CHAPTER 2

Literature review

2.1 Introduction

Orange, lemon, pomelo, mandarins and limes belong to the genus Citrus of flowering plants in the family Rutaceae. The most recent research indicated an origin in Australia, New Caledonia and New Guinea (Liu *et al*., 2012). Some authors found that the origin of citrus is in the part of Southeast Asia bordered by Northeast India, Myanmar and the Yunnan province of China, (Gmitter and Hu, 1990; Scora, 1975) and it is in this region that some commercial species such as oranges, mandarins, and lemons originated (Fig 2.1). Citrus fruit has been cultivated in an ever widening area since ancient times; the best-known examples are the oranges, lemons, grapefruit and limes.

Citrus fruit appeared 30 million years ago in the world. There seems to be evidence that the citrus fruits are planted in early 2200 BC in China. Nippur in Mesopotamia is the place of origin where citrus cultivation dates back to 4000 BC. The origin of Rutaceae family 78 species of indigenous are in India, incluce: Two species of subgenus Eucitrus - *Citrus indica* and *Citrus assamensis* and three species of subgenus Pepeda - *Citrus ichangensis*, *Citrus latipes* and *Eucitrus macroptera* indigenous Assam province, Indian (Chaudhry *et al*. 2004).

Citron was introduced between 250 and 200 BC. In Europe Citron was the first among citrus fruit emigrant. The Greeks found citron (C. medica) growing in Medica and Persia. In India, Citron is found under wild conditions particularly in Nilgiris, Assam and lower Himalayas. The sweet orange is believed to have been originated in southern China. Sweet oranges have been introduced into Europe in the 16^{th} century by the Portuguese(Ahmad and Ghafoor 2004). The main area of orange, lemon commercial production are Southern China, areas along the Mediterranean, South Africa, Australia, the southern region of the United States and parts of South America. In the United

States, Florida, Texas and California are the main production regions, while the other States along the southern United States have also grown on a smaller scale. Nowaday each country has been growing different varieties hybrids of citrus and divided into 7 main species: pomelo, lemon, orange, mandarin, kumquat, lime, tangelos (Fig. 2.1).

2.2 Component, chemical composition, nutritive, medicinal value of orange fruit

The citrus tree is a perennial plant, large shrubs or small to moderate-sized trees, reaching 2–15 m in tall, with spiny shoots and alternately arrangedevergreenleaves with an entire margin. The flowers are solitary or in small corymbs, each flower 2–4 cm in diameter, with five (rarely four) white petals and numerous stamens; they are often very strongly scented (https://en.wikipedia.org/wiki/Citrus).

The fruit is a specialised berry, sphere, 4–30 cm in long and 4–20 cm in diameter, with pericarp was peel. The outermost layer of the pericarp is an "exocarp" called the zest or counted as the flavedo. The middle layer of the pericarp is the mesocarp, which in citrus fruits consists of the white, spongy "albedo". The segments are also called "liths", and the space inside each lith is a locular filled with juice vesicles, or "pulp". From the endocarp, string-like "hairs" extend into the locular, which provide nutrition to the fruit as it grows up (https://en.wikipedia.org/wiki/Citrus).Citrus fruits are delicious, beautiful and high in nutrients. In citrus fruit, fruit comprise of 28-56% for water, 22 - 22.5% for peel, 1.3 to 2.5% for seed. Citrus juice comprise: 4-11.6% for sugar, 0.1-2% for citric acid and organic acids, vitamins A, B, C, minerals, ect. (Loi, 2003).

In general, citrus fruit varieties include 3 parts: Exocarp (Peel): Peel includes epidermis with thick cuticle and the stomata, essential oils are contained on spotted peel. Beneath the epidermis is the layer of thin parenchyma cells, chloroplasts so it can wealthy photosynthesis when unripe fruit.

In the maturity stage, chlorophyll decompose, group xanthophyl and carotene pigments become important, fruit color changes from green to yellow or orange. The essential oils in the tissue are retained under the turgor of surrounding cells.

