Nanomaterials – Recent Advancements in Edible Coating Technology

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INTRODUCTION

The agriculture sector plays a prominent role in fostering world economic revenue. Most importantly this sector also paves a new route for reshaping a healthier world. Rising trends towards health-conscious eating habits have evoked the consumption of fresh fruits and vegetables as an available option for better, healthier and smarter solutions that meet modern lifestyle and needs. International organisations such as the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) of the United Nations are aggressively promoting and creating awareness in the consumption of fruits and vegetables in daily food intake. However, despite numerous policy interventions, statistics show that daily intake of fruits and vegetables is generally still below the recommended levels.

One of the winning strategies for increasing access to and consumption of fruits and vegetables is to focus on reducing horticultural crop losses, and maintaining the post-harvest quality of fresh fruits and vegetables. Issues associated with shelf-life stability have become the main concern in the horticulture sector. It is a fact that fruits and vegetables undergo progressive deterioration after harvest due to biochemical processes, *i.e.* (1) tissue softening, (2) fermentation due to an increase in sugar level, (3) degradation of chlorophyll upon maturation, (4) production and loss of volatile compounds, (5) cell rupture as a result of respiration, (6) shrivelling, and (7) microbial growth (Sharma and Singh, 2000).

Therefore, it is worthwhile to search for a feasible method on how to preserve the quality and freshness of fruits and vegetables whilst improving their shelf-life upon harvest. Various preservation techniques (physical and chemical processes) have been extensively deliberated upon in literature; these include sterilisation, radiation, refrigeration, use of synthetic chemicals and petroleum-based wax, application of active or passive modified atmosphere packing (MAP), controlled atmosphere storage (CAS), hypobaric storage, osmotic and heat treatments as well as incorporation of active agents. Nevertheless, the use of packaging is still the ultimate step in the food preservation process (Debeaufort *et al.,* 1998).

Synthetic packaging materials (such as resin, composites, cellulosic materials, synthetic waxes, petroleum-based materials and plastic-films) are widely used due to their efficiency in reducing mass, gas and solute transfer between the food and its surroundings. As most of the synthetic packaging materials are not edible and biodegradable, the use of edible coatings has been proposed as an alternative food preservation technique for active foods which will offer cost efficiency to the industry.

Recently, the application of edible coatings has been shown to be a promising technique for improving the quality and for

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extending the storage and shelf-life of various fruits and vegetables such as papaya, strawberry, berries, avocado, guava, tomato and chilli (Fauzi and Abu Hassan, 2016). Thus, comprehensive research endeavours are being pursued to further explore their potential benefits and value.

This treatise provides the latest advancements in edible coating technology, aiming to incorporate, encapsulate and/or control the release of active compounds, *e.g.* antioxidants, anti-microbials, micronutrients and functional ingredients, using nanotechnology approaches such as nanomaterials, nanoemulsions, nanoparticles, nanoencapsulation, cross-linking and also multilayered systems. Interested readers seeking information about nanotechnology in food and agricultural systems may additionally refer to a report published by CSREES, USDA (2003) (Weiss *et al*., 2006).

NANOTECHNOLOGY – GREAT THINGS FROM A TINY WORLD

Nanotechnology is recognised as a rapidly expanding field due to its prospects in developing new products in a wide range of industrial sectors while its application in the food industry (such as food production, processing, analyses and packaging) is forecast to increase in investments and market share (He and Hwang, 2016), as well as to counter global food challenges (Sun-Waterhouse and Waterhouse, 2016). Weiss *et al*. (2006) defined nanotechnology as characterisation, fabrication and manipulation of biological and non-biological structures smaller than 100 nm. Structures on this scale have been shown to have unique and novel functional properties.

In 2003, the United States Department of Agriculture (USDA) published a roadmap addressing the application and importance of nanotechnology in agriculture and food industries.[1]

EMERGING TRENDS OF EDIBLE NANO COATINGS

In deliberation of the rapid progress in nanotechnology, its application in coating is actively being investigated. Nano-packing technology applied on fruits and vegetables exhibited better physico-chemical, sensory physiological and preservation properties compared to normal packaging (Li and Wang, 2006; Li *et al*., 2009).

There are a numbers of different methods or techniques being developed in nano-packing technology which involved the incorporation of nanostructures such as nanocellulose and nanoclays in edible coatings as additives or even main component of the coating materials.

Nanolaminates

- Nanolaminates comprise two or more multilayers of a substance, *e.g.* a globular protein and a mixture of lipids with nanometer dimensions (1-100 nm).

LbL Electroposition

- Layer-by-layer (LbL) electro-position involves sequential multiple nanolayers of different materials with different oppositely charged particles to form interfacial thin films/coatings.

Nanocomposites

- A nanocomposite is a mixture of polymers with organic or inorganic additives with nanoscale geometries which can exhibit better mechanical properties, stability, gas and vapour barrier characteristics in edible coatings. It also offers extra benefits such as low density with good flow, better surface properties and transparency to edible films and coatings (Lacroix, 2009).

