CHAPTER 2

LITERATURE REVIEW

2.1. Introduction

Longan is an evergreen tree which belongs to the Sapindaceae family with many scientific names include *Dimocarpus longan* Lour., *Euphoria longana* Lam., *E. longan* Strand., *E. morigera* Gagnes., and *E. scanderns* Winit & Kerr. Its English common name is 'Longan', derives from a Cantonese name, which means "Dragon's eye". Its vernacular names in different countries is not similar include: 'Lamyai' in Thailand, 'Lam Nhai' in Laos, 'Kyet Mouk' in Myanmar, 'Nhan' in Vietnam, and 'Lengkeng' in Indonesia and Malaysia. Plants in the same family which are also of economic value, include rambutan (*Nephelium lappaceum* L.), and lychee (*Litchi chinensis* Sonn.; *N. litchi* Camb.; *Scytalia chinensis* Gaertn.; *D. lichi* Lour.) (Morton, 1987; Montoso Gardens, 2007). Longan fruit is grown commercially in many countries including China, Thailand, Taiwan, India and Vietnam (Jiang *et al*., 2002). The longan tree is a part of sustainable agricultural system in many Asian countries, either as a backyard crop or in large cultivated plantations (Tongdee, 2001). China has the largest longan industry in term of cultivated area and production, with the crop having undergone a rapid expansion in parallel with lychee since 1980. In 2000, there were 465,600 ha in main land China producing 608,500 tons (Huang *et al*., 2005). Thailand is the major producer and exporter of longan in the world. Besides consumed as fresh fruit, it is also processed as dried and canned longan.

The total area under cultivation is 57,261 ha, with production of 186,800 tons in 2001 (Anupunt and Sukhvibul, 2005). In Taiwan, longan reached 12,258 ha and 110,925 tons of production in 2002 (Yen *et al*., 2005). Longan production is relatively new in Australia but has increased rapidly over the last 5 years. Production has now reached 1,500 tons (Drinnan, 2004).

In Vietnam, 'Long' longan flower blooms in February through March and the fruit matures between July and September in every year (Tran, 1999; Duong, 2003). The differences in the times of flowering and fruit maturity are due to differences in rainfall and the difference of environmental temperature between day and night. The flowers are small and yellow brown. The limited natural flowering period leads to a short production and marketing window. Growers in Vietnam have been using some chemical treatments by spraying to extend the fruiting season. Among them, chlorate and/or plant growth regulators are the most popular such as Fruitka Forlia (50% K_2O); potassium chlorate (99.6%) and potassium oxide; and etc. As there is a high domestic demand, longan can be a profitable crop for Vietnam as there seems to be no major climatic problems affecting growth and development in both the North and the South. Exports of fresh fruits, dried and canned longan fruits to the southern China and neighboring countries as Singapore and Hong Kong are becoming very significant. However, a high quality standard must be maintained for these export products (FAO, 2004).

2.2. Fruit Morphology

Longan fruit contains a relatively large black or brown seed at maturity. The fruits are conical, heart-shaped or spherical with a thin leathery and indehiscent pericarp. The pericarp can vary in color from yellowish to light brown and the skin is smooth. The edible portion of longan fruit is a freshly, translucent white aril. The aril is an extension of the funiculus or seed stalk that

arises from placenta and surrounds the seed. The pulp is similar in flavor to the lychee, although the texture is relatively firmer and less juicy, and there is a single fruit seed with a smooth taste (Jiang *et al*., 2002). 'Long' longan fruit is spherical shape to ovoid shape, growing in the panicle and the number of fruit can be up to 80 fruits per panicle. The fruit is big (average diameter of fruit is 2.9-3.0 centimeters and average weight is 11-12 grams per a fruit), bright brown color, small seed (average weight of a seed is 1.68±0.27 grams), and thick flesh (the percentage of flesh per fruit weight is 63.0±3.1%) (Tran,1999; Nguyen *et al*., 2001; Duong, 2003). The translucent flesh or aril is white to off-white surrounding a brown or black seed that separates easily from the flesh, which is sweet taste and juicy. It is middle in flavor and less acidic than lychee (FAO, 2004).

