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ORIGINAL ARTICLE

Lipid-containing Edible Coating and Application in Fruits: A Review

[*2]Ung Hua Ting and [1,2]Mohd Zahid bin Abidin

[1]Centre of Research for Innovation and Sustainable Development (CRISD), University of Technology Sarawak, 96000 Sibu, Sarawak, Malaysia

[2]School of Engineering and Technology, University of Technology Sarawak, 96000 Sibu, Sarawak, Malaysia

ABSTRACT - Edible coating derived from natural biopolymers is a promising approach to maintain the quality of fruits and extend their postharvest shelf-life. As part of the fruits, they are readily consumed. They are biodegradable and does not leave harmful residues to the environment. The edible coating emulsion is produced from a single or multiple miscible components of biopolymers which can be incorporated with the other functional ingredients like pH regulators, antioxidants and antimicrobials. Lipids are widely adapted as the natural biopolymer in producing the edible coating. This article discusses the rationale of lipids in the formulation of edible coating and describes the challenges of producing an effective lipid-containing edible coating. A detailed account of the lipid-containing edible coating emulsion in the fruits is also presented, which significantly enhance their postharvest shelf-life through the monitoring respiration or ripening rate. The effect of the coating on the fruits are analyzed in terms of physical appearance, firmness, weight loss and biochemically reactions through the evaluation of the activities of enzymes, production of volatile compounds and microbial growth. The findings show that lipids are promising biopolymer in the development of edible coating that can be intelligently applied to the fruits by horticultural growers either solely, jointly with multiple lipids or compositely with the other biopolymers to achieve more advantageous properties.

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INTRODUCTION

During the postharvest storage of fruits, the proper control of their biochemical and physiological changes is critical for successful trade and marketability. For the climacteric horticultural products, the main criteria that affect the postharvest shelf-life are respiration and ripening process. The metabolic process should be optimally controlled before reaching the final consumers. Accelerated ripening gives rise to the rapid degradation of organic acids and chlorophyll content, loss of firmness and moisture in the fruits. Ripening is also associated with the release of volatile aromatic compounds as well as the production of sugars and carotenoids [1], [2], followed by senescence stage. Huge spoilage that caused by rapid ripening and microbial attack pose challenges to the plantation owners and cause unwanted wastage in terms of labour and cost. The common chemical postharvest treatment is a promising way to extend the shelf-life of fruits and vegetables. For examples, fungicides like imazalil, benomyl or thiabendazole solutions have been applied in controlling the fungal spoilage of fruits [2]. However, chemical treatment is discouraged due to the health and environmental concerns as well as the resistance of pathogens towards the chemicals. It also has no effect in reducing the ripening rate of the fruits.

Nowadays, the eco-friendly postharvest technologies are demanding. Normally, the postharvest shelf-life of horticultural produce is able to be extended by monitoring the respiration or ripening rate. This gives rise to the application of modified atmosphere packaging (MAP) or controlled atmosphere packaging (CAP)

*Corresponding Author: Ung Hua Ting, University of Technology Sarawak (UTS), email: doreentuh@gmail.com

which the low level of oxygen (1 – 3%) and high level of carbon dioxide are targeted to limit the aerobic respiration [3]. However, the anaerobic respiration is initiated once the oxygen is depleted and the postharvest crops will decay ultimately. One of the techniques to extend the postharvest shelf-life of fruits is edible coating. It resembles the 'natural coat' (also known as cuticles) on the surface of fruits and can achieve the similar effects of MAP and CAP by modifying the internal atmosphere at the cuticle. After harvesting, the cuticles are diminished as the crops are subjected to several postharvest handling process like cleaning, packaging and mass transferring. This exposes the crops to a higher exchange of gases and moisture between their tissue and the surrounding [4], [5]. Nevertheless, appropriate storage conditions are also vital to extend the shelf-life of fruits and vegetables. For instance, high temperature contributes to an increase in the respiration and ripening rate whereas low temperature storage below 10 ^{o}C is reported to cause chilling injury and high risk of microbial spoilage [2].

Dated back to 12th centuries, wax was the first coating material. At that time, waxing was widely applied for oranges and lemons by Chinese to extend the shelf-life but they did not discover about the mechanism of waxing in slowing down the respiration rate of citrus fruits. In 1930s, paraffin wax, which synthetically derived from the petroleum source, was mostly adapted as the fresh fruit coating material [3], [6]. Considering the potential migration of the synthetic molecules to the coated substrates, the researchers later developed the edible coatings derived from natural biopolymer component, such as hydrocolloids (polysaccharides and proteins) and lipids, be it alone or used in the combinations. Each single component of biopolymer has its own superiors and limitations from the views of gases and moisture barriers as well as the structural integrity.

In the last two decades, the composite coating made up of polysaccharides-lipid and protein-lipid had been proven to have enhanced barriers of moisture and gases as well as the physical properties like mechanical strength. Lipids have superior hydrophobic characteristics in resisting the moisture loss but poor barrier to the gases. The polysaccharides are opposite to the lipid coating. Hydrocolloids also provide structural property in supporting the lipid-based coatings. This led to the extensive development of natural biopolymer-based complex matrices with the incorporation of the other minor components of food additives like pH regulators, plasticizers and surfactants. At the same time, it also led to the establishment of edible composite coating in various forms such as bilayer and emulsion. In 1950s, the carnauba wax was dispersed in water to form a lipid-based coating emulsion to the fruits and vegetables. In the last two decades, the trend of edible coating had been shifted to the addition of antimicrobial agents from essential oils or nanoparticles and antioxidants into the biopolymers to modify the functional property of edible coating [3], [7], [8].

