SUNSHINE AGRICULTURE e-Newsletter

ISSN (E): 2583 – 0821

Sun. Agri.:e- Newsletter, (2025) 5(11), 1-3

Article ID: 461

Role of Nanotechnology in Food Preservation and Packaging

Khan Chand[1], Sonu Bajad[2], Sachin Sharma[3]

[1]Professor; Department of Agricultural Engineering, School of Agricultural Science, Nagaland University, Medziphema Campus-797106, India

[2&3]Assistant Professor, School of Agriculture, Eklavya University,-470661

*Corresponding Author

Khan Chand*

Available online at

www.sunshineagriculture.vitalbiotech.org

Article History

Received: 25. 10.2025

Revised: 30. 10.2025

Accepted: 1. 11.2025

INTRODUCTION

The challenges of maintaining safety, quality, and enhancing the shelf life of food products are persistent in the food industry globally. Food spoilage due to microbial contamination, oxidation, and moisture loss is one of the major contributors to enormous post-harvest losses all over the world. The FAO estimates that close to a third of all food produced globally goes to waste every year, largely due to inefficient methods of preservation and packaging.

Within this context, nanotechnology has emerged as an innovation that promises to offer new possibilities regarding food preservation, packaging, and safety. It is the science and engineering of materials at the nanoscale, between approximately 1 and 100 nanometers, where unique physical, chemical, and biological properties can be used to enhance food systems.

Nanotechnology in food science paves the way to the development of a variety of advanced nanomaterials, nanocomposites, and Nano sensors that enhance the quality and safety and improve the shelf life of food. It bridges the gap between science and sustainability by enabling smart, efficient, and eco-friendly packaging solutions.

2. Concept of Nanotechnology in Food Systems

Nanotechnology involves manipulation of material at the atomic or molecular level, in general producing structures with improved properties, for instance, increased surface area, strength, reactivity, and stability.

In food applications, their use can be made for:

- ✓ Improve the barrier properties of packaging materials against gases, moisture, and light.
- ✓ Develop antimicrobial coatings to prevent food spoilage.
- ✓ Nano-encapsulate preservatives for controlled release.
- ✓ Nano sensors could be used for real-time food quality and contamination monitoring.

These nanotechnologies contribute much to food safety, extending shelf life and building consumer confidence.

3. Nanotechnology in Food Preservation

Food preservation helps prevent spoilage and maintains quality during storage and transportation. Preservation can be enhanced by using nanotechnology in the following ways:

ISSN (E): 2583 – 0821

3.1 Nano encapsulation of Preservatives

Nano encapsulation involves the incorporation of bioactive compounds or preservatives into Nano carriers like liposomes, micelles, or polymeric nanoparticles.

This technology:

- ✓ Protects sensitive compounds from degradation.
- ✓ Allows controlled and targeted release of preservatives.
- ✓ Improves the bioavailability of natural antimicrobials and antioxidants.

Example:

Nano encapsulation of some essential oils, such as oregano or clove oil, could prevent bacterial growth without affecting the taste or odor of food items.

3.2 Antimicrobial Nanomaterials

Metal nanoparticles such as silver (AgNPs), zinc oxide (ZnO), and titanium dioxide (TiO_2) exhibit strong antimicrobial properties.

They inhibit microbial growth by:

- ✓ Breaking down cell membranes.
- ✓ Production of reactive oxygen species (ROS).
- ✓ Interfering with microbial DNA replication.

These nanoparticles are used in coatings, films, and sprays applied to food surfaces or packaging materials for reducing spoilage and contamination.

3.3 Nanocomposites for Barrier Enhancement

Nano clays, Nano cellulose, and carbon nanotubes can be added into packaging polymers to enhance barrier properties.

Such nanocomposite films significantly reduce:

- ✓ Oxygen permeability: To avoid oxidation,
- ✓ Moisture transmission reduces microbial activity.
- ✓ UV light penetration (preventing nutrient degradation).

This technology extends the shelf life of perishable foods like dairy products, meats, and fruits.

4. Nanotechnology in Food Packaging

4.1 Active Packaging

Active packaging involves nanomaterials interacting with either the food or the environment to maintain product quality.

Examples include:

- ✓ Oxygen scavengers: Nanoparticles that absorb oxygen to prevent oxidation.
- ✓ Antimicrobial Films: Silver or zinc oxide nanoparticles incorporated in packaging to prevent microbial growth.
- ✓ Ethylene absorbers: Nanomaterials that delay the ripening of fruits and vegetables.

Such smart packaging assures food freshness, improves storage stability, and reduces chemical preservatives.