2.3. Harvest Maturity

Longan is a non-climacteric fruit and must be harvested when fully mature. The stage of maturity when fruits have become fully physiological mature (size, firmness, taste, flavor, color) (United Nations, 2007). The mature longan fruit has a dark, smooth skin, the inside of which is netted and has sweet taste. Normally, picking is done twice at an interval of 7 to 10 days (FAO, 2004). General guidelines for harvesting time are difficult to set because of the wide range of varieties grown. The mature longan fruit is small (1.5 – 2 cm diameter) and fruit will not continue to ripen once removed from the tree. Maturity can be determined by fruit weight, flesh sugar and acid concentrations (Jiang *et al*., 2002). According to the experiences of Vietnamese farmers, the best harvesting time is the color of pericarp changes to bright color, smoother and the seed of fruit changes to black color. Another way for most longan fruits in Vietnam, maturity can be determined by Brix degree when Brix degree reaches 17-21 (Duong, 2003). 'Long'

longan fruit must be harvested when its skin becomes yellow-brown and flesh reaches optimal eating quality (Tran, 1999).

2.4. Harvesting Method

Harvesting is an important step of the postharvest handling chain to maintain quality produce before reaching the final consumers. Harvesting methods depend on the habits and experience of local people (United Nations, 2007). In Vietnam, the harvesting time of 'Long' longan will be started between middle of July and middle of September. Fruits are harvested in the morning or in the afternoon, avoid high temperature like at noon and when it is raining. Bunches of fruit on the trees are cut by a scissors and place immediately in the shade after harvest (Tran, 1999). For sale, bunches are laid in the plastic baskets or sponge boxes with 5 or 10 or 20 kilograms of weight. At the bottom and on the top of baskets or sponges are lined with fresh longan leaves or soft papers.

2.5. Some Studies on Storage of 'Long' Longan Fruit in Vietnam

'Long' longan fruit shelf life is limited by a decrease in visual appearance, a reduction in organoleptic quality and the development of disease. Rapid moisture loss occurs from fruit during storage time. Under low humidity conditions, visual appearance decrease to unacceptable levels due to skin dehydration and pericarp browning.

In Vietnam, most fruits are marketed in bunches on the fruit stalk and are consumed within 2-3 days after picking, without any postharvest treatments. Longan is transported by the trucks for a short distance transport or the cold container transporters for a long distance

transport. To extend shelf life and maintain postharvest quality of Vietnamese longan fruit, many postharvest treatments were applied to the fruits as the followings:

Sulfur dioxide fumigation with dosage was 0.5-3.5 g/m³ and stored at room temperature for 5 days. The above treatments were not suitable for extending storage life of 'Long' longan because of high percentage of fruit decay (about 20%) (Nguyen *et al*., 2001).

Fruits dipping in 0.1% benlate solution and the fruits were dried in the shade, thereafter were packed in polyethylene bags (0.02 mm of thick) with 10-15 kg of weight per bag and put in carton boxes or bamboo baskets. Finally, stored in 3-5ºC; 90% relative humidity (RH) could be prolonged the 'Long' longan fruit shelf life for 10-15 days (Tran, 1999).

The another treatment was fruits dipping in chitosan solutions at various concentrations, then dried in the shade; packed in 250 x 350 mm LDPE bags, 0.01 mm of thick, holed 20% surface of a bag. The result did not show any positive effect for 'Long' longan fruit (Nguyen *et al*., 2001).

In case of fruits dipping in sodium metabisulfite solutions with the concentrations of 0.1-0.9%, and then dried in the shade, after that packed in LDPE bags (0.01 mm of thick) and stored at room temperature for 5 days. The above treatments were not suitable for extending storage life of 'Long' longan fruit because of high postharvest losses (more than 20%) (Nguyen *et al*., 2001).

