EDIBLE NANOCOATING: THE EFFECT OF DIFFERENT TYPES OF NANOPARTICLES INCORPORATED WITH POLYSACCHARIDE-BASED MATERIALS ON ANTIBACTERIAL AND ANTIFUNGAL ACTIVITY

Nur Izzah Azhar[1], Noor Asnida Asli[3,4], and Nadya Hajar[1,2*]

[1]*Department of Food Science and Technology, Faculty of Applied Sciences, Universiti Teknologi MARA, Cawangan Negeri Sembilan, Kampus Kuala Pilah, 72000 Kuala Pilah, Negeri Sembilan, Malaysia*
[2]*Alliance of Research & Innovation for Food (ARIF), Universiti Teknologi MARA, Cawangan Negeri Sembilan, Kampus Kuala Pilah, 72000 Kuala Pilah, Negeri Sembilan, Malaysia*
[3]*NANO-SciTech Lab, Functional Materials and Nanotechnology Centre, Institute of Science, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia.*
[4]*Faculty of Applied Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia*

**Corresponding author*: *nadya1844@uitm.edu.my*

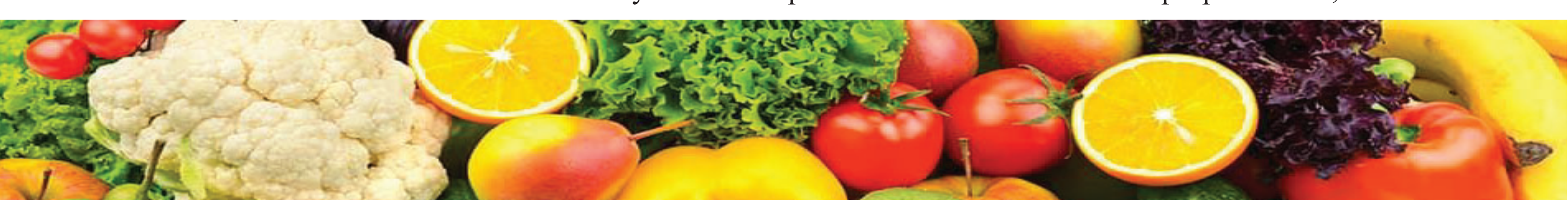
Abstract: The demand rate for fruits supply increases over the years due to their nourish nutrients and rich flavours. However, they can be easily deteriorated by bacterial and fungal activities when stored at room temperature. Regarding this matter, it is necessary to rejuvenate the quality of the fruits by reducing the possibilities of the infection from happening. Polysaccharide-based material is considered as an edible source that promises protection from microbes' contamination if coated on the fruits. Several recognisable metal nanoparticles such as zinc oxide, silver and titanium dioxide nanoparticles could alter the interaction of microorganism development when incorporated with polysaccharides-based materials. The purpose of this review is to study the effect of different types of nanoparticles incorporated with polysaccharide-based materials, for example, chitosan, cellulose, guar gum, xanthan gum and sodium alginate on antibacterial and antifungal activity. The combination of these elements helps to inhibit the growth of microbial colonies and fungus such as *Staphylococcus aureus*, *Escherichia coli*, *Bacillus subtilis*, *Phyllosticta psidicola*, *Colletotrichum gloeosporioides*, *Alternaria alternata*, mould, and yeast. The observation methods of the microorganism were done based on disk-diffusion agar, pour plate agar, nutrient agar, potato dextrose agar, plate count agar and physical counts according to lesion rot on the fruit's surface. Hence, the bacterial and fungal activities can be inhibited when the nanoparticles are incorporated with polysaccharide-based materials and result in increasing the shelf life of the fruits.

Keywords: Edible nanocoating, metal nanoparticles, polysaccharide, antibacterial, antifungal

1. Introduction

Breaking down of chemical structures drives the spoilage of fruits to happen. Most of the fruits are susceptible towards the internal and external changes including the temperature, storage, moisture, pH as well as the microbial activity. The way fruits deteriorate is by releasing the unpleasant smell, discolouration, loss of flavour and firmness. The use of nanoparticles in agriculture and food industries are reported to offer better quality and improve the shelf life of fruits. One of the nanoparticles' properties is that they act as antibacterial and antifungal agents.

Zinc oxide (ZnO), silver (Ag) and titanium dioxide (TiO_2) nanoparticles combined with polysaccharide-based materials are the most studied nanocoating due to their excellent attributes shown on the fruits. Fruit diseases such as anthracnose, black mould and fruit rot can be inhibited on the edible nanocoated fruits. Every metal nanoparticle has its own functional properties. So, the



objectives of this review are to determine and analyse the different types of nanoparticles ($ZnO/Ag/TiO_2$) incorporated with different polysaccharide-based materials (chitosan, cellulose, xanthan gum, guar gum, and sodium alginate) on antibacterial and antifungal activity coating on fruits.

2. Discussion

2.1. Types of polysaccharide-based materials

Several common polysaccharide-based materials widely used as coating solutions in the food industry are chitosan, cellulose, xanthan gum, guar gum and sodium alginate. They have the ability to maintain firmness, delay the ripening process and act as anti-browning agents. In recent research, they are integrated with $ZnO/Ag/TiO_2$ nanoparticles to promote better protection on behalf of physical, chemical and biological quality of the fruits.