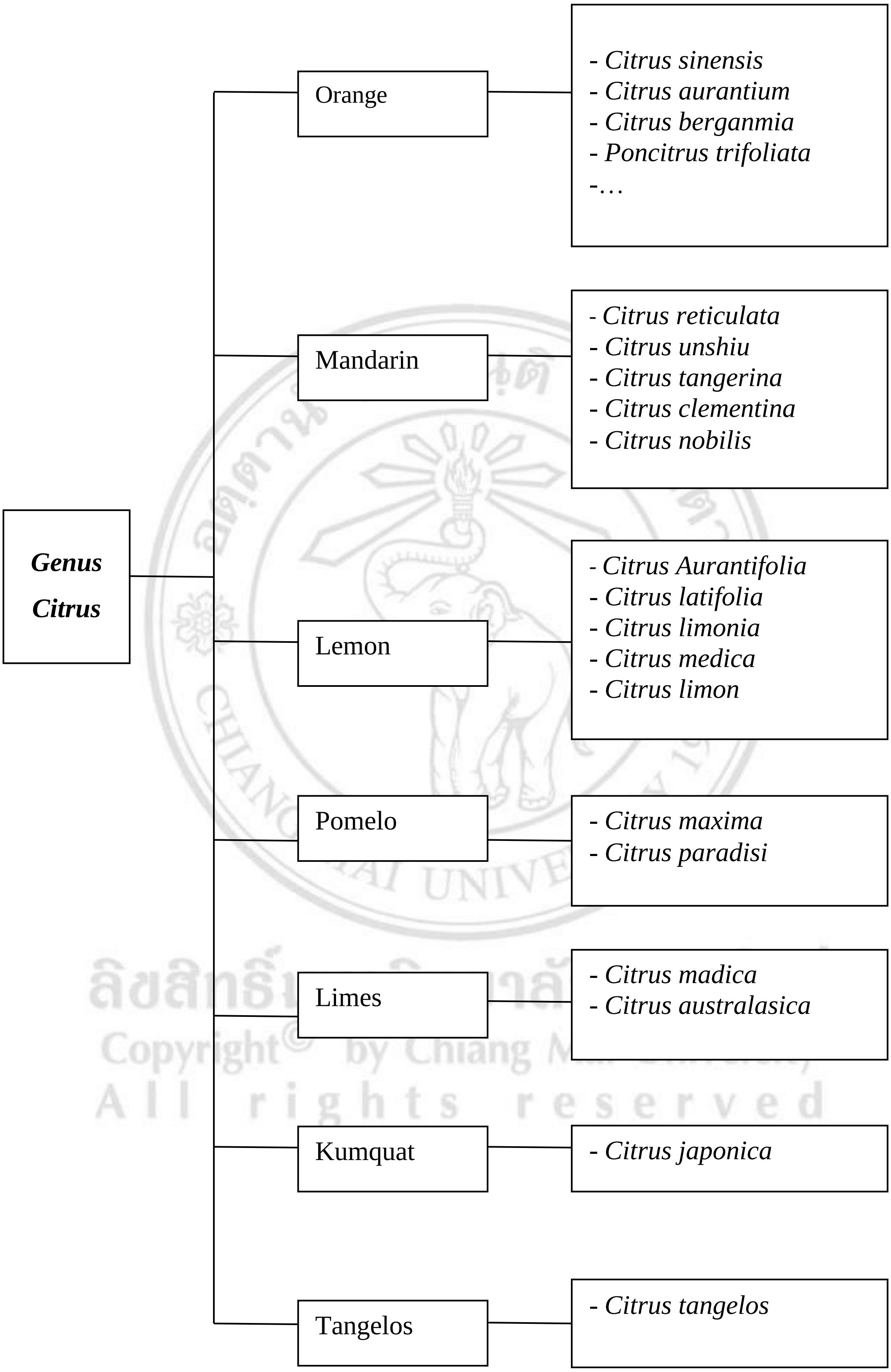

Figure 2.1 Some main genus Citrus

Endocarp: The inside layer of the pericarp is called the endocarp, this is a multi-layer composite cell, white, sometimes light yellow. The cells have formed large intercellular space, with much sugar, starch, vitamin C and pectin. Young fruit contains high levels of pectin (20%) and it is an important role to the fruit absorbs water. Depending on the species of citrus, this endocarp is thick or thin, this part is connected to the peel with endocarp of fruit, when the fruit grows up big and soft.

Pulp: pulp is surrounded by thin endocarp inside the citrus fruit. Multicellular filaments gradually develop. Water is full insides, small 'shrimps' in the pulp, and only some space for seed development. Edible part of the fruit contains many sugars, acids and minerals with the percentage changing depending on plant species and growing conditions.

Citrus fruits are famous for flavour due to flavonoids and limonoids (which in turn are terpenes) contained in the peel, and most are juice. The juice contains a high quantity of vitamin C, citric acid, and flavonoids. The flavonoids comprise various flavones, flavonoids (https://en.wikipedia.org/wiki/Citrus).

Medicinal: Citrus is highly appreciated in traditional medicine: Fresh citrus peel contains 3.8% essential oil, 61.25% water, vitamins A, B,... Citrus leaf has about 0.5% oil (Loi, 2003). Fresh citrus fruits are sweet, sour, warm, and high in vitamin C. Oranges and tangerines are very good for health, good for high blood pressure person, coronary artery disease, stomach pain, malnutrition, and physical weakness after illness. (Loi, 2003).

The peel of citrus is sometimes used as a facial cleanser after consumption. In the industry fermentation processes, citric acid is produced with lemon being the primary commercial source (González *et al*., 2013). Whereas, citrus fruit juices, such as orange, lime and lemon, may reduce for the risk of kidney stones (Grape fruit and medication, 2005). Lemons have the highest concentration of citrate of any citrus fruit, and daily consumption of lemonade has been shown to decrease the rate of kidney stone formation (Carr, 2010). Grape fruit is another fruit juice that can be useful to lower blood pressure because it blocks with the metabolism of calcium channel (Grape fruit and medication, 2005). Dried citrus peel is called ‘Tran Bi’. ‘Tran Bi’ is used as alternative medicine in Vietnam, to improve digestion, relieve intestinal gas and bloating, and resolve phlegm. This peel acts primarily on the digestive and respiratory systems and reduces loss of appetite, vomiting or diarrhoea, or coughs with copious phlegm. The rind of the immature bitter orange relieves gas, bloating and constipation. (Don, 2010)

Seed of citrus fruit is bitter, and can be used to reduce pain the colon, the loss of appetite, and diarrhoea (Loi, 2003).Leaf of citrus is bitter, and can be used to promote good liver function, cure melt lumps, sore ribs, breast pain, lumps in the breast (Loi, 2003).

Sweet orange cv. Canh trees are hybrid varieties of orange, grown for 2-3 years then harvested and average 50-100kg orange cv.Canh/tree after 5 year growing. The trees are strong and have a circular canopy, dark green leaves (Fig. 2.2).The height of tree ranges from 3 to 3.5 m, between 2 and 3 m in diameter of tree-trunk, and flowers from February to March. Fruits are harvested from November to December.

Orange cv. Canh fruit weighs about 100g. The peel is very thin, and smooth, lane both ways citrus peel out. Each fruit has 11-13 segments, and the segment membrane is thin, with small ‘shrimps’. The pulp hasorangecolor, very sweet, high nutrition and has a low acidity of 0.1%. In addition, fruit has an attractive shade on skin and a deep red to purplish pigmented pulp with a special delightful aroma that makes the commodity in great demand domestically and as a potential candidate for export.