Fruits were dipped in Carbendazim solution at a concentration of 0.2% for 3 minutes, dried in the shade, and then packed in 250 x 350 mm LDPE bags with 0.01 mm of thick. After that 'Long' longan fruits were stored at room temperature and at 10ºC. The results showed that longan fruit can be prolonged the shelf life with good quality for 6 days at room temperature and 20 days at 10ºC, the percentage of fruit decay was about 10% (Nguyen *et al*., 2001).

2.6. Some Popular Longan Cultivars in Vietnam

In company with 'Long' cultivar, there are several longan cultivars in Vietnam, among them the most popular cultivars are Cui, Duong Phen, Nuoc, Vinh Chau, Tieu (Duong, 2003). Among them, 'Long' cultivar has the highest economic value and nutrient values. The price of 'Long' longan was 90-110 Baht (50,000-60,000 VND) per kilogram in 2009 (The Electric Newspaper of Communist Party of Vietnam, 2009). Some popular longan cultivars in Vietnam are introduced as follows:

'Cui' longan fruit is spherical shape, the pericarp is yellowish-tan in color. The average weight is 7-11 grams per fruit, and the average peel thickness is 0.5 mm. The average rate between flesh and fruit is 58% (Tran, 1999).

'Duong Phen' longan fruit is dark brown in color, small seed, thick peel and brittle, thick flesh, high sugar rate, sweet taste. Fruits are circle in shape and average weight is 7-12 grams per fruit. The average rate between flesh and fruit is 60% (Tran, 1999).

'Nuoc' longan fruit is small (the average weight is 5.3-6.2 grams per fruit), thin flesh, flabby flesh, high moisture and the seed separates difficultly from the flesh. The average rate between flesh and fruit is 58% (Tran, 1999).

'Vinh Chau' longan fruit is big, green brown color, smooth peel, high water and the seed separates difficultly from flesh, and big seed. Although this cultivar has low values but it is very suitable with the land in southern Vietnam (Duong, 2003).

'Tieu' longan fruit is dark brown color, thick flesh, small seed, moderate sweet taste. The average weight is 10 grams per fruit, and the average rate between flesh and fruit is 60% (Tran, 1999).

2.7. Chemical Composition of 'Long' Longan Fruit

'Long' longan flesh is very sweet taste. The total sugars are approximately 20.5%, the main sugars present in longan fruit are sucrose, fructose and glucose. The total soluble solids content ranged between 17 and 21.15 %Brix, total acids are 0.07 and 0.09%, and moisture content ranged between 72.4 and 84.9% in 100 grams of flesh (Tran, 1999; Nguyen *et al*., 2001; Duong, 2003). During storage, total sugars, reducing sugar and total soluble solids contents of longan fruits increased, pulp cell permeability decreased and flavour improved (Pan *et al*., 1996).

2.8. Some Main Causes Affect Postharvest Quality of Longan Fruit

2.8.1. *Pericarp browning*

One of the most important problems in longan fruit marketing is a rapid pericarp browning within a few days after harvest. Browning can be associated with desiccation and/or heat stress, senescence, chilling injury and pest or pathogen attack (Jiang *et al*., 2002). Browning has been attributed to enzymatic oxidation of phenolics by polyphenol oxidase (Sodchit *et al*., 2008). Although this situation is only a visual symptom and has no effect on flavor but color deterioration causes the fruit to bring a low price in market and even becomes unmarketable because of consumers preference for visual appearance (Jiang *et al*., 2002). The effect of SO_2 treatment on the overall quality of longan fruit ('Shixia') during cold storage (4ºC) was investigated. The results indicated that the content of anthocyanin in longan pericarp decreased and the fruit color was improved after SO_2 treatment (Han *et al*., 2000). Fresh longan production of the world markets are in competition and mostly depend on the quality e.g. fruit pericarp color, size, shelf life and also the safety of the fruits. The use of N-acetyl-L-cysteine and 4-