COMPONENTS OF EDIBLE COATING AND LIPID COMPONENTS

The edible coating material is divided into two types. The examples of natural type are biopolymers that derived from animal or plant origin, minerals and petroleum such as paraffin and microcrystalline waxes whereas the synthetic types are carbowax and polyethylene wax. Figure 1 summarizes the natural biopolymers that act as the major components in the formation of edible coating. They are biodegradable, non-toxic and eco-friendly. The lipid-based coating will be further elaborated in terms of their functions or significances especially when used in the combination with the other hydrocolloids. In the case of composite coating, multiple lipids are mixed together [9]–[12] or combined with hydrocolloids [8], [13] to improve the hydrophobicity while the hydrocolloids usually form the structural base of the lipid coating emulsion.

As shown in Figure 1, these components are deployed to create the edible coating in appropriate ratios and the formulations are often added with the other minor components for the functional and film-forming physical properties of the coating material. The acids or bases can be added to modulate the pH in the development of the coating. Likewise, alkaline condition yields soy protein coating with better characteristics as compared to acidic condition [14]. The glycerol is often added into the polysaccharides [15] and proteins [16] for the plasticizing effect of the coating. The essential oils are also added to contribute the antimicrobial and antioxidant characteristics of the coating [17].

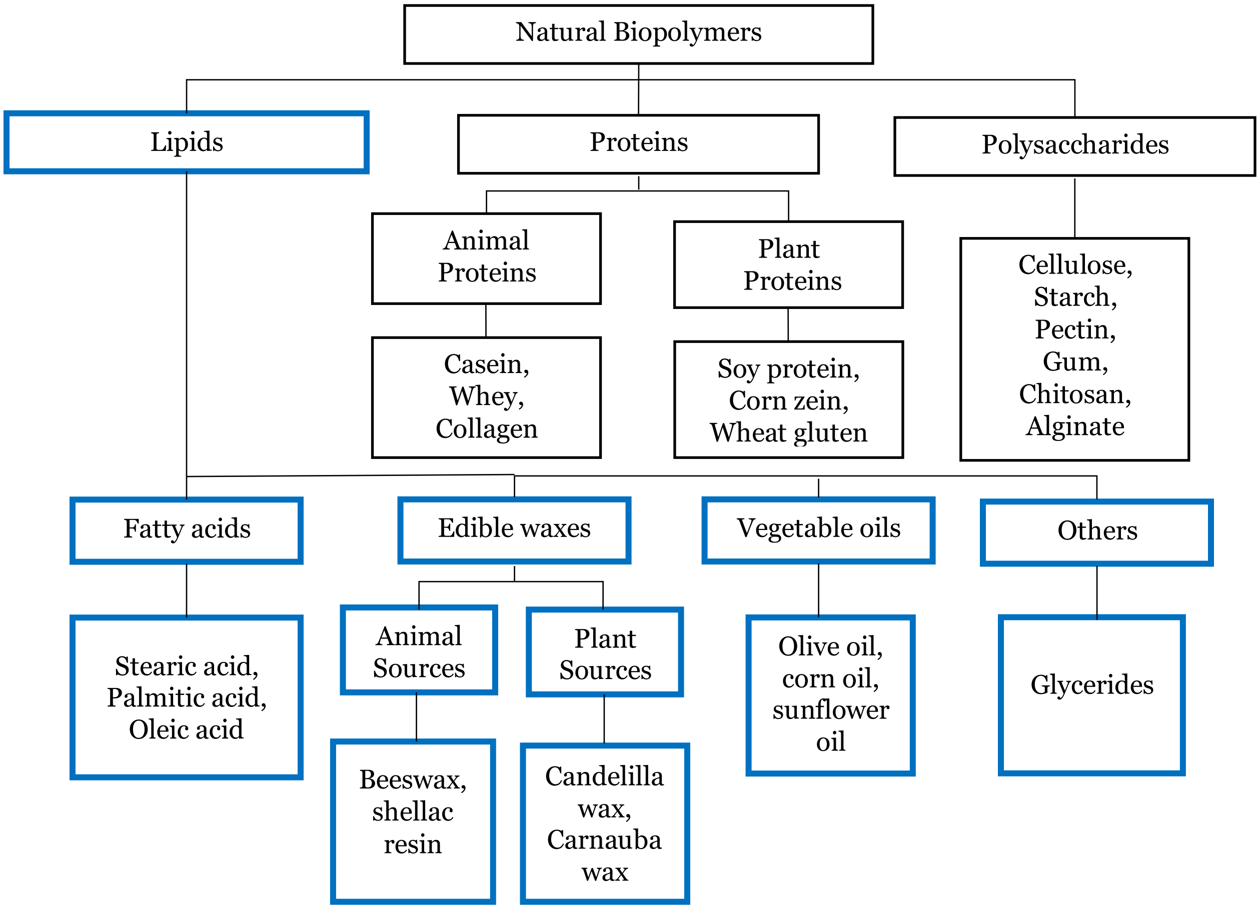

Figure 1. Natural Sources of Biopolymers in Edible Coating

FUNCTIONS OF LIPID COMPONENTS IN EDIBLE COATING

Moisture Barrier Property

The ratio of hydrophilic and hydrophobic influences the rate of moisture permeability. Lipids have high hydrophobicity that it is often added in the coatings by laminating onto the hydrocolloids layer or dispersing in the coating emulsion to reduce the loss of the moisture from the fruits. In the study, it has been found that the coating emulsion produced from cassava starch has improved moisture barrier when it is formulated with the 1.5% glycerol, 0.8% stearic acid and 0.2% carnauba wax [18]. With the lipid edible coating, the stomata of fruits can be closed and this contributes to the reduction in the transpiration and respiration rate. Through coating with hydrophobic biopolymers, the migration of moisture though the fruits can be controlled effectively and reduce the water availability for the growth of microbes, thus extending the shelf-life of fruits.