In Vietnam, the main growing areas of sweet orange cv. Canh are BacGiang, PhuTho, Hanoi, Hung Yen, HoaBinh provinces.

There is not any researches to store orange fruit cv. Canh or the problems of fruit after harvest. During storage time, the fruit have high weight loss, high decay and poor quality, fast wrinkling. So, there is a need to search for effective methods to prolong the shelf-life of the orange cv. Canh.

Figure 2.2 Leaf, flower, fruit, treeof orange cv. Canh

2.3 Some main causes that affect the postharvest quality of orange fruit

After planning post harvest management for citrus fruit, it was necessary to solve the cause and nature of loss in stages: Losses are physical (weight loss and decay), nutritional, sensory (loss of appearance as a result of shrinkage), and losses can be economic in nature.

2.3.1 Weight loss

Losses in mandarins at wholesale were 5% where as retail markets were roughly 15% in North India (Chauhan *et al*., 1987). The damage to 'Nagpur' mandarin fruit are considerably less in clipping and hence the lower decay losses in storage. In the quick harvesting, citrus fruit was 8-9% weight loss (Sonkar *et al*., 1999). Post harvest losses of fruit in Thailand in general are higher both in stage of quality and quantity and with some storage facilities and postharvest treatments, but damage of weight decreased in citrus fruit lower than other fruit (Siriphanich, 1999). Therefore total losses during marketing in the 'Nugpus' mandarin were up to 24 % (6% at farm, 8 % at wholesale, and 10 % at retail level (Ladaniya, 2004). According to Ladaniya (2008), citrus fruits have small surface area to volume ratio and lose water more slowly, but 5-6% water damage present in some change in firmness, appearance of citrus that can be a disadvantaged in the consumer market. 'Mosambi' orange losses at farm level were 1.2% including insect-damaged, over-ripe, and very small-sized fruit, loss was 7% from decay at retail level (Ladaniya and Wanjari, 2003). The result showed that water loss doesnot affect appearance or esthetic value but also reduces saleablity, thus causing direct economic loss.

2.3.2 Fruit decay, and the development of microorganism and fungus

Postharvest decays are caused by latent or wound-induced fungal infections. Latent infection typically become established on the fruit prior to harvest, but exist in a resting or dormant state until the conditions are right for fungal growth after harvesting (Postharvest Handling Technical Bulletin, 2004b).

Losses from postharvest disease caused by various pathogens account for nearly 50% of the total wastage in citrus fruits, and infection and contamination occur at different stages in the field, after harvest and during marketing. Decay from postharvest infection is *Penicilium* rots, *Aspergillus* rots, *Rhizopus* rots, and *Fusarium* rots (Ladaniya, 2008). Hatton *et al.* (1987) reported that mandarin cv. Sunburst fruits subjected to 66h of degreening showed 10% decay, whereas fruits degreened for 45h <2% decay. Ladaniya and Wanjari (2003) reported that 'Mosambi' orange fruit could be stored with calcium carbide powder kept in the paper bag, rate of rotting damaged 5% at the retail level. Ladaniya (2008) concluded that 'Mosambi' orange lost 2-3% due to decay that was the major sweet-orange variety grown in Maharashtra state, India at the retail level.

2.3.3 Chilling injury

Mark (2013) showed that oranges in California and Arizona may develop chilling injury when held at temperatures below about 3 to 5 ºC (37.4 to 41 ºF).Symptoms of chilling injury include pitting, brown staining, increased decay, internal discoloration, off-flavors, and watery breakdown. 'Mosambi' sweet oranges did not preserve at 3-5ºC for long time because of chilling injury in central India (Nagpur). The optimum temperature for storage of 'Mosambi' orange was 5.5-7ºC, and fruits can be preserved over 90 days in acceptable condition (Ladaniya, 2004). Mandarin was sensitive to chilling injury under 4ºC, so symptoms of chilling injury are recognized as formation of irregular dark spots, browning around the surface of the mandarin and oil darkening (Perez *et al*. 2003). Near central India, Nagpur mandarins increased chilling injury at 3.5–5.0ºC after 30 days storage, where as citrus grown in northern India could preseve at 2.2–3.9ºC without chilling injury. Injury increases over 3 month (Mukherjee and Singh, 1983; Ladaniya and Sonkar, 1996).

2.3.4 Harvest maturity indices

Orange fruit can be not picked immature as after-ripening the fruit contain little starch and are non-climacteric. Unfortunately, colour is not good indicator of maturity, so percentage of soluble solid (TSS) (%Brix, of which 70-80% is composed of sugar) and titrable acid of the juice are used as a maturity index: acid ratio ranging from 8 to 10 is generally accepted as a measure of minimum maturity, while ratio of 10 to 16 is considered to be acceptable quality (Baldwin, 1993).

Maturity indices are based on TSS, TA, TSS/TA, and/or juice content and color. Specific regulations are established for different growing regions. For Florida: minimum maturity indices for fresh fruit shipments modify depending to harvest date and are based on TSS and TSS/TA. For California and Arizona: for fruit with yellow-orange color on ≥ 25% of the surface, TSS:TA must be 8 or higher, and on fruit with green-yellow color on ≥ 25% of the surface, TSSC:TA ratio must be 10 or higher. Florida oranges also have minimum requirements for TA (0.4%) and juice content (4.5 gal per 1.6 bu box) (Mark, 2013). Mai and Hoa (2005b) concluded that the best harvesting time of orange fruit cv. Sanh is from 28-32 weeks after fruit setting.Vietnamese orange cv. Canh can be picked immature for ripening, depending on time of pollination, orange fruit is harvested at 220-235 days after fruit set (Huyen, 2013).

