EDIBLE NANOCOATING: THE EFFECT OF DIFFERENT CONCENTRATIONS OF METAL NANOPARTICLES INCORPORATED WITH POLYSACCHARIDE-BASED MATERIAL ON ANTIMICROBIAL AND ANTIFUNGAL ACTIVITY

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Abstract: Fruit spoilage is very common during the postharvest phase due to extrinsic factors and therefore it renders them unsuitable for human consumption. The microbial and fungal spoilage in fruits results in substantial financial losses throughout the entire supply chain. Applying nanotechnology on the fruit can reduce significant privation. This review elaborates on the antimicrobial and antifungal activity by applications of polysaccharide and metal nanoparticles on fruits. Metal nanoparticles of silver, zinc oxide and titanium dioxide demonstrate attractive antimicrobial and antifungal properties on different concentration nanoparticles such that 0.02% - 8% by weight of polysaccharide could potentially be used. Incorporating nanoparticles in various polysaccharides pullulan, hydroxypropyl methylcellulose (HMPC), carrageenan, chitosan, and pectin polymer matrix increase the efficiency against *Aspergillus niger*, *Bacillus subtilis*, *Colletotrichum gloeosporioides*, *Escherichia coli*, *Fusarium oxysporum, Staphylococcus aureus*, and *Saccharomyces cerevisiae*. All samples display consequential inhibitory effects with increasing metal nanoparticles concentration incorporated with polysaccharide materials. The results obtained possessed a better understanding of different concentrations of polysaccharides incorporated into Ag/ZnO/TiO_2 nanoparticles to inhibit fungal and microbial growth which could be used in fighting against postharvest disease and improve the shelf life of fruits. The aims of this research work were to determine and analyse the effects of different concentrations of metal nanoparticles incorporated with polysaccharides-based material on antimicrobial and antifungal activities.

Keywords: Nanoparticles, concentration, polysaccharide, antimicrobial, antifungal

1. Introduction

Fruit spoilage is mainly caused by three factors such as physical, enzymatic activity, and microbial growth. The common microorganisms that cause the spoilage of fruits are bacteria, yeast, and moulds which have deteriorated the fruit quality. As mentioned by Erkmen and Bozoglu (2016), a contact between spoiled and unspoiled fruits can also lead to microorganism contamination due to the poor environmental condition from harvesting to marketing. In consequence, microbial spoilage contributes to approximately 20% of fruits harvested and leads to major economic loss. Therefore, an alternative using a coating treatment is needed to prevent susceptible fruits from easily being spoiled. In this review, the coating consists of a combination of metal nanoparticles

(NPs) and polysaccharides as base materials. Nanoparticles which have ultrafine materials with lower than 100 nm dimensions (Shamim et al., 2019) by using Ag, ZnO and TiO_2 NPs. They are generally recognized as safe and no threat to humans, animals, or the environment thus commonly used in daily products and applied in the food packaging field, antifungal additive, and nutritional supplement. These metallic nanoparticles will improve the shelf life of fruits by incorporation with polysaccharides as a coating treatment on fruits. When the polysaccharides are incorporated into Ag, ZnO, TiO_2 NPs, they further substantiate the stability of metal/metal oxide nanoparticles.

2. Discussion

2.1. Background of study

Fruit spoilage has affected a supply chain from farmers to the consumers due to the deterioration of fruits caused by bacterial, fungal, and insect pests. The deterioration contributes to undesirable odour, appearance, texture, and taste to the fruits for human consumption which is unfavourable (Rawat, 2015; Yahaya & Mardiyya, 2019). Normally, in a storage period, most fruits discolour and give an unpleasant taste due to oxidation and polyphenolic compounds in the fruits. For example, fungus *Colletotrichum gloeosporioides* has caused Anthracnose disease which led to development of dark circular lesions on the fruits' skin (Sarkar, 2016).

2.2. Nanocoating

With coating treatment of metal nanoparticles (NPs) and based materials, the fruits can maintain their quality without any mould present on the skin compared to uncoated fruits. In this review, metal NPs used are silver (Ag), zinc oxide (ZnO) and titanium dioxide (TiO_2) incorporated with polysaccharides as based materials such as pullulan, cellulose, chitosan, pectin and carrageenan. Polysaccharides can be obtained from natural sources such that pullulan is yielded from fermented starch by the fungus Aureobasidium pullulans; cellulose from wood pulp and cotton; chitosan made from the deacetylation of crustacean and insect chitin; carrageenan mainly from the red seaweed; and pectin which can be extracted from citrus fruits' peels or various kind of fruits.

As highlighted in this paper, different concentrations of metal NPs are used due to the different toxicity and level permitted by USFDA such that Ag NPs are ranging from 0 to 0.01 g, ZnO NPs from 0 to 0.25 g and TiO_2 NPs from 0 to 0.09 g. Then, a few physicochemical analyses such as pH measurement, total soluble solids, titratable acidity, weight loss, peel and colour appearance, and fruits' firmness are evaluated from fruit coated samples. A coating treatment at high concentration of ZnO NPs exhibited an overall acceptance of all analyses compared to Ag NPs and TiO_2 NPs. Thus, this will attract the consumers' eyes and purchase the fruits without hesitation; hence coating treatment can be applied to maintain the quality of fruits.

2.3. Analysis of antifungal and antimicrobial properties

On the effect of antibacterial and antifungal activity on different concentrations of metal NPs incorporated with polysaccharides-based material, the high concentration of metal NPs inhibited the bacterial and fungal cell. This is because each metal NPs manage to induce the production of reactive oxygen species (ROS). The interaction between bacterial and fungal cell and coating materials has caused particles to penetrate the cell wall and cell membrane of microbial cells. The

antimicrobial mechanisms of ZnO NPs proved that the production of reactive oxygen species (ROS) and the release of the Zn^{2+} ion, which can enter the cell wall and react with the cytoplasmic substance, causes oxidative stress in fruits (Anugrah et al., 2020). Intracellular components leaked due to interactions between amino groups in chitosan and electronegative charges on the microbial cell surface (Lavinia et al., 2020). Then, oxygen free radicals which consist of H_2O_2, OH^- and O^{2-} target the outer membrane and damage the cell's DNA, destroy the electronic transport processes and bacterial oxidation that result in bacterial death (Nithya et al., 2015). However, the disruption of fungal cell walls is mainly due to the existence of ultraviolet (UV) light. According to Medici et al. (2019), the actual mechanism behind the antifungal effect of metal NPs is still unknown. It was only found that Ag NPs can damage the fungal cellular membrane and impair the normal budding process which is similar to how bacteria are affected by the metal NPs.

3. Conclusion

The best alternative on fruits' coating would be ZnO NPs bound with chitosan with concentrations ranging from 0.1 - 0.25 g. ZnO NPs exhibited a small weight loss, high inhibition of microbial and fungal growth, increase in fruits' firmness, reduced colour changes thus delaying the ripening and extending the fruits' shelf life. To prevent the fruits from losing their nutrients', coating treatment is needed to preserve the ripeness and juiciness of the fruits with significant sugar content. Incoming research, metal NPs of silver, zinc oxide, and titanium dioxide could be widely studied on the application of various fruits which are especially sold in every market as they are prone to microbial and fungal spoilage.

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