Table 1 depicts the water vapour permeability of some common lipids. It can be noticed that the moisture barrier of single lipid layer will be affected once it is emulsified into or layered onto the hydrocolloids system. The lipids with higher solid fat content, like beeswax and carnauba wax generally results in the coating with better moisture barrier as compared to the lipids with lower fat content like hydrogenated vegetable oils. The water vapour permeability of coatings is also influenced by environmental condition like relative humidity [19].

Table 1. Water Vapour Permeability of Single Lipid, Lipid-containing Bilayer and Emulsion [19]

Composition	Temperature (°C)	Relative Humidity (%)	Water Vapour Permeability (10^{-11} g.m^{-1}.s^{-1}.Pa^{-1})
Single Layer			
Beeswax	25	0 – 100	0.06
Shellac	30	0 – 84	0.36 – 0.77
Shellac	30	0 – 100	0.42 – 1.03
Candelilla wax	25	0 – 100	0.02
Paraffin wax	25	0 – 100	0.02
Palmitic acid	23	12 – 56	0.65
Stearic acid	23	12 – 56	0.22
Myristic acid	23	12 – 56	3.47
Capric acid	23	12 – 56	0.38
Hydrogenated palm oil	25	0 – 85	227
Bilayer			
Beeswax + methylcellulose	25	0 – 100	0.058
Candelilla wax + methylcellulose	25	0 – 100	0.018
Paraffin wax + methylcellulose	25	22 – 84	0.2 – 0.4
Stearic acid + hydroxypropyl methylcellulose	27	0 – 97	0.12
Hydrogenated palm oil + methylcellulose	25	22 – 84	4.9
Emulsion			
Beeswax + sodium caseinate	25	0 – 100	11.1 – 42.5
Beeswax + whey protein isolate	25	0 – 90	23.9 – 47.8
Paraffin wax + wheat gluten	25	22 – 84	1.7
Palmitic acid + whey protein isolate	25	0 – 90	22.2
Myristic acid + methycellulose + polyethylene glycol 400	23	12 – 56	3.5
Hydrogenated palm oil + methycellulose	25	22 – 84	13.2
Hydrogenated palm oil + wheat gluten	25	22 – 84	7.4

Physicochemical properties of lipid need to be considered for developing the coatings. The lipids with low polarity such as fatty acids and beeswax is more efficient in controlling moisture migration than the fatty acid alcohols [1]. The lipids with higher degree of saturation also have lower water vapour permeability as compared to the lipids with lower degree of saturation. The unsaturated parts in lipid structure have contributed to the polarity and low efficiency in modulating moisture migration. So, the moisture barrier can be enhanced by increasing the degree of saturation and the length of fatty acid chain.

However, the high degree of saturation of the lipid used produce edible coatings with high brittleness when they are used alone or in combinations with other biopolymers due to the high level of solid fat content. The coating emulsion produced from high carnauba wax content (0.4%) produces coating with low barriers to moisture whereas 0.2% carnauba wax formulation yields the coating with the most desirable barrier properties to moisture and gases as well as the mechanical flexibility. Large solid fat content in carnauba wax causes the polymer discontinuity [18]. Although lipid helps in the moisture barrier property, the increase of lipids in the coating does not necessarily result in increased moisture barrier as their interaction with the other biopolymers is not negligible. After all, the uniformity of dispersed lipid particles in the biopolymer matrix is the main factor that contributes to the effective moisture barrier property of lipid coating emulsion. So, the state and concentration of lipid, concentration of the other biopolymer, aids of other minor components like plasticizers, emulsifiers or surfactants should also take into considerations.

Besides, the preparation technique of the coating also influences the moisture barrier property. Typically, emulsion coating is mostly adapted as compared to the bilayer coating due to the convenience of coating application without another drying stage. For bilayer, hydrocolloids serve as the first layer, followed by the lipid layer after drying [1]. The delamination problem is observed in the bilayer coating and it causes pinholes development on the coated surface. On the other hand, the emulsion is homogenously set up by blending lipid globules into the colloidal matrix. However, after drying, some emulsion coating encounters the phase separation problem that is similar to the heterogenous setup of bilayer coating. It can be deduced that the lipid globules in small size need to be attained when setting up the emulsion coating to increase the surface area for the uniform dispersion. Numerous technologies of homogenization can be used to reduce the lipid size, like high-pressure homogenization, micro fluidization and rotor-stator homogenization [20]. The surfactants like Tween solution can also be added to disperse lipids uniformly in emulsion[21] .

Modification of Mechanical Properties

Some lipids like vegetable oils and free fatty acids and some hydrocolloids like starch lack of mechanical or structural property that seldom produced as a stand-alone film. These biopolymers often require the aid of other more mechanically-strong biopolymers to develop the coatings. On the other hand, some lipids like beeswax or carnauba wax and hydrocolloids like chitosan that have excellent film-forming ability can be used to form the stand-alone coating although they have their own barrier limitations in gases and moisture.