2.3.5 Shrinkage pattern

Ladaniya and Wanjari (2003) showed that total loss of 'Mosambi'orange fruit is 7.2 % and shriveling does not lead to complete loss in spring crop season. Shrinkage pattern causes loss of weight and softening, so a decrease in price. Weight loss of fruit appeared after 14 days of preservation time and fruit did not attract color, and detected wrinkles on the peel (Raghav and Gupta, 2000). Waxing improves the appearance of fruit skin, waxing aims to prevent shrinkage, weight loss, and extend the shelf life of fruit and vegetables throughout the preserving time (Postharvest Handling Technical Bulletin, 2004b).

2.3.6 Quality of fruit

Changes in the quality of citrus fruit (TSS, vitamin C, sugars and titrable acid) are conditional upon preservation time.Fructose and sucrose contents in limes reduced but citric acid kept unchanged at 15°C in Palestine during keeping in storage (Arras and Piga,1997). Nagar (1991) reported that the TSS and reducing sugars progressively rise, irrespective of the harvesting period and storage at ambient temperature. 'Nagpur' mandarin and 'Kinnow' mandarin showed to reduce in juice percentage, and the acidity in juice decrease under cold storage conditions (Mukherjee and Singh, 1983); (Ladaniya and Sonkar, 1996).

Citrus fruit was lost in vitamin C when extended storage and changed at low temperature compared to room temperature (Pal *et al*. 1997). Similar to the report of Thakur *et al*. (2002), citrus fruit preserved at lower temperatures (7, 10 and 12ºC) had significantly higher ascorbic acid as compared to fruits stored under ambient conditions. Hagenmaier (2002) concluded that ethanol contents are the same at 3°C and 5°C while ethanol content increase two times i.e., 90 mg. kg/l in samples which are stored under warm conditions (> 20°C).

2.4 Postharvest technology of orange fruit

2.4.1 Wax coating

1) History and application of edible coating on fruit

Edible coatings have been used for centuries due to the high demand of consumers for better quality of fresh fruit and longer shelf life as well as for environmentally friendly packaging, reducing subsequence softening and shriveling (Woods, 1990), and also to improve appearance by imparting shine (Baldwin, 1994; Bai *et al.*, 2002). Coatings can also be used for flavour or nutrient encapsulation (Chen *et al.*, 2006). The first recorded use was in China in the twelfth century on citrus and later in England using lard or fats to prolong shelf life of some product (Baldwin and Hagenmaier, 2011). Since the early to mid twentieth century, coatings have been used to prevent water loss and add shine to fruits and vegetables (Baldwin, 1994). Depending on their formulations, coatings applied to fruits can have the same effect on fruit interior gas concentration as controlled atmosphere chambers or modified atmosphere packaging have on the outer fruit environmental atmosphere. However, if oxygen levels fall too low, the anaerobic pathway of fruit respiration can be initiated and ethanol is produced, which can cause off-flavour (Wills *et al.*, 1981; Baldwin, 1994; Bai *et al.*, 2002).

Coatings can also be used as carriers of functional ingredients, such as fungicides for fruit coatings (Brown, 1984; Baldwin and Hagenmaier, 2011). Other antimicrobials, such as preservatives, antibrowning agents, antioxidants, and firming agents have all been added to coatings to improve the coated product microbial stability, appearance, and texture (Baldwin *et al.*, 1996).

Basically, coating film formers consist of polysaccharides, proteins, lipids, resins, alone or, more often, in combination. Polysaccharide coatings (cellulose derivatives, starch derivatives, chitosan, pectin, carrageenans, alginate, and gums) are hydrophilic and intermediate among coating materials in gas exchange properties but are poor barriers to moisture. Proteins (corn zein, wheat gluten, peanut, soy, collagen, gelatin, egg, whey and casein) are similar in properties, being also hydrophilic. Lipids and waxes tend to be more permeable to gases but present a better barrier to water vapor and include carnauba, candelilla, rice bran waxes, and bees wax; petroleum-base waxes such as paraffin and mineral oils; vegetable oils (corn, soybean and palm), acetoglycerides, and oleic acids. Resins are the least permeable to gases and intermediate in resistance to water vaporandinclude shellac, wood rosin, and coumarone indene resin (Baldwin, 1994).

Components of edible coatings can be classified into three categories: hydrocolloids, lipids (waxes, shellac, and oil) and composites (combining substances from the two categories). The hydrocolloids include coating forming carbohydrates (cellulose derivatives, starch derivatives, chitosan, pectin, carrageenans, alginate, and gums…) and coating-forming proteins (corn-zein, wheat gluten, peanut, soy, collagen, gelatin, egg, whey and casein...). The lipids consist of carnauba, candelilla, and rice bran waxes; bees wax; petroleum-base waxes such as paraffin and mineral oils; vegetable oils; acetoglycerides; and oleic acid. The hydrocolloid component provides the necessary durability while the lipid component can serve as a barrier to water vapor. Coating forming carbohydrates are hydrophilic and intermediate among coating materials in gas exchange properties but are poor barriers to moisture. Coating forming proteins are similar in properties, being also hydrophilic (Krochta, 2002). The oxygen permeability of protein films, corn-zein and wheat are also lower than those of cellulose films, methyl cellulose and hydroxypropyl cellulose. Lipids and waxes tend to be more permeable to gases but present a better barrier to water vapor while shellac, wood rosin, and coumarone indene resin are the least permeable to gases and intermediate in resistance to water vapor (Baldwin *et al.*, 1997; Hagenmaier and Baker, 1997; Bai *et al.*, 2002). The characteristics of some commercial coatings are shown in Table 2.5 (Bai and Plotto, 2012). Hagenzmaier and Baker (1997) found that almost coating formulations from wax were effective moisture barriers, with the best being those containing candelilla waxes, bees wax, and petroleum wax. Carnauba wax coatings had the best gloss, but were also the most brittle. Emulsion clarity improved by using some myristic acid or palmitic acid and oleic acid (Hagenmaier and Baker, 1997).

