and manipulate atoms and molecules on the smallest of scales. "Nano" means 10^{-9} or one billionths of something. Nano-materials have one, two or three dimensions of 1-100 nm.

The Concept of nanotechnology was first introduced by American physicist Richard Feynman, known as the father of nanotechnology. The term 'Nanotechnology' was coined in 1974 by Norio Taniguchi from the Tokyo Science University.

Properties of Nanomaterials

These are materials with 100 nm size with larger surface area, porous, anti-toxic and with better absorption properties, *etc*. and also possess the following properties:

• *Anti-bacterial properties*: Metal ionic particles - Zn, Ag, Cu, Co, Ni, Al and Fe & few organic Nano-materials - liposomes, dendrimers, polymeric micelles and carbon nanomaterial have anti-bacterial properties.

• *Barrier properties*: Act as a barrier against gas transmission, moisture properties, *etc*., which are beneficial for increased storage life.

• *Mechanical properties*: It is based on two principles, *i.e.*, (1) stress transfer on the nanoparticles-matrix's interface and (2) positive hydrogen bonds and ionic interactions between nanoparticles. Nanoparticles improve the mechanical property of coating and stabilize the packaging units of vegetables.

Article History
Received on: 20th October 2022
Revised on: 26th October 2022
Accepted on: 27th October 2022

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• *Thermal properties*: In nano-materials, the interaction between nanoparticles and continuous dimensional phase helps increase the material's thermal efficiency.

Approaches in Nanotechnology

There are two approaches to nanotechnology followed (Figure 1).

1. Top-down Approach: Creating Nano-scale materials by physically or chemically breaking down larger materials.

2. Bottom-up Approach: Assembling Nano-materials atom-by-atom or molecule-by-molecule (self-assembling).

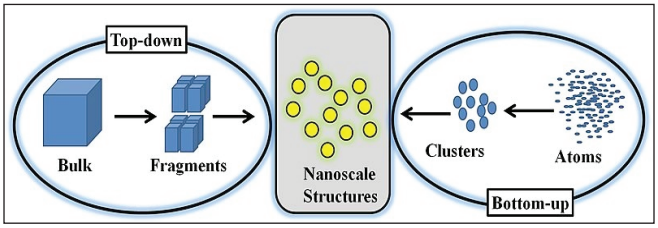

Figure 1: Approaches in nanotechnology

Applications of Nanotechnology in the Food Industry

Nanotechnology is potentially used in the field of food and agriculture. Nanotechnology is important to food science, food packaging, food preservation, science and agriculture engineering (Yadav *et al*., 2020).

• The utilization of nanotechnology increases the safety measures in food manufacturing, processing, packaging and distribution.

• It can be used to sense, detect and provide a warning about possible problems during processing.

• Utilized to increase the flavor and introduce anti-bacterial nanoparticles into food.

• Most probably, nanotechnology is utilized to enhance the shelf life of food.

• For safe packaging of food, nano-barcodes are used and monitor the distribution of food products.

• This technique can easily incorporate nano-supplements to increase nutritional components in the food.

• The IP Nano-sensors have a huge benefit in the food industries, which are useful for monitoring the food in all its phases (production, processing, packaging, and distribution).

Nanotechnology Implications in Shelf Life Enhancement

1. Nano-Coating

Nano coating is the thin layer of < 1-100 nm thick built onto surfaces. Nano-coating is formed from single or multiple applications of coating materials. Nano coating helps to provide barriers against foreign materials and other substances. Nano coating not only prolongs shelf life but also provides additional nutrients. It is a time-saving technique for coating perishable produce like fruits and vegetables. Due to coating, the pores on the skin responsible for water loss are blocked. Wax coating is used for many fruits such as citrus, tomato, apple *etc.* Wax coating is used to improve the external appearance of the food and reduce the rate of oxygen and water vapor transmission. Food-grade waxes are used for the fruits.

2. Nano-Laminates

Nano laminates are also thin films. These are formed by two or more layers of food-grade materials. Antimicrobials, antioxidants, and anti-browning agents can be incorporated into the films. These agents help to increase the shelf life of the product. Different substances can create layers, such as polysaccharides and phospholipids. Fresh fruits and vegetables have high moisture content; hence, there are high biological activities. Nano laminates are used in fruits and vegetables to control biological activity and improve shelf life. Nano laminates are very useful in reducing post-harvest losses in fruits and vegetables such as tomatoes. The use of edible laminates is mainly based on post-harvest agriculture techniques to solve microbial growth problems during transportation and storage.

3. Nano-Sensors

Nano sensors are the devices used for determining the condition of food products. Nano sensors improve the problems of food packaging. Nano sensors give surety to consumers about the products they are purchasing. Nano sensors help to provide fresh and safe food to consumers. The presence of Nano sensors helps to reduce the frequency of food-borne illness, which is useful for maintaining food safety. Nano sensors are nothing but nanoparticles which are having characteristics of pathogen detection. Nano sensors are mechanical or chemical sensors used to detect physical or chemical parameters. Nano sensors are used in food industries to achieve the desired level of sensitivity. The advantage of Nano sensors over conventional sensors is their improved sensitivity and specificity.

4. Nano-Emulsions

Nano emulsion consists of lipid Nano droplets (between 10-100 nm diameters) dispersed in an aqueous solution, and surfactant molecules surround each oil droplet with unique physicochemical and functional characteristics.

5. Nano-Composites

Nano composite is a multiphase solid material where one of the phases has a Nano composition of less than 100 nm.

Role in Food Packaging

• Reduce weight.

• Improve mechanical strength.

• Increase heat resistance.

• Degradation of ethylene.

• Improve barrier against oxygen, carbon dioxide, UV radiation, moisture and volatiles.

6. Smart Food Packaging

• Smart packaging responds to environmental conditions or repairs it or alerts a consumer to contamination or the presence of pathogens.

• It is an intelligent packaging that operates under the "release on command" method of preservative application using an efficient bio-switch.

• It warns consumers when oxygen gets inside, or food is going off.

• Detect food spoilage and release nano-antimicrobials to extend the shelf life.

7. Nano-Packaging

Oxygen scavenging material - food deterioration due to indirect contact with oxygen includes food spoilage by aerobic microorganisms. Oxygen scavengers are available commercially in sachets containing metallic or inorganic reducing agents like iron oxide, ferrous carbonate *etc*.

Commonly used Nanoparticles in Packaging

Nano-copper oxide, Nano zinc oxide, Nano chlorine oxide, Nano-silver, Nano-titanium dioxide, Nano-magnesium oxide, and Carbon nanotubes.

Advantages of Nanotechnology

• Lower pesticide use.

• Improved traceability & safety of food products.

• Reductions in fat, sugar, salt & preservatives.

• Enhanced nutritional value.

• Better retention of flavors & textures.

• Maintenance of food quality & freshness.

• More hygienic food processing.

• Extended product shelf life.

Disadvantages of Nanotechnology

• Expensive.

• Adverse effects on beneficial microbial flora, fauna & the ecosystem.

• Health risks to human beings (Handford *et al*., 2014).

Conclusion

Nanotechnology is a new and emerging approach and is becoming important in the food sector for the preservation of vegetables. Minimizing post-harvest losses in vegetables with safe, effective and economical means is a major challenge in agriculture. Incorporating the nanomaterials in the packaging of vegetables increases the barrier property of packaging against oxygen, water vapor and invasion of microorganisms. Because of the higher solubility, stability and eco-friendly biodegradability of nanoparticles, it finds enormous application in minimizing post-harvest losses with improved longevity of fresh vegetables.

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