4.2 Intelligent (Smart) Packaging

Intelligent packaging systems use Nano sensors to detect, monitor, and report the condition of food during storage or transportation.

These Nano sensors are capable of:

- ✓ Detect gases such as carbon dioxide, ammonia, or hydrogen sulfide that are indications of spoilage.
- ✓ Measure temperature and humidity fluctuations.
- ✓ Signal contamination or tampering, color changes, or digital indicators.

Example:

Such a Nano sensor-based label, which changes color when the meat starts to spoil, visually indicates freshness to the consumer and thereby helps ensure food safety while reducing waste.

4.3 Nanocomposites for Mechanical Strength

The addition of Nano clays, silica nanoparticles, or graphene in the making of nanocomposite films increases the mechanical strength, flexibility, and thermal stability of packaging materials.

Such packaging is lightweight while being strong and less prone to damage during transportation.

5. Safety, Regulation, and Environmental Aspects

5.1 Safety Concerns

Even though the benefits are considered promising, nanoparticles usage in food packaging raises several safety issues related to migration of nanoparticles into food.

Possible risks include:

- ✓ Accumulation of nanoparticles in human tissues.
- ✓ Unknown toxicological effects due to long-term exposure.

Toxicological evaluation and risk assessment are therefore imperative before commercial application.

5.2 Regulatory Framework

Preliminary guidelines on the use of nanomaterials in food contact materials have been defined by different organizations such as FDA, EFSA, and FAO/WHO.

These regulations highlight:

- ✓ Labeling transparency.
- ✓ Safety evaluation and migration studies.
- ✓ Compliance to food safety standards.

5.3 Environmental Impact

Nanotechnology could also assist in sustainability by:

- ✓ Reduction of plastic use by biodegradable nanomaterials.
- ✓ Improved recyclability of packaging.
- ✓ Lower carbon emissions because of lighter packaging material.

Incorrect disposal of nano-packaging material might contaminate the environment, so proper waste management is necessary regarding this aspect.

6. Nanotechnology Advantages in Food Packaging and Preservation

Aspect Nano technological Benefit

Shelf life Extended due to enhanced barrier and antimicrobial activity

Food safety; Real-time spoilage detection by Nano sensors

Quality retention: protection against oxidation, moisture, and UV radiation

Environment: Reduced use of synthetic chemicals, reduced waste

Economic benefit Reduction in spoilage/wastage in the supply chain

Nanotechnology, therefore, supports the global goals of food security, sustainability, and resource efficiency.

7. Future Prospects

The prospect of nanotechnology in food packaging is bright, with a focus on biocompatible, eco-friendly, and smart systems of packaging. The research is expanding in areas such as:

- ✓ Edible nano-coatings for fruits and vegetables.
- ✓ Biodegradable nanocomposites from plant polymers.
- ✓ Blockchain-integrated intelligent packaging for tracking and ensuring quality.

The collaboration between scientists, industry, and regulatory entities will be needed to ensure that such innovation is safe and responsible.

8. CONCLUSION

Nanotechnology has opened a new frontier toward food preservation and its packaging, revolutionizing the way food is stored, transported, and consumed. It guarantees better safety, quality, and sustainability through Nano encapsulation, antimicrobial films, and smart sensors.

As with any emerging technology, however, innovation must be balanced with concern for safety and the environment. How nanotechnology will succeed in global food systems will be determined by the regulatory frameworks, public awareness, and interdisciplinary research.

In the years to come, nanotechnology will continue to play a key role in building smart, sustainable, and resilient food packaging solutions that guarantee safe and nutritious food for all consumers on the global landscape.

REFERENCES

Biswas, R., Alam, M., Sarkar, A., Haque, M. I., Hasan, M. M., & Hoque, M. (2022). Application of nanotechnology in food: processing, preservation, packaging and safety assessment. *Heliyon*, *8*(11).

Alfadul, S. M., & Elneshwy, A. A. (2010). Use of nanotechnology in food processing, packaging and safety–review. *African Journal of Food, Agriculture, Nutrition and Development*, *10*(6).

Chellaram, C., Murugaboopathi, G., John, A. A., Sivakumar, R., Ganesan, S., Krithika, S., & Priya, G. (2014). Significance of nanotechnology in food industry. *APCBEE procedia*, *8*, 109-113.

Singh, T., Shukla, S., Kumar, P., Wahla, V., Bajpai, V. K., & Rather, I. A. (2017). Application of nanotechnology in food science: perception and overview. *Frontiers in microbiology*, *8*, 1501.

Berekaa, M. M. (2015). Nanotechnology in food industry; advances in food processing, packaging and food safety. *International Journal of Current Microbiology and Applied Sciences*, *4*(5), 345-357