Table 2.1 Water vapour, O_2 and CO_2 permeability of edible coatings

Coating	Permeability			Temperature (°C)
	Water vapour (10^{-12} g m^{-1} s^{-1} Pa^{-1})	O_2 (10^{-12} L m^{-1} d^{-1} Pa^{-1})	CO_2	
Lipid				
Shellac	1.46-7.71	0.96	0.34-1.31	20-30
Bees wax	0.58	1.06	-	25
Candellila	0.17	6.22	23.61	25-30
Carnauba wax	0.33-0.61	0.19	2.62-16.89	25
Polyethylene	-	8.30	26.1	30
Polysachcharide				
Methycellulose	76-92	2.17-12.96	69-743	25-30
Starch	2170	1591	29209	23-25
Chitosan	490	0.0014	-	25
Pectin	-	6.6-29.5	472	25
Protein				
Gluten	43-616	0.2-28.6	2.1-811	23-25
Soy	3540	0.775	-	
Whey	616-4170	0.012	2.13	25
Zein	89-132	1.79-3.81	2.7-13.1	20

(Source: Bai and Plotto, 2012)

Table 2.5 shows that various coating materials can create from low to medium of water vapour that limit water loss while materials having high O_2 and CO_2 permeability do not create anaerobic internal atmosphere (Bai and Plotto, 2012).

2/ Properties and effect of waxing on quality fruit

All fruits and vegetables are living organisms, and as such require intake of O_2 and release CO_2 for respiration (aerobic). They also release vapour in to the atmosphere through diffusion. Both these processes create a loss in the weight of the produce. All fruits and vegetables are covered naturally with a cuticle, which is a barrier to gas exchange. The cuticle is impermeable to O_2, slightly more permeable to CO_2 and several magnitudes more permeable to water vapour. Unwaxed fruits or vegetables have pores in their surface through which most the diffusion of O_2 and CO_2 offers. Water vapour can move through the pores (stomata and lenticels), cuticle, and micro-cracks in the cuticle (Bai *et al.*, 2002).

Waxing replaces the natural wax and is able to reduce the weight loss, respiration, transpiration and the shrinkage; improve the appearance and the freshness, inhibit mold growth and prevent other physical damage and disease (Hung 2006; Thirupathi *et al.*, 2006). Baldwin *et al.* (1999) reported that the concentration of wax emulsion effected the quality of coated fruit. If the wax concentrations are increased 5% or higher the result will be development of off-flavour. The effect of fruit coating with 'Vapor Gard' in a 1.3% solution was to reduce water loss, retard firmness decrease, reduce the loss of ascorbic acid content, inhibit malic enzyme activity and increase polygalacturonase activity compared to untreated fruit.

Oxygen permeability is an important characteristic for fruit coatings. If the permeability is too low, anaerobic respiration will commence, resulting in a build-up of acetaldehyde, ethanol and off-flavour as well as product deterioration. If coating permeability is too high, the internal atmosphere will not be modified sufficiently to result in a beneficial reduction of ethylene synthesis and delayed ripening (Baldwin, 1994). Polysaccharide coatings are less permeable to respiratory gases, such as O_2, and more permeable to water vapour compared to carnauba wax. Only the polysaccharide coating delayed ripening and increased concentrations of flavour volatiles. The carnauba wax coating significantly reduced water loss compared to non-coated and polysaccharide-coating treatments. Compared to wax coatings made with ammonia-based emulsions, those made with morpholine had higher permeability to oxygen and water vapor, possibly because the morpholine, being less volatile than ammonia, stayed longer in the coating (Hoyle, 1999). Hagenmaier and Shaw (1992) and Baldwin *et al.* (1997) reported that the cellulose-based polysaccharide coating was less permeable to these volatiles than the carnauba wax coating, thus their levels were building up within the coating barrier.

3/ Bees wax

Bees wax is the most important natural wax in commerce. Bees wax is produced from honey bees *Apis mellifera*, although other important taxa exist, such as the Asiatic *A. dorsata*, *A.florea and A. indica* and the African *A. adansonii*. A honey bee keeper typically yields 10 pounds of honey and 1 pound of wax. An approximate chemical formula of beeswax is $C_{15}H_{31}COOC_{30}H_{61}$. Its main components are esters of fatty acids and various long chain alcohols such as palmitate, palmitoleate, hydroxypalmitate and oleate esters of long chain (30-32 carbons), aliphatic alcohols. Wax content types of beeswax are hydrocarbons 14%, monoesters 35% (triacontanylpalmitate is a major component), diesters 14%, triesters 3%, hydroxy monoesters 4%, hydroxy polyesters 8%, acid esters 1%, acid polyesters 2%, free acids 12%, free alcohols 1%, and unidentified 6%. Bees wax can be classified generally into European and Oriental types. The ratio of saponification value is lower (3-5) for European, and higher (8-9) for Oriental types (Bees wax, 2015).

Bees wax has a high melting point range, of 62 to 64°C(144 to 147°F). If bees wax is heated above 85°C (185°F) discolouration occurs. The flash point of beeswax is 204°C (399.9°F). Density at 15°Cis 0.958 to 0.970 g/cm^3 (Bees wax, 2015).

Purified and bleached bees wax are used in the production of foods, cosmetics, and pharmaceuticals. Beeswax is used as a coating for cheese, to protect the food as it ages. As a food additive, bees wax is known as E901 (glazing agent). As a skin care product, a German study found beeswax to be superior to similar "barrier creams" (usually mineral oil based creams, such as petroleum jelly), when used according to its protocol. Bees wax is an ingredient in moustache wax, as well as hair pomades (Bees wax, 2015).