The mechanical property is normally analyzed through tensile strength (resistance to break under tension) and elongation at break. The elongation at break indicates the rigidity of the coating film which a more rigid film has lower elongation at break as it has higher resistance of deformation. It also indicates the tensile strength as higher elongation at break means higher tensile strength. It has been reported that the incorporation of stearic acid at a concentration greater than 5% improved the tensile strength of cassava starch coating film as compared to control [22]. It is deduced that the incorporation of lipids to improve the tensile strength needs to be controlled optimally to increase the polymerized network resistance effectively by uniformly dispersed in the system. Excessive addition of lipids into the hydrocolloid polymer emulsion leads to heterogenous distribution of lipids and unstable polymerized network.

Besides, an increase in the stearic acid concentration yields the starch coating film with reduced elongation at break and increased rigidity [22]. The similar result has been observed in the other research that incorporate lipid into the polysaccharide coating. An increase in the carnauba wax yields the cassava starch coating film with reduced elongation at break [18]. So, the lipid incorporation can help to modify the mechanical properties of hydrocolloids which is affected by the concentration of lipids and the interaction of lipids with the hydrocolloids.

Generally, hydrophilic plasticizers with a low molecular weight help to modify the coatings in terms of flexibility. Glycerol is generally formulated into the hydrocolloid coating as a hydrophilic plasticizer [15], [16]. It has been found that increasing in the glycerol amount helps to improve the flexibility of starch coating film by decreasing brittleness and increasing the extensibility [18], [22]. Plasticizers like glycerol increase the hydrocolloids biopolymer solubility in the emulsion as it acts in the space between the polymer chains and facilitates the diffusion of water due to its hydrophilic nature. So, the emulsion is less dense and under tension, it is more flexible to be coated onto the substrate as illustrated in Figure 2 [23] because the intermolecular forces between the adjacent chains of polymers can be weakened with the aid of plasticizer.

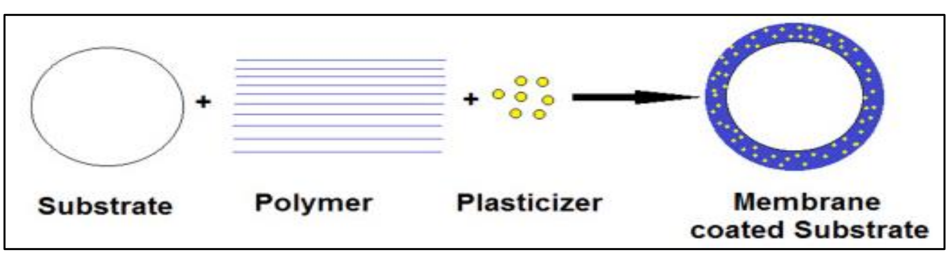

Figure 2. Plasticizing Effect [23]

Nevertheless, the lipids can be used in the hydrocolloids-based coating as a hydrophobic plasticizer. For example, free fatty acids and vegetable oil are natural plasticizers [15]. The incorporation of linoleic and oleic acids as plasticizers in the corn zein protein-based coating has produced the results of higher flexibility and elongation [24]. It is more ideal to use hydrophobic plasticizer in the consideration of moisture barrier property although the elongation effect or flexibility of the hydrocolloid film plasticized by hydrophobic substances is inferior to the one plasticized by hydrophilic substance. It has observed that the ester citrate derivative contributes lower flexibility to the gelatin protein film than the sorbitol and glycerol [25]. In this case, the hydrophobic plasticizers produce a more complex chain, which is more difficult when acting between the protein biopolymer chains as compared to the hydrophilic plasticizers.

However, the addition of hydrophobic plasticizer like ester citrate derivative has improved the flexibility and tensile strength of gelatin protein film with a significant reduction of the water vapour permeability as compared to the single protein film without hydrophobic plasticizers addition [25]. In the whey protein isolate film, the addition of beeswax reduces the amount of hydrophillic plasticizer required and gives extra benefit in term of moisture barrier. It has been observed that increasing glycerol content in the whey protein isolate coating increases the water vapour permeability due to its hydrophilic property [26]. In addition, the water vapour permeability also varied for the hydrocolloid film that plasticized by different types of hydrophobic plasticizer. Likewise, the acetyl tributyl citrate with lower polarity due to the presence of acetyl group has resulted in the gelatin protein film with a lower water vapour permeability than the tributyl citrate [25]. The types of lipids, position and number of hydroxyl groups present in the lipids and their interaction with the other biopolymers needs to be taken into considerations when adapting lipids as plasticizers in the coating.

Furthermore, the glycerol monostearate, a type of mono- and diglycerides, is also added into the gum Arabic coating film as a plasticizer to improve the flexibility [27]. On the other hand, the plasticizing effect of wax is affected by the viscoelasticity. Beeswax which is more viscous and has high likelihood of deformation has higher plasticizing effect than carnauba wax which is less viscous and low deformation likelihood [26]. Apart from that, the lipids also play a role as the emulsifiers. Glycerol monostearate is also an emulsifier that is ideal to form the water-in-oil emulsion as it has low value of hydrophilic-lipophilic balance (HLB) [28]. Through emulsifiers, the dispersion of particles is stabilized in the colloidal systems especially in the development of the coating emulsion. Emulsifiers also play a role in modifying the surface energy of the coating film. This ensures the good adhesion and wettability of the coating on the coated substrate. The concentration of lipid plasticizers or emulsifiers and their miscibility with different hydrocolloids should be considered to achieve the stable coatings with enhanced mechanical properties.

