EDIBLE NANOCOATING: THE EFFECT OF DIFFERENT STARCH-BASED MATERIALS INCORPORATED WITH NANOPARTICLES ON THE ANTIMICROBIAL ACTIVITY

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Abstract: The application of starch-based film is extensively used as fruit coating in the agricultural sector in the assurance of postharvest quality. A starch-based film such as cassava, corn, and rice film can provide a semi-permeable barrier to moisture and water vapour, however poor in mechanical strength. Thus, several attempts have been made to overcome this limitation by incorporating metal-based antimicrobial agents such as zinc, silver, and titanium into the starch-based coating at the fruit's outer layer. Although extensive study is being done in this field, the comprehensive review focussing on the antimicrobial activity of metal-starch nanocomposite is still lacking. Hence, this study aims to review the effectiveness of different starch materials incorporated with a different metal-based antimicrobial agent as edible nanocoating in the assurance of the postharvest quality of fruits. Zinc oxide nanoparticles (ZnONP), silver nanoparticles (AgNP), and titanium dioxide nanoparticles (TiO_2NP) incorporated into cassava, rice, sago, and corn exhibited antimicrobial activity. Therefore, a comprehensive study on the inhibition of metal-starch-based nanocomposite on fungal that affects the post-harvest quality of fruit is recommended.

Keywords: Edible nanocoating, starch, metal nanoparticle, antimicrobial, antifungal

1. Introduction

Fruits are well recognized as good in balancing the diet and promoting a healthy lifestyle. However, fruits could be infected by postharvest diseases that arise from bacteria and fungi which could cause quality losses, affect the shelf-life stability of fruits and contribute to the wastage and losses in economies. Microbes and fungi affect the quality of fruits during pre-harvest and post-harvest causing the quality reduction. The post-harvest disease problem can be encountered by applying nanotechnology in the disease's prevention method that improves the mechanical action of particles. For example, using zinc oxide nanoparticle (ZnONP), silver nanoparticle (AgNP), and titanium dioxide nanoparticle (TiO_2NP).

Starch is one of the biodegradable polymers that is highly preferred by the consumer as it can reduce the environmental impact. However, starch is also known as having the limitation in mechanical properties and barrier properties. The addition of metal nanoparticles into starch

improves the mechanical, water vapour barrier, and antimicrobial properties (Ji et al., 2016; Kotharangannagari & Krishnan, 2016).

2. Discussion

Zinc oxide is an inorganic compound with the chemical formula of ZnO and it is present in white powder. The solubility of zinc oxide is quite different according to its sizes of particles, and basically, crude zinc oxide (ZnO) is generally insoluble in water. The synthesis of zinc oxide nanoparticles (ZnONPs) can be carried out by many physicochemical routes such as co-precipitation, laser vaporization, sol-gel processes, microemulsion, and ball milling (Alamdari et al., 2020). Zinc oxide nanoparticle is functioning as antimicrobial activity and has potential to inhibit the spoilage of the food products with and without the photocatalytic activity.

Silver is a metal element with the chemical formula of Ag and it is known as transition metal with a soft and shiny surface. The synthesis of AgNP can be applied using several methods such as photo- irradiation, chemical, biological and photochemical methods (Jafarzadeh et al., 2021). Furthermore, AgNP possesses a higher antimicrobial effect because they can easily integrate within the cell membrane due to their smaller size and the release of silver ions from the silver particle will be easier (Echegoyen & Nerín, 2013).

Titanium dioxide or also known as titania is a semiconductor metal oxide with a chemical formula of TiO_2, non- toxic, bright white colour. The photocatalytic activity in the presence of oxygen and water molecules, resulting in the production of reactive oxygen species and hydroxyl radicals that are accountable for the bactericidal function (Lin et al., 2015). The synthesis of titanium dioxide nanoparticle can be conducted by the method of chemical vapor deposition, chemical precipitation, microemulsion hydrothermal, and sol-gel methods.

The mechanism of action of Zinc Oxide against microbes is by releasing of antimicrobial ions and damaging the integrity of the bacterial cell (Naveed Ul Haq et al., 2017). Meanwhile, the mechanisms' reaction of silver against microbes is through intrusion with vital cellular processes by binding to sulfhydryl or disulfide functional groups on the surfaces of membrane proteins and other enzymes, disruption of DNA replication (Duncan, 2011). All metals have mechanisms of reactive oxygen species (ROS), and TiO_2NP with under the exposure to UV light.

Starch is the most promising biocompatible and biodegradable material because of its advantages in low cost and readily available from many sources of plants (Tunma, 2018). Starch is a major polysaccharide composed of two macromolecules amylose and amylopectin. Thus, the mechanical strength of its starch depends on the amylose/amylopectin ratio, the average granule sizes, and the percentage of distribution of the different sized groups of granules (Vafina et al., 2018). Table 1 shows the effect of different types of starch incorporated with metal-based nanocomposite on the particle distribution.

Table 1. Particle distribution of metal-starch based nanocomposite film.

	Metal-starch Based	Mechanical
Cassava	ZnONP, AgNP	Agglomerates
	TiO_2NP	Hard-brittle
Rice	ZnONP, TiO_2NP	Agglomerates
	AgNP	Coarse and rough surface
Sago	ZnONP, TiO_2NP, AgNP	Almost uniform
Corn	ZnONP, TiO_2NP, AgNP	Evenly distributed

3. Conclusion

Post-harvest diseases threaten the quality and shelf life of the fruits; however, the diseases can be controlled by using edible coating. The coated fruits using starch-metal-based nanocomposite able to reduce the post-harvest diseases on the fruit's surfaces. With the process of releasing ions, cell disruption, DNA replication disruption, and reactive oxygen species (ROS), the inorganic metals zinc oxide, silver, and titanium are useful as an edible coating in their antimicrobial activity. The morphology of starch metal-based influences the particle distribution of the coating and thus affects the antimicrobial effectiveness. However, the study of antifungal using metal-starch based is still limited.

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