Addition of bees wax to the hydroxypropyl methylcellulose film matrix (HPMC) reduced film mechanical resistance and oxygen barrier, and improved film moisture barrier properties. Flavour was not affected by coating application. Results indicate that HPMC-bees wax coatings with 20 g/100 g beeswax would provide the best compromise to extend shelf life of Angeleno plums (Navarro-Tarazaga *et al.*, 2011). Shahid (2011) speculated that the bees wax coating decreased the respiration rate of fruit, thus reducing the weight loss and increasing shelf life of the minimally processed fruit.

4/ Carnauba wax

Carnauba wax can produce a glossy finish and as such is used in automobile waxes, shoe polishes, dental floss, food products such as sweets, instrument polishes, and floor and furniture waxes and polishes, especially when mixed with bees wax and with turpentine.

Technical characteristics:

- Name in International Nomenclature of Cosmetic Ingredients (INCI name) is *Copernicia cerifera* wax, name in European Union is E903.
- Melting point: 82–86°C(180–187°F), among the highest of natural waxes.
- Relative density is about 0.97
- It is among the hardest of natural waxes, being harder than concrete in its pure form.
- It is practically insoluble in water and ethyl alcohol while soluble on heating in ethyl acetate and in xylene. Usage levels are unlikely to exceed 200 mg/kg.

Although too brittle to be used by itself, carnauba wax is often combined with other waxes (principally bees wax) to treat and waterproof many leather products where it provides a high-gloss finish and increases leather's hardness and durability (Carnauba wax, 2015).

Carnauba wax is relatively hydrophobic and presents a good barrier to moisture loss. Hagenmaie and Shaw (1992) and Baldwin *et al.* (1997) reported that levels of methanol were significantly higher in fruit coating formulations contenting carnauba wax compared to controls. Otherwise, the coated fruit exhibited similar levels of volatile compounds to control fruit and less weight loss than cellulose-based polysaccharide treatment and control. Carnauba wax is much more permeable to gases including CO_2 and O_2 and more permeable to water vapor compared to polysaccharide cellulose or shellac coatings (Baldwin *et al.*, 1997). Carnauba wax is as a carrier for aroma encapsulation (Bugarski *et al.*, 2008)

Permeability of the carnauba wax coating was more affected by high relative humidity (RH) during chilled storage and condensation. At 60% RH, polysaccharide-based had relatively low O_2 permeability while the carnauba wax coating had a comparatively high value, about half that of polyethylene film (Baldwin *et al.*, 1999).

5/ Mixed wax coating in storage of orange

Post-harvest quality of mandarin oranges (*Citrus reticulata* Blanco cv Sai Nam Peung), teva wax (18% food grade shellac, polyethylene) coating was significantly different from no wax (control) in % weight loss, shelf life, and glossiness of the fruit in cold storage for 1 month (Ni *et al.* 2008). Edible composite coatings based on hydroxypropyl methylcellulose (HPMC), hydrophobic components (bees wax and shellac), and food preservatives with antifungal properties were used to evaluate on ‘Valencia’ oranges during long-term cold storage. The result showed that selected food preservations included potassium sorbate (PS), sodium benzoate (SB), sodium propionate (SP), and their mixtures inhibited *Penicillium digitatum* and *Penicillium italicum* that were coated and stored up to 60 days at 5 ◦C followed by 7 days of shelf-life at 20°C (Silvia *et al.*, 2009). Shellac coating (shellac 5%, glycerol 0.3%) used to preserve orange cv Vinh could extend the shelf life for 7 weeks, loss of weight was 6.7% (Ha *et al.*, 2009). The ‘Delta Valencia’ orange were coated with carnauba - based wax and refrigerated at 5±1ºC and 85±2% RH for 28 days. Carnauba - based wax coated fruit showed no signal of dehydration keeping their shiny green peel up to the end of the storage (Pereica *et al.* 2013).

2.4.2 Phenylactic acid (PLA)

In recent years, numerous studies on the antimicrobial activity of a wide range of the natural compounds from different origins have been reported. Many microorganism pathogens causing of foodborn diseases and fresh food decay can be inhibited by the natural compounds (Fisher and Phillips, 2008). Among these, phenyllactic acid (PLA) is a promising candidate for its application in fresh-cut fruit and vegetable products. Phenyllactic acid (PLA) is a novel antimicrobial compound recently produced from lactic acid bacteria. PLA is proven to have a broad inhibitory spectrum against fungal species including some mycotoxigenic species belong to *Aspergillus* and *Penicillium* (Lavermicocca *et al*., 2000).

In addition, the inhibitory ability of PLA has been demonstrated against both Gram-positive and Gram-negative bacteria, such as *Listeria monocytogenes*, *Staphylococcus aureus*, and *Escherichia coli* O157:H7 (Dieuleveus *et al.*, 1998). However, there have been few studies which applied PLA for preserving fresh produce. PLA has mainly been applied in some processed foods such as milk products, bread and bakery goods (Magnusson and Schnurer, 2001; Li *et al*., 2007). Sathe *et al*. (2007) demonstrated the ability of *L. plantarum* CUK501 to inhibit growth of four different fungi on cucumbers for up to 8days when compared to non-treated (control). PLA has been reported to be one of the most abundant aromatic acids to which antibacterial properties have been attributed and to occur in several honeys with different geographical origins (Weston *et al.*, 1999). Effects of PLA on animals and human health were investigated and showed no toxicity (Oberdoester *et al*., 2000).