hexylresorcinol, which are defined as GRAS (Generally Recognized As Safe) could be used to reduce pericarp browning (Sodchit *et al*., 2008). The yellow skin color remains even when fruit is stored at low temperatures and low humidity's because the fruit does not suffer from chilling injuring or discoloration from dehydration. Both of these factors add significantly to the shelf life and appearance of longan (Drinnan, 2004). Dipping longan fruit in sodium metabisulfite is effective against pericarp browning if followed by an acid dip (Jiang *et al*., 2002). Boonin *et al*. (2006) reported on effect of anti-browning substances on peel color and quality of longan fruit cv. Daw during storage. This report was studied by soaking the fruits in 7.5% sodium metabisulfite solution or 5% oxalic acid solution and the combination of both substances as soaking in sodium metabisulfite solution before oxalic acid solution, oxalic acid solution before sodium metabisulfite solution and the mixed solutions of sodium metabisulfite and oxalic acid. All fruits were dipped for 5 minutes at 25ºC and then were stored at 5ºC for 7 weeks. The results showed that the treatments of soaking in oxalic acid before sodium metabisulfite, and the mixed solution of sodium metabisulfite and oxalic acid could maintain L* and b* values and did not show browning or brown circle on the peel when compared to the other treatments. Moreover the quality of longan did not show any difference when compared with the control during storage.

2.8.2. *Respiration rate and ethylene production*

Being a tropical fruit longans have high rates of respiration so that if they are not stored carefully they can have a very short shelf life, deteriorating easily and quickly within a few days at room temperatures (Drinnan, 2004). Longan fruit is non-climacteric, harvested only when it is mature and has attained acceptable eating qualities. Rates of respiration range from 10 to 16 milliliters (ml) CO_2/kg.h and 2 to 6 ml CO_2/kg.h at 22ºC and 5ºC, respectively (Tongdee, 2001) .

For ‘Shixia’ longan fruit, respiration decreased on the first day after harvest and then increased (Pan *et al*., 1996). A later rapid increase in respiration was possibly associated with disease development. Fruit stored at 4ºC had a continuous decline in respiration, and low temperature thus effectively inhibits longan fruit inspiration (Jiang *et al*., 2002). Longan fruit produce relatively low level of ethylene after harvest (< 2.3µL/kg.h) in comparison with climacteric fruits. However, high ethylene production rates (28.3µL/kg.h) have been recorded in association with fungal infection (Shi, 1990). Moderate to high in ethylene production rates have been also recorded coincident with skin desiccation and after keeping at high temperatures of 26 - 32ºC (Pan *et al*., 1996). Ethylene evolution ranges from undetectable to trace, immediately after harvest (Tongdee, 2001). Shi (1990) has reported that the ethylene production rate of fruit stored at 1 or 4ºC remained relatively constant for 30 days after establishing on the first day. An increase in ethylene production rate after 30 days was associated with decay (Jiang *et al*., 2002).

2.8.3. Postharvest diseases

Postharvest disease affects fruit quality. The consumers will not purchase fruit which is obviously infected, while the presence of internal infections will spoil the eating experience and deter future consumption. Infected fruits must be discarded and the producers lose confidence in their ability to store the fruits (Sugar, 2002). Fruit deteriorates rapidly after harvest, mainly on account of fruit rotting caused by saprophytic fungal growth on the fruit surface and dehydration of the rind, the shelf- life of fruit at room temperature (30ºC) is only two or three days. The most important microorganisms are *Botryodiplodia* sp. growing saprophytically on the fruit surface, and yeasts, *Saccharomyces* sp. The latter gain entry through the stem end of insect-pierced fruit, causing aril disintegration, wherever there is free moisture, the yeast forms a milky slimy mass

oozing from the fruit surface. At low relative humidity condition deterioration by microorganisms is reduced but the fruit losses its freshness. The rind turns dry and brittle, although the aril may still be acceptable. The rot problem is reduced but not entirely eliminated by cold storage. Shelf-life can be extended for two days at 18ºC. At 12ºC, 20% of fruit rotted after one week and all fruits rotted after two weeks (Tongdee, 2001).