Antioxidant and Antimicrobial Properties

The essential oils such as lemongrass and cinnamon oil are also added to contribute the antioxidant property by reducing the oxidation of the natural antioxidants found in the fruits like phenolic compounds and flavonoids. The antioxidant capacity is evaluated by the radical scavenging activity of 2,2-diphenyl-1-picrylhydrazyl (DPPH). The DPPH activity of the guava coated with essential oil is higher than the control and the enhanced antioxidant property also helps in reducing the oxidation and loss of vitamin C at the concentration of 1 – 2% essential oils [17]. Besides, the incorporation of lipid in the edible coating also helps to enhance the shelf-life of coated fruits by carrying the other lipid-soluble active components onto the surface of fruits and protecting the biopolymers edible coating. In a study, the α-tocopherol, an antioxidant, has been found reducing the oxidation of the sodium caseinate film effectively and reducing the transmission of oxygen through the film. It may be due to the formation of cross-links between the antioxidant and the amino acids present in the sodium caseinate film. By incorporating α-tocopherol to the coating, the free radical activity is reduced with a lower oxygen permeability [16].

The lipids also function as antimicrobial agents that can extend the shelf-life of coated fruit. It is contributed by the lipophilic moiety of the lipids and the polar groups that present (C=O and O-H groups). Meanwhile, the lipids like essential oils contain the other active compounds that inhibit the microbial growth and lower the enzymatic browning activity. For example, cinnamaldehyde present in cinnamon oil inhibits the growth of yeasts, molds and bacteria. The antimicrobial compounds also form hydrogen bonding with the enzymes that involve in the browning of fruit such as polyphenol oxidase and peroxide oxidase [17] and deactivate their functions. Thus, the incorporation of essential oils in the edible coating prolongs the shelf-life of the coated fruits. In the other studies [9]–[11], the lipid-based coatings have been found reducing the microbial spoilage of fruits when the coconut oil is formulated into the coating. The antimicrobial of coconut oil is associated with the presence of monolaurin, which is converted from the lauric acid endogenously. It possesses antiviral, antifungal and antibacterial spectrums. extending the shelf-life of fruits.

CHALLENGES OF LIPID-CONTAINING EDIBLE COATING

The lipid-based or lipid-containing edible coatings have several drawbacks in term of sensory characteristics. The shellac and wax cause the fruits to appear greasy and have waxy sensation. It has been found that the strawberries that stored under 10 °C and coated with either beeswax-coconut oil or candelilla wax-coconut oil are able to extend the shelf-life with reduced fungal spoilage but both coated samples are less sensorially accepted as compared to the control. However, the sensory score obtained from the fruits coated with beeswax-coconut oil is higher than those coated with the candelilla wax-coconut oil [9]. The opacity of the coating also increases with the availability of the solid-state lipids in the coating. After coating with wax, the opacity and greasiness of the fruit surface reduces the sensory acceptance [9]. In another study, the lemon that coated with coconut oil has a higher sensory score than the control at the end of ambient storage on Day 18 as the green colour is still retained for the coated lemon with some shininess [11], Hence, the ideal coating adds glossiness to the fruits without affecting clarity or transparency of its natural color.

The wax should be applied in an amount without much impact on the consumers acceptance and that can optimally enhance the shelf-life of fruits through effective control of the gases and moisture diffusion. In order to prevent excess coating, the physical attributes of the thickness and wettability can be analyzed [3]. Wettability refers to the uniform spread of coating on the surface of fruits under the sufficient cohesions between the particles in the coating and adhesions between the coating material and the coated surface. However, the wettability varies based on the compositions of biopolymer in the coating and their interactions among themselves and with the coated surface. On the other hand, there is no ideal range of thickness since it varies with concentration, density and viscosity of the biopolymers that used in coating formulation [1].

Besides, the storage conditions like temperature and relative humidity of the fruits after being coated with lipid-containing materials are vital to avoid the problem of chalking, also known as wax-shifting. This is due to the fluctuation of the temperature and humidity during storage and generally observed in the shellac-coated fruits that transferred from chiller to the condition of higher humidity and temperature. The lipid partially solubilizes in the moisture on the surface of fruits which is formed as a result of condensation process [4]. As shown in Figure 3, when chalking problem occurs, there are white and translucent particles depositing on the surface which affecting the appearance of the fruits. The chalking problem worsens when there is heavy and thick waxing being applied.

Figure 3. Chalking Problem on Apple [29]

The lipid-containing edible coating has exposed to oxidation issue which causes the development of off-flavour due to rancidity [20]. In other cases, some lipids like wax and shellac have high restriction of gases transfer and cause the level of oxygen in the internal atmosphere becomes extremely low that it leads to the anaerobic respiration [1]. The anaerobic respiration causes the production of carbon dioxide, ethanol and acetaldehyde which causes the off-flavour development. The anaerobic respiration also affects the taste of the fruit. For instance, an acidic taste has been detected in the strawberries waxed with beeswax and candelilla wax due to the anaerobic respiration although they effectively extend the shelf-life of fruits through the reduction of the loss of moisture from the fruits and microbial spoilage [9].

APPLICATION OF LIPID-CONTAINING EDIBLE COATING IN FRUITS

The lipid-containing edible coating can be produced by using single lipid component or multiple lipids, or combining lipid with the other biopolymers. Table 2 summarizes the effectiveness of several lipid-containing edible coating in controlling the postharvest quality maintenance of different types of fruits. The physicochemical properties of fruits such as weight loss, firmness, total chlorophyll and carotenoid content, titratable acidity (TA), total soluble solids (TSS) and ripening index (RI) are parameters to evaluate the potency of edible coating.