Lavermicocca *et al.* (2003) showed that PLA inhibits a wide range of mold species isolating from bakery products, flour, and cereals, including some mycotoxigenic species, namely *Aspergillus ochraceus*, *Penicillium roqueforti*, *P. citrinu*, etc. The ability of PLA acts as a fungicide providing new perfectives for the possibility of using this natural antimicrobial compound to control fungal contaminats and prolong the storage life of food and or feedstuffs. PLA production has been reported using various microorganisms, including *Geotrichum candidum* (Dieuleveux *et al*., 1998), propionibacteria and lactic acid bacteria (LAB) (Lavermicocca *et al*., 2000). Previous studies showed that PLA can be produced by a wide range of LAB species but its production is strain-dependent. Lavermicocca *et al*., 2000 reported the production of PLA by *L. plantarum* 21B used as a starter in sourdough bread, which was the first report showing the production of PLA by LAB. PLA has also been identified from culture supernatants of several LAB strains, such as *L. plantarum* MiLAB 393 (Magnusson and Schnurer, 2001).

L. coryniformis Si3 and *L.sakei*. In a recent study, 70 of 112 LAB strains isolated from Chinese traditional pickles could produce relevant amounts of PLA (Li *et al*., 2007). Although PLA can be produced by a wide range of *Lactobacillus* sp., its production is rather low with levels up to 94 mg/l when the LAB was cultured in MRS broth. Li *et al*. (2007) reported that PLA content increased 14-fold in *Lactobacillus* sp. SK007 fermentation, which reached 1.12 g/l, when phenylpyruvic acid was used to replace phenylalanine as substrate.

2.4.3 Temperature storage

Temperature management is one of the most important ways to maintain quality of fresh horticultural produce after harvest, low temperatures reduce respiration and ethylene production rates, water loss, pathogen growth, and decay incidence (Kader, 2002; Thompson *et al.*, 2002). Minimum safe temperatures for postharvest storage of mandarins were between 5 and 8◦C (Kader and Arpaia, 2002; Burn, 2004). Liu *et al.* (1998) found that 'Ponkan' fruit (*Citrus tankan* H.) in Miaoli, Taiwan could be preserved at 12.5-15°C that is optimum temperature to store and extend self life for 3 months. This fruit preserved at 5 °C for 3 months increased chilling injury. According to the research of Mai and Hoa (2005a), orange fruit cv. Sanh stored at 8ºC could prolong the shelf life of fruit for 5 weeks when compared to the control fruit is a week. In addition, the rate of weight loss was approximately 8%. Tugwell and Chvyll (1995) showed that 'Navel' and 'Valencia' orange in Australia increase surface pitting after some weeks at under 4.5°C. Opitmum temperatures of 4.4–6.1ºC was better than 2.2–3.9ºC for 'Kinnow' mandarins in Saharanpur (Mukherjee and Singh, 1983).

2.4.4 Decay management

1) Pesticide

Infections occur through wounds only when the nutrients are available to stimulate the germination of spores. These injury are caused by activities such as poor handling during harvesting, and processing. Green mold is the fastest growing. Initial infections occur such as water soaked, high moisture (Brown, 1984). The blue mold *Penicillium digitatum* is caused by producing green fibers and is recognised on the surface of infected citrus (Zhang *et al.*, 2004). Blue mold could be treated by the application of synthetic fungicides such as Imazalil and thiabendazole (Brown *et al*. 2000).

In recent years there was some researches to store orange fruit in Vietnam. Thoa *et al*. (1996) reported that mixed solution of Topsin and Methyl tiophalat 0.1% have a good effectiveness to kill fungi on the surface of orange fruit. At present in Vietnam, the recommended method to store orange fruit have been using treatment of chitosan coating at concentration of 2% in combination with 0.7 g/l carbendazim, and packed in PE0.01mm, and then storing them at ambient condition. The results showed that the orange fruit can be prolonged shelf-life with good quality for 90 days, without being rotten, mold, or stem loss (Binh and Dien, 1995). Lam *et al.* (2011) reported that dipping fruit in thiabendazol 150ppm for 150 second 'Ham Yen' orange inhibited the growth of blue, green mold *Penicilium digitatum* and *Penicilium italicum*.

'Valencia' orange treated with Imazalil and carnauba significantly reduced the development of fungus at pre-storage and post-storage (Ncumisa *et al.*, 2012). The 'Kinnows' mandarin used TBZ 1000ppm and polyethylene wax at concentration of 800ppm showed maximum storage life of 105 days during storage period at 5°C temperature (Babar, 2007). Carbendazim, thiabendazol, imazalil, topsin and methyl tiophalatare types of fungicide, and are damaging to the health of people and to the environment.

2) Bio-pesticide

A 2% concentration of PLA completely inhibited the growth of green mold *Penicillium digitatum* in oranges. 'Vangiang' orange fruit treated with 2% PLA followed by coating with wax (CP-01) maintained quality and appearance, while reducing the spoilage rate during 8wk in storage at ambient conditions (Thuy, 2013). According to Lavermicocca *et al*. (2001), the antifungal compounds produced by LAB display growth inhibition against common fungal strains such as *Aspergillus niger, A. terreus, A. flavus, A. nidulans, Penicillium roqueforti, P. corylophilum, P. expansum.* Prema *et al.* (2010) showed that inhibitory concentration of PLA produced by a *L. plantarum* strain against fungal spoilers such as *Aspergillus fumigatus* and *Penicillium camemberti* was 6.5 - 12 mg/ml. However, *L. plantarum* IMAU10014 exhibited limited ability to prevent fungal spoilage.

The yeast *Debaryomyces hansenii* reduced the activity of *Penicillium* rot (Mehrotra *et al*., 1996) and sour rot of orange fruit (Mehrotra *et al*., 1998). Strain 43E of *Candida famata* (*Torulopsis candida*) when used together with 0.1g TBZ/L at a concentration of 10^6 cells/ml gives signifycantly better disease control then either TBZ or the yeast alone (Arras and Piga, 1997). The strain of commonly used yeast in wineries, *Sacchromyces cerevisiae* was detected to inhibit the development of *Aspergillus niger* in 'Nagpur' mandarins and limes (Naqvi, 1998). The fungus *Muscodo ralbus*, a bio-fumigant that produced certain low molecular weight volatiles has been used to fumigate whole rooms of lemons to control pathogens during storage, and was effective against sour rot and *Penicillium* mold (Mercier and Smilanick, 2005).