Nanoemulsions

- Nanoemulsions are nano-sized emulsions that can improve barrier properties and increase functionality of coatings because submicronic systems allow for more efficient control of coating properties with better distribution and homogeneity on the coated fruit skin (Zambrano-Zaragoza *et al.*, 2013).

Nanoparticles

- Nanoparticles are recognised as microadditives and submicroscopic particles which enhance the physical properties of food packaging such as edible films and coatings.

Nanoencapsulation

- Micro- and nanoencapsulation of active compounds used in edible coatings control their release under controlled rates and conditions (Lopez-Rubio

[1] The Food and Drug Administration (FDA) and Codex Alimentarius together with the World Health Organization (WHO) and Food and Agriculture Organization (FAO) of the United Nations are among the bodies responsible for regulating and ensuring safe practices, monitoring risks and conducting risk assessment and appraising the implications of many aspects of nanotechnology applications in food production.

et al., 2006), and thus protect the coated items from moisture, heat or other extreme conditions while enhancing their stability and viability (Jimenez *et al.*, 2004).

Solid-lipid Nanoparticles

- The most recent development in edible coatings is the use of solid-lipid nanoparticles (SLN) as studied by Zambrano-Zaragoza *et al.* (2013). SLN are lipid colloidal submicronic systems that have been developed to encapsulate and deliver lipophilic functional components using a lipid and an aqueous surfactant solution to produce an oil-in-water (O/W) nanoemulsion by a hot homogenisation technique.

PALM OIL AND NANOTECHNOLOGY – DISCERNING STRATEGIES FOR BIO-BASED EDIBLE COATINGS

In general, there are four major types of materials from which edible coatings are made; these include lipids, resins, polysaccharides and proteins. Vegetable oils as one of the lipid-based coatings have been extensively used on whole fruits and vegetables. They help in improving physical appearance by generating a shine on the fruits and vegetables, and in providing effective barriers against moisture, thus extending shelf-life.

Palm oil is a golden crop oil with versatile properties and functionalities. Being one of the most traded premium vegetable oils in the world with nearly 17 million tonnes produced in 2016 by Malaysia alone, palm oil and its fractions such as palm stearin and palm olein pose as materials with potential for developing edible nano coating materials. Apart from being safe, non-toxic and biodegradable, the high productivity of oil palm ensures continuous supply of the raw materials while providing economically viable solutions. Moreover, naturally occurring antioxidants (tocopherols and tocotrienols) in palm oil are found to inhibit enzymatic browning and thus prolong the shelf-life of the coated fresh produce when loaded or dispersed in lipid nanoemulsions.

In addition, it is noteworthy to highlight the potential of wastes from palm oil refining, such as cellulose nanofibres derived from empty fruit bunches (EFB) (Lani *et al.,* 2014) and oil palm trunks (Mazlita *et al*., 2016) which can be used in developing coating materials. Cellulose is a linear-chain polysaccharide that can exhibit excellent film-forming properties with the ability to provide good mechanical strength. *Figure 1* illustrates the substantial uses of the oil palm providing alternative materials for the development of edible nano films and coatings.

CONCLUSION

Combination of nano-packaging technology and lipid in edible coating could be intriguing in the search of much safer and reliable materials in edible coating technology. On top of that, further exploration into the use of the above-mentioned palm oil-derived materials and in combination with advancements in nanotechnology could trigger new strategies for developing bio-based edible coating materials. The exploitation of this innovation could lead to the extension of shelf-life and improve the quality of food while reducing packaging waste.

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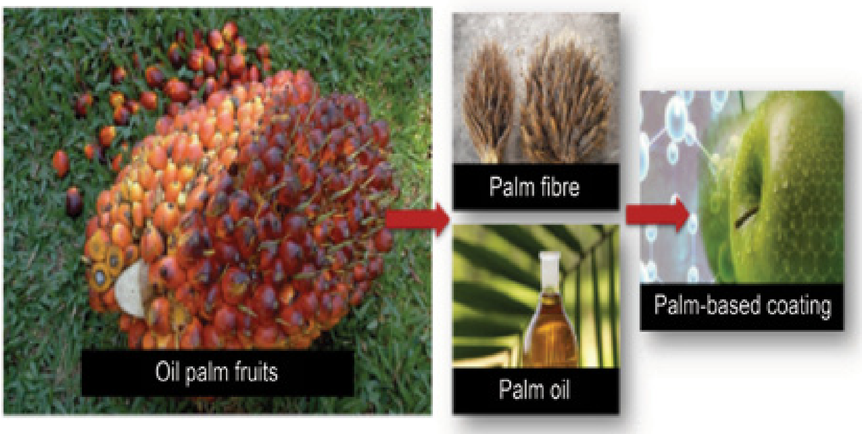

Figure 1. Valorisation of oil palm fruits and wastes into edible nano coating materials.

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