2.2. Properties of edible nanocoating

The properties of this edible nanocoating are similar among the different polysaccharide-based materials incorporated with $ZnO/Ag/TiO_2$ nanoparticles. Most researchers reported that they are safe, non-toxic, can improve the mechanical barrier and physical properties of the coated fruits. Furthermore, those three nanoparticles can encourage the action of antibacterial and antifungal to defend the fruits from microorganism development. ZnONP and TiO_2NP propose natural photocatalytic effects while AgNP performs electrostatic force to release the free radical ions and they penetrate into microbial cells (Lavinia et al., 2020; Chand et al., 2020).

2.3. Effect of different edible nanocoating on antibacterial activity

Reactive oxygen species (ROS) are generated by photocatalysis processes that happen with the presence of $ZnO/Ag/TiO_2$ nanoparticles and UV light. The free radicals that were originally released by ROS start to attack the cell wall of bacteria or fungi then shut off the reproduction of their DNA. The disruption of internal structure continues to happen by breaking down the membrane thus increasing the cell permeability. Oxidative stress then takes place after the penetration of free radicals hence killing the bacteria cell. The observation of microbial growth is done on agar and also direct count. Nanocoating is capable of securing the quality of banana, strawberry and blueberries (Qin et al., 2019; La et al., 2021; Xing et al., 2021).

2.4. Effect of different edible nanocoating of antifungal activity

Fungi initiate the development of mould and black spots that are physically seen on the fruit's peel. The action of antifungal activity on coated fruits has a similar mechanism as the antibacterial activity. However, it depends on the toxins content of the fungi. The killing of the fungal spores poses to drive the membrane destruction, then causes the responsible cell to die. The reduction of fungal growth on nanocoated persimmon, tomatoes and mangoes were claimed in recent findings (Saekow et al., 2019; Xing et al., 2020).

2.5. The best material as edible nanocoating

Regarding the outstanding function of antimicrobial activity of nanoparticles, AgNP is stated to be the finest compound to fight against microbes. Besides, chitosan provides the best physical properties such as reducing weight loss, maintaining the colour and firmness to the coated fruit as compared to other reviewed polysaccharide-based materials. As a result, this review indicates that chitosan-AgNP is the most decent corporation as an edible nanocoating to coat on fruit surface.

3. Conclusion

The application of edible nanocoating on the fruits is proven to hinder the development of bacteria and fungi. The proliferation of pathogen cells can be inhibited with the presence of ROS which at first is generated by nanoparticles itself. The incorporation of coating material might as well improve the physicochemical and biological features of the fruits. Thus, the best nanocoating combination for fruit coating is chitosan-AgNP. This nanotechnology topic is fiercely explored by most researchers in current days to dig for greater discovery. Therefore, further study is needed relating to ozone treatment incorporated with sonication, the toxicity of nanocoating film and the antifungal effects on coated fruits when coating with ZnONP and polysaccharides-based materials.

References

Chand, K., Cao, D., Fouad, D. E., Shah, A. H., Lakhan, M. N., Dayo, A. Q., & Mohamed, A. M. A. (2020). Photocatalytic and antimicrobial activity of biosynthesized silver and titanium dioxide nanoparticles: A comparative study. *Journal of Molecular Liquids*, *316*, 113821.

La, D. D., Nguyen-Tri, P., Le, K. H., Nguyen, P. T., Nguyen, M. D.B., Vo, A. T., & Chung, W. J. (2021). Effects of antibacterial ZnO nanoparticles on the performance of a chitosan/gum arabic edible coating for post-harvest banana preservation. *Progress in Organic Coatings, 151*, 106057.

Lavinia, M., Hibaturrahman, S., Harinata, H., & Wardana, A. (2020). Antimicrobial activity and application of nanocomposite coating from chitosan and ZnO nanoparticle to inhibit microbial growth on fresh-cut papaya. *Food Research*, *4*(2), 307-311.

Qin, Y., Liu, Y., Yuan, L., Yong, H., & Liu, J. (2019). Preparation and characterization of antioxidant, antimicrobial and pH-sensitive films based on chitosan, silver nanoparticles and purple corn extract. *Food Hydrocolloids, 96*, 102-111.

Saekow, M., Naradisorn, M., Tongdeesoontorn, W., & Hamauzu, Y. (2019). Effect of carboxymethyl cellulose coating containing ZnO-nanoparticles for prolonging shelf life of persimmon and tomato fruit. *Journal of Food Science and Agricultural Technology (JFAT)*, *5*, 41-48.

Xing, Y., Yang, H., Guo, X., Bi, X., Liu, X., Xu, Q., & Shui, Y. (2020). Effect of chitosan/nano-TiO_2 composite coatings on the postharvest quality and physicochemical characteristics of mango fruits. *Scientia Horticulturae*, *263*, 109135.

Xing, Y., Yang, S., Xu, Q., Xu, L., Zhu, D., Li, X., & Bi, X. (2021). Effect of chitosan/nano-TiO_2 composite coating on the postharvest quality of blueberry fruit. *Coatings, 11*(5), 512.