3) Hot water treatment

Dipping in hot water had generally been utilized as a fungal pathogen control, since fungal spores and latent infections were either on the surface or in the first few cell layer under peel of the fruit and vegetable (Barkai-Golan and Phillips, 1991). Applying time and temperature depend on cultivar, maturity level, fruit size, and conditions during the growing season (Fallik, 2004). Treatment for citrus fruit can range from 36ºC for 3 days to 62 ºC for 2 seconds (Watkin and Ekman, 2005). The tangerine fruit cv SaiNumPung dipping in hot water at 50ºC for 3 min and 55ºC for 3 min had no effects on chilling injury symptons, percentage of electrolyte leakage and TSS during storage at 2ºC for 30days (Sirisopha, 2009). Schirra and D'Hallewin (1997) found that pre-storage dipping of 'Forture' mandarins in water at 50, 52, or 52ºC for 3 min reduced decay both during cold storage at 6^{o}C and stimulated shelf-life at 20^{o}C without causing adverse effect to the rind surface. Dipping in hot water at 50-53^{o}C for 2-3 min showed to impact treatment at 36^{o}C for 3 days in conducting chilling injury and decay rate in some citrus fruit and are much cheaper, because they are treating shorter time in during storage (Rodov *et al*., 1995).

2.4.5 Control atmosphere (CA) and modified atmosphere-packaged (MAP)

Orange consumers are becoming cautious regarding carbendazim residue, due to it being a type of pesticide. CA and MAP are methods to replace carbendazim treatment, with less harm to humans and the environment. An alternative method was the use of CA technology in combination with MAP (Hoan *et al*., 2002). Accoding to Ladaniya (2007), Nagpur mandarin (*Citrus reticulata* Blanco) fruit of tropical crop season sealed with permeable Cryovac films (D955; 15 and 25 µm) in trays and storing for 4 weeks, decay losses were 5-10% in packaged and non-packaged fruit under MAP over the period of 4 weeks.

The weight loss of orange could be reduced and their shelf-life could be extended to 9 weeks in storage by ozone treatment in conjunction with CMC film (or pectin film), and package in polyethylene (PE) bag or PP bag at 10^{0}C (Thuy and Tuyen, 2011). After 30 days in storage, the weigh loss of ‘Irani’ and ‘Thompson navel’ orange cumulative at ambient (14^{o}C and 67% RH) and refrigerated (5^{o}C and 85% RH) conditions with PE liner was 25% firmer when compared with those of without polyethylene wrapped liner (Tabatabaekoloor, 2012). Hung (2006) concluded that packaging orange fruit cv. Ha Giang by PEmp (25 µm thick) with $0.0092m^2$/fruit (average was 0.2 kg/fruit) and storing them at $22^{o}C \pm 2$ can maintain the good quality for 80 days. In addition, the rate of fruit decay was 7.84%. For cv. Vinh, packaging fruit by LDPE 30 µm ($0.08m^2$/1.2kg fruit) kept the lowest fruit decay (6.0%) after 80 days in storage.

2.5 Application of phenyllactic acid (PLA), bees wax and carnauba wax coating on storage of fruit in Vietnam and in the World

PLA was produced by fermentation of *Lactobacillus plantarum* and applied for preserving fresh produce, canning, juice, semi- processing; processed foods such as milk products, bread and bakery goods in the world (Lavermicocca *et al.*, 2001, Magnusson and Schnurer, 2001; Li *et al*., 2007). Wang *et al.* (2012) showed that the strain F3A3 of *L. plantarum* has an excellent ability to prevent the fungal spoilage caused by *P. digitatum* KM08 in kumquat. Thuy *et al.* (2012) reported that PLA at concentration of 2% shows to be able to inhibit completely the growth of green mold *Penicillium digitatum* infected in orange. 'Van Giang' orange fruit treated with 2% PLA followed by coating with CP-01 still maintained quality and appearance, while reducing in spoilage rate during 8 weeks in storage at ambient condition.

The suitable wax coating for 'Cat HoaLoc' mango fruit was 3.6% bees wax mixing with 2.4% carnauba wax, this treatment could reduce weight loss, extend shelf-life, and delay the ripening at low temperatures storage (Thinh, 2013). Hai *et al.* (2015) proved that dipping longan fruit in oxalic acid and coating in 6% MW (mixed wax of 3.9% bees wax and 2.1% carnauba wax) postponed decay rate and peel browning rate for 25 days in preservation time, and the TSS content maintained unchanged at 5°C. Baldwin *et al.* (1999) showed that waxes should be also generally recognized as safe (GRAS), substances for human consumption. Carnauba wax- based coatings improved appearance and reduced water loss of mango compared to polysaccharide - based coating, but did not delay ripening.

Thang *et al.* (2013) showed that orange fruits cv Vinh coated in polyethylene (16%) containing bees wax (4%) and stored at room temperature, after 7 weeks in storage, the weight loss was 4.73%; and the fruits respiratory intensity, firmness, color and solid content changed slower than the control fruit. Lam *et al*. (2013) concluded that orange fruits cv Vinh coated in mixed wax (5% carnauba wax and 10% polyethylene), and stored at room temperature, after 6 weeks in storage, the weight loss was 10.5%; and the fruits sensory score, firmness, color, respiratory intensity and TSS changed slower than the control fruit. Wilawan *et al*. (2013) showed that bees wax and resin coating materials could decrease weight loss during storage of tangerine fruit. In addition, it could be used with a commercial coating machine for coating tangerine fruit. The quality of the coated 'Sai Nam Pueng' tangerine fruit was accepted by the consumers when stored at 25°C for 2 weeks after coating and up to 5 weeks when stored at 15°C.