2.9. Sodium Metabisulfite ($Na_2S_2O_5$)

Sulfiting agents such as sulfur dioxide, sodium metabisulfite have been used in food (Tongdee, 1993). When mixed with water, sodium metabisulfite releases sulfur dioxide (SO_2). Sodium metabisulfite was used to wash mushroom to remove unwanted particulate matter, and to enhance mushroom whiteness (Apai, 2009). The sulfities display a wide range of useful effects in food, including inhibition of non-enzymatic browning, as an antioxidant, and as a reducing agent by inhibition of various enzymatic catalysed reactions (notable enzymatic browning involving oxidation of phenolic compounds present in food), and inhibition and control of microorganisms (Tongdee, 1993). According to the decision of number 46/2007/QD-BYT of the Vietnam Ministry of Health, the sodium metabisulfite is regarding as a substance in the "Codex inventory of all compounds as processing aids" (Vietnam Ministry of Health, 2007). The threshold for sulfite sensitivity varies among individuals and the type of food, ranging from about 3 mg to 120 mg SO_2 equivalent. A joint FAO/WHO Expert Committee on Food Additives applied a 100-fold safety factor, and estimated the acceptable daily intake (ADI) for humans at 0.7 mg/kg of body weight (Tongdee, 1993). Allowable SO_2 level for fresh grape in United States of America (USA) was 10 ppm, for fresh lychee in France was 30 ppm (temporary level considering to lower to 10 ppm) (Tongdee, 1993). Sodium metabisulfite is generally recognized

as safe (GRAS) approved by Food and Drug Administration (FDA) and used as food preservative (Apai, 2009). The SO_2 works by bleaching and disinfecting the skin, resulting in a uniform yellow color and protecting it from microbial decay. Allowable SO_2 level (ppm) in food in selected countries is shown in the **Table 2.1**.

Table 2.1 Allowable SO_2 levels in food in selected countries.

Country	Food	Allowable SO_2 levels (ppm)
Canada	Dried fruit and vegetable	2500
	Wines	350 (total)
	Tomato paste and products	500
	Fresh fruit	0
Hong Kong		350
Malaysia	Dried fruit	2000
	Fruit juice (conc.)	350
	Wines	450
	Fresh fruit	0
Singapore	Dried fruit and vegetables	2000-3000
	Fruit (other than fresh fruit)	350
	Wines	300
	Tomato pulp and products	350

	Fresh fruit (pulp)	0
Japan	Standards of usage for foods in general	30
Netherlands		100 (not exceeding 300 at the exporting countries)
France	Flesh lychee	30 (temporary considering to lower to 10)
USA	Fresh grape	10

(Source: Tongdee, 1993)

2.10. Effect of Low Temperature Storage on Postharvest Quality of Longan Fruit

Low temperature storage is the first line of defense against postharvest pathogens. Temperate fruits and subtropical fruits can usually be stored at low temperatures to retard the development of postharvest decay significantly (Sugar, 2002). In addition, the demand for extended duration of fruit storage results in sufficient time for postharvest infections to occur. It is a common goal of fruit handlers to bring down the internal temperature of the fruit as soon as possible after harvest. Steps include avoiding harvesting during the hottest hours of the day, keeping filled harvest containers in shade while awaiting transport and removing field heat as quickly as possible (Sugar, 2002). Hydrocooling is the most common precooling method used. Precooling removes field heat and provides effective temperature management during subsequent container shipment of fruit for export. SO_2 fumigation and precooling are two of the most critical control points in the handling steps (Tongdee, 2001; Sugar, 2002). Longan fruit can be stored at low temperature (1 - 5ºC) and high humidity (85 – 95%) for 30 – 40 days depending upon the cultivars (Jiang *et al*., 2002). Longan fruits cvs. Daw, Seechompoo and Baew Kiew

were stored at 1, 5 and 10ºC for 14 days. The analysis results showed that during storage at 1ºC, all longan cultivars showed chilling injury symptoms. The L* values of the outer and inner skins were decreased, whereas the pH values, the percentage of moisture loss and the skin electrolyte leakage were increased higher than the fruits those stored at 5 and 10ºC. At 5ºC temperature, the longan fruits also showed chilling injury symptoms but these were happened on the later stage of storage (Boonyakiat *et al*., 2002).