Table 2. Application of Lipid-containing Edible Coating Emulsion in Fruits

Fruit	Storage Condition and Duration	Coating Material	Findings	References
Guava	20 °C, 15 days	Mesquite gum, candelilla wax, mineral oil	Reduced ripening rate of coated samples as indicated by the reduction in the production of ethylene, weight loss and loss of texture. Coated samples appeared greener and had lower TSS[1] content than the control on Day 6.	[30]
Strawberry	4 ± 1 °C, 10 days	Chitosan, oleic acid	Through the addition of oleic acid, the chitosan-coated samples had improved moisture barrier and antimicrobial activity but reduced luminosity and the sensory score for flavour and aroma. Delayed fungal decay in all chitosan-coated samples, regardless with or without oleic acid and reduced respiration rate with the increase of oleic acid addition. No significant changes of TSS[1], TA[2] and anthocyanin content which were not affected through coating.	[31]
Guava	25 – 27 °C, 80 – 90% RH[3], 10 days	Beeswax, palm stearin, palm olein	Reduced rate of weight loss in coated samples	[12]
Apricot, strawberry	Ambient condition and 4 °C (35 days for apricot), (50 days for strawberry)	Beeswax, coconut oil, sunflower oil	Coated apricot samples that stored at 4 °C showed higher score of appearance, retention of Vitamin C and lower weight or moisture loss than the uncoated samples that stored under the same condition on Day 10. The coated strawberry samples that stored at 4 °C showed higher score appearance, retention of Vitamin C and lower weight or moisture loss than the control that stored under ambient condition on Day 5.	[10]

Strawberry	4 °C & 10 °C, 10 days	Beeswax, candelilla wax, coconut oil	The samples coated with both beeswax-coconut oil and candelilla wax-coconut oil exhibited a lower weight loss and able to store up to 10 days at 4 °C. The samples stored at 10 °C depicted a higher microbial spoilage than those stored at 4 °C. The samples with beeswax coating at 4°C had a slower loss of vitamin C. Both wax coatings affected the sensorial acceptance of samples in terms of flavour and taste.	[9]
Blueberry	4 °C, 75% RH[3], 35 days	Quinoa protein, chitosan, sunflower oil	Delayed rate of ripening and microbial spoilage was indicated in the coated samples as compared to the control. There is reduced degradation of organic acids in the samples through coating, as a higher TA[2] and lower pH were observed in coated samples. Coating affected the colour of samples in term of waxiness.	[32]
Pear	28 ± 5 °C, 60 ± 10% RH[3], 5 days	Soy protein isolate, HPMC[4], olive oil, potassium sorbate	Reduced weight loss in the samples was observed with an increase of olive oil addition. The increase in the concentration of HPMC caused a significant reduction in the respiration rate as indicated by a lower TSS[1] content and pH while a higher TA[2] in the coated samples.	[8]
Guava	4 – 7 °C for 35 days and thereafter 25 ± 2 °C for 5 days	Gum Arabic, sodium caseinate, cinnamon oil, lemongrass oil	The addition of 2% cinnamon oil or lemongrass oil to the coating made up of gum Arabic and sodium caseinate was able to extend the shelf-life of coated samples to 40 days whereas the control only last for 7 days. Through the coating, the samples showed slower rise of sugar content, higher phenolic compounds, Vitamin C and flavonoid contents with a lower rate of PPO[5] which will cause enzymatic browning.	[17]
Lemon	Ambient (21 ± 2 °C, 50 ± 5% RH[3]) & MAP[6], 18 days	Coconut oil, beeswax	All coated samples (coconut oil only and coconut oil-beeswax) showed only a slight increase of the respiration rate while the uncoated samples showed a significant increment, regardless the different storage condition. The maximum loss of weight was observed in the uncoated samples that stored under ambient condition, whereas MAP[6] reduced the weight loss whether the samples coated or not. The samples coated with only coconut oil and beeswax-coconut and stored under MAP[6] had immense effect of retention of chlorophyll, firmness, moisture content, weight and reduction of respiration rate.	[11]

Fig	4 °C, 70% RH[3] for 19 days and thereafter 25 °C for 2 days	Chitosan, alginate, olive oil	Both chitosan-olive oil and alginate-olive oil coated samples was able to extend longer shelf-life (14 – 19 days) than the control (< 14 days) after being stored at 4 °C and allowed to ripen at 25 °C for 2 days. As compared to the uncoated samples, a slower fungal decay rate, ripening rate, softening rate was indicated in the coated samples that stored at 4 °C on Day 1, 7, 14 and 19. For the coated samples that have been removed from 4 °C to 25 °C for 2 days at different time interval, they had shown a significant increase in the postharvest ripening indicators.	[33]
Pomegranate	5 ± 1 ºC, 95 ± 2% RH[3] for 42 days and thereafter 20 ± 0.2 ºC, 60 ± 10% RH[3] for 5 days	Gum Arabic, maize starch, lemongrass oil, glycerol	The reduction of ripening indicators such as reduced weight loss and respiration rate was indicated in the coated samples and which was mainly affected by the concentration of gum Arabic and maize starch. The coating also reduced the rate of TSS[1] decline, depicted a slower oxidation rate of sugars due to slower respiration rate. No significant effect of the coating on the reduction of the consumption of organic acids, causing the decrease of TA[2].	[34]

[1]Total soluble solids; [2]Titratable acidity; [3]Relative humidity; [4]Hydroxypropyl methylcellulose; [5]Polyphenol oxidase; [6]Modified atmosphere packaging.

CONCLUSION

To date, a lot of biodegradable biopolymers have been studied as promising edible coating material on the food products. Nonetheless there is still limited research regarding the lipid-containing edible composite coating in the fruits by merging barrier properties of both hydrocolloids and lipids. It is recommended to study and characterize more potential substitutes to formulate the edible composite coating emulsion. The type and amount of the biopolymers that used decide the properties of the edible coating emulsion that formed and the effectiveness in prolonging the shelf-life of fruits. There is also lack of research on the effect of adding food additives like pH regulator, hydrophobic plasticizer and antimicrobial agent on the performance and physicochemical attributes of the edible coating. In the future, it is expected that the advancement in technology allows the development of different edible coating through nanotechnology and formulation with the other bioactive components. Even so, the edible coating must oblige to the demands of consumer acceptance, safety and legality besides enhancing the postharvest shelf-life of fruits.

REFERENCES

[1] Lin D. and Y. Zhao, "Innovations in the Development and Application of Edible Coatings for Fresh and Minimally Processed Fruits and Vegetables," 2007.

[2] Murmu S. B. and H. N. Mishra, "Post-harvest shelf-life of banana and guava: Mechanisms of common degradation problems and emerging counteracting strategies," *Innovative Food Science and Emerging Technologies*, vol. 49. Elsevier Ltd, pp. 20–30, Oct. 01, 2018. doi: 10.1016/j.ifset.2018.07.011.

[3] Vargas M., C. Pastor, A. Albors, A. Chiralt, and C. González-Martínez, "Development of edible coatings for fresh fruits and vegetables: possibilities and limitations," *Fresh Produce*, vol. 2, no. 2, 2008.

[4] Chan M., "The Coat on Fruits - Wax?," *Food Safety Focus*, Jul. 2016. https://www.cfs.gov.hk/english/ multimedia/ multimedia_pub/multimedia_pub_fsf_120_02.html (accessed Apr. 08, 2022).

[5] Osman A., N. Saari, R. Saleh, J. B. Noor, D. Zainal, and M. Yacob, "Post harvest handling practices on selected local fruits and vegetables at different Levels distribution chain," *Journal of Agribusiness Marketing*, vol. 2, 2009.

[6] Reddy K. S. and J. Singh, "Edible coatings in fruits - a review," *International Journal of Current Microbiology and Applied Sciences*, vol. 9, no. 11, pp. 2953–2969, Nov. 2020, doi: 10.20546/ijcmas.2020.911.359.

[7] Jose A., S. Pareek, and E. K. Radhakrishnan, "Advances in Edible Fruit Coating Materials," in *Advances in Agri-Food Biotechnology*, Springer Singapore, 2020, pp. 391–408. doi: 10.1007/978-981-15-2874-3_15.

[8] Nandane A. S., R. K. Dave, and T. V. R. Rao, "Optimization of edible coating formulations for improving postharvest quality and shelf life of pear fruit using response surface methodology," *Journal of Food Science and Technology*, vol. 54, no. 1, pp. 1–8, Jan. 2017, doi: 10.1007/s13197-016-2359-9.

[9] Peñarubia O. R., M. Filomena, J. Raposo, R. M. Santos Costa De Morais, A. Maria, and M. Bernardo De Morais, "Beeswax-and candelilla wax-coconut oil edible coatings extend the shelf life of strawberry fruit at refrigeration temperatures," *Int. J. Postharvest Technology and Innovation*, vol. 4, pp. 221–234, 2014.

[10] Mladenoska I., "The potential application of novel beeswax edible coatings containing coconut oil in the minimal processing of fruits," *Advanced technologies*, vol. 1, no. 2, pp. 26–34, 2012.

[11] Nasrin T. A. A., M. A. Rahman, M. S. Arfin, M. N. Islam, and M. A. Ullah, "Effect of novel coconut oil and beeswax edible coating on postharvest quality of lemon at ambient storage," *Journal of Agriculture and Food Research*, vol. 2, Dec. 2020, doi: 10.1016/j.jafr.2019.100019.

[12] Mohd Zahid A., C. S. Cheow, A. R. Norizzah, Z. M. S. Halimahton, and M. S. Adi, "Optimization of guava edible coating using response surface methodology," *Journal of Applied Horticulture*, vol. 12, no. 2, pp. 97–101, 2010.

[13] Parreidt T. S., M. Lindner, I. Rothkopf, M. Schmid, and K. Müller, "The development of a uniform alginate-based coating for cantaloupe and strawberries and the characterization of water barrier properties," *Foods*, vol. 8, no. 6, Jun. 2019, doi: 10.3390/foods8060203.

[14] Rayner M., V. Ciolfi, B. Maves, P. Stedman, and G. S. Mittal, "Development and application of soy-protein films to reduce fat intake in deep-fried foods."

[15] Vieira M. G. A., M. A. da Silva, L. O. dos Santos, and M. M. Beppu, "Natural-based plasticizers and biopolymer films: a review," *European Polymer Journal*, vol. 47, no. 3. pp. 254–263, Mar. 2011. doi: 10.1016/j.eurpolymj.2010.12.011.

[16] Fabra M. J., A. Hambleton, P. Talens, F. Debeaufort, and A. Chiralt, "Effect of ferulic acid and α-tocopherol antioxidants on properties of sodium caseinate edible films," *Food Hydrocolloids*, vol. 25, no. 6, pp. 1441–1447, Aug. 2011, doi: 10.1016/j.foodhyd.2011.01.012.

[17] Murmu S. B. and H. N. Mishra, "The effect of edible coating based on Arabic gum, sodium caseinate and essential oil of cinnamon and lemon grass on guava," *Food Chemistry*, vol. 245, pp. 820–828, Apr. 2018, doi: 10.1016/j.foodchem.2017.11.104.

[18] Chiumarelli M. and M. D. Hubinger, "Evaluation of edible films and coatings formulated with cassava starch, glycerol, carnauba wax and stearic acid," *Food Hydrocolloids*, vol. 38, pp. 20–27, 2014, doi: 10.1016/j.foodhyd.2013.11.013.

[19] Morillon V., F. Debeaufort, G. Blond, M. Capelle, and A. Voilley, "Factors affecting the moisture permeability of lipid-based edible films: A review," *Critical Reviews in Food Science and Nutrition*, vol. 42, no. 1, pp. 67–89, 2002, doi: 10.1080/10408690290825466.

[20] Galus S. and J. Kadzińska, "Food applications of emulsion-based edible films and coatings," *Trends in Food Science and Technology*, vol. 45, no. 2. Elsevier Ltd, pp. 273–283, Oct. 01, 2015. doi: 10.1016/j.tifs.2015.07.011.

[21] Ruzaina I., "Utilisation of palm-based and beeswax coating on the postharvest-life of guava (Psidium guajava L.) during ambient and chilled storage," *International Food Research Journal*, vol. 20, no. 1, pp. 265–274, 2013.

[22] Schmidt V. C. R., L. M. Porto, J. B. Laurindo, and F. C. Menegalli, "Water vapor barrier and mechanical properties of starch films containing stearic acid," *Industrial Crops and Products*, vol. 41, no. 1, pp. 227–234, Jan. 2013, doi: 10.1016/j.indcrop.2012.04.038.

[23] Khatri P., D. Desai, N. Shelke, and T. Minko, "Role of plasticizer in membrane coated extended release oral drug delivery system," *Journal of Drug Delivery Science and Technology*, vol. 44. Editions de Sante, pp. 231–243, Apr. 01, 2018. doi: 10.1016/j.jddst.2017.12.020.

[24] Santosa F. X. B. and G. W. Padua, "Tensile properties and water absorption of zein sheets plasticized with oleic and linoleic acids," *Journal of Agricultural and Food Chemistry*, vol. 47, no. 5, pp. 2070–2074, May 1999, doi: 10.1021/jf981154p.

[25] Andreuccetti C., R. A. Carvalho, and C. R. F. Grosso, "Effect of hydrophobic plasticizers on functional properties of gelatin-based films," *Food Research International*, vol. 42, no. 8, pp. 1113–1121, Oct. 2009, doi: 10.1016/j.foodres.2009.05.010.

[26] Pau Talents and John M Krochta, "Plasticizing Effects of Beeswax and Carnauba Wax on Tensile and Water Vapor Permeability Properties of Whey Protein Films," *Journal of Food Science*, vol. 70, 2005.

[27] Valiathan S. and K. A. Athmaselvi, "Gum Arabic based composite edible coating on green chillies," *International Agrophysics*, vol. 32, no. 2, pp. 193–202, Apr. 2018, doi: 10.1515/intag-2017-0003.

[28] HanJ., "What is Glycerol Monostearate (E471) in Food & its Uses?," Apr. 16, 2020. https://foodadditives.net/emulsifiers/glycerol-monostearate/ (accessed Apr. 19, 2022).

[29] Fernandes M., "Fruit Waxing," Feb. 28, 2018. https://www.medindia.net/dietandnutrition/fruit-waxing.htm (accessed May 12, 2022).

[30] Tomás S.A., E. Bosquez-Molina, S. Stolik, and F. Sánchez, "Effects of mesquite gum-candelilla wax based edible coatings on the quality of guava fruit (Psidium guajava L.)," in *Journal De Physique IV*, 2005, vol. 125, pp. 889–892. doi: 10.1051/jp4:2005125206.

[31] Vargas M., A. Albors, A. Chiralt, and C. González-Martínez, "Quality of cold-stored strawberries as affected by chitosan-oleic acid edible coatings," *Postharvest Biology and Technology*, vol. 41, no. 2, pp. 164–171, Aug. 2006, doi: 10.1016/j.postharvbio.2006.03.016.

[32] Abugoch L., "Shelf-life of fresh blueberries coated with quinoa protein/chitosan/sunflower oil edible film," *Journal of the Science of Food and Agriculture*, vol. 96, no. 2, pp. 619–626, Jan. 2016, doi: 10.1002/jsfa.7132.

[33] Vieira T.M., M. Moldão-Martins, and V. D. Alves, "Composite Coatings of Chitosan and Alginate Emulsions with Olive Oil to Enhance Postharvest Quality and Shelf Life of Fresh Figs (Ficus carica L. cv. 'Pingo De Mel')," 2021, doi: 10.3390/foods.

[34] Kawhena T.G., U. L. Opara, and O. A. Fawole, "Optimization of gum arabic and starch-based edible coatings with lemongrass oil using response surface methodology for improving postharvest quality of whole 'wonderful' pomegranate fruit," *Coatings*, vol. 11, no. 4, Apr. 2021, doi: 10.3390/coatings11040442.