CHAPTER 2

LITERATURE REVIEWS

2.1 The longan fruit

Longan (*Dimocarpus longan* Lour.), classified in Sapindaceae family, is closely related to the lychee and rambutan (Paull and Chen, 1987). Longan tree is medium to large evergreen tree, 10 to 20 m tall, with a dense canopy, brittle wood and corky which splits and peels. Tree shape depends on the cultivars varying from erect to spreading. The inflorescences are large, 30 to 50 cm long, with multi-branching and leafless. These inflorescences are developed on the new growth produced during tropical mid-summer or autumn. The individual flower is small, inconspicuous with yellow-brown in color. There are 3 types of the flower including staminate, pistilate and hermaphrodite flowers (Srikum, 1970). Longan fruit is non-climacteric with a thin green-yellow pliable skin. The translucent fleshy aril is white to off-white, or pinkish, in color wrapping around a red brown, or brown-black, seed which can be easily separated from the flesh. The fruit is sufficiently sweet with high sugar content, where the flavor is milder with less acidic than lychee fruit (Fletcher, 1995).

The drupaceous fruits are spherical to ovoid, conical or heart-shaped growing in panicles of up to 40 fruits. The fruit size ranges between 1 to 3 cm in diameter and 5 to 20 g in weight. The pericarp varies in color from yellowish to light brown, and the skin is thin, leathery, and smooth to warty and indehiscent pericarp. The pericarp

remains green until the fruit reach maturity, when yellow pigment synthesis is initiated (Huang, 1995). The pericarp of mature longan fruit consists of three layers: the outermost epicarp with a discontinuous cuticle, a uniseriate epidermis and subepidermal sclerenchyma, the parenchymatous tissue as middle mesocarp, and the inner endocarp which made up of small, thin-walled, unsuberized epidermal cells (Qu *et al*., 2001). The aril is white to off-white, or pinkish, and translucent where it is flavorful and sweet with 15-21% total soluble solids. A longan fruit has a single seed which is globular and shiny with brown to dark-brown in color. The duration between flowering to mature fruit, ready to be harvested, is 140 to 190 days. The fruits are normally harvested and marketed in cluster when the skins become smooth and the fruit color changes to yellowish brown or light brown, depending on the cultivar (Kader, 2002).

2.2 Fruit growth and development

Longan fruit has a sigmoidal growth curve (Huang, 1995). Initially, the seed and the pericarp develop simultaneously followed by aril growth. The same growth pattern is seen in different cultivars (Li and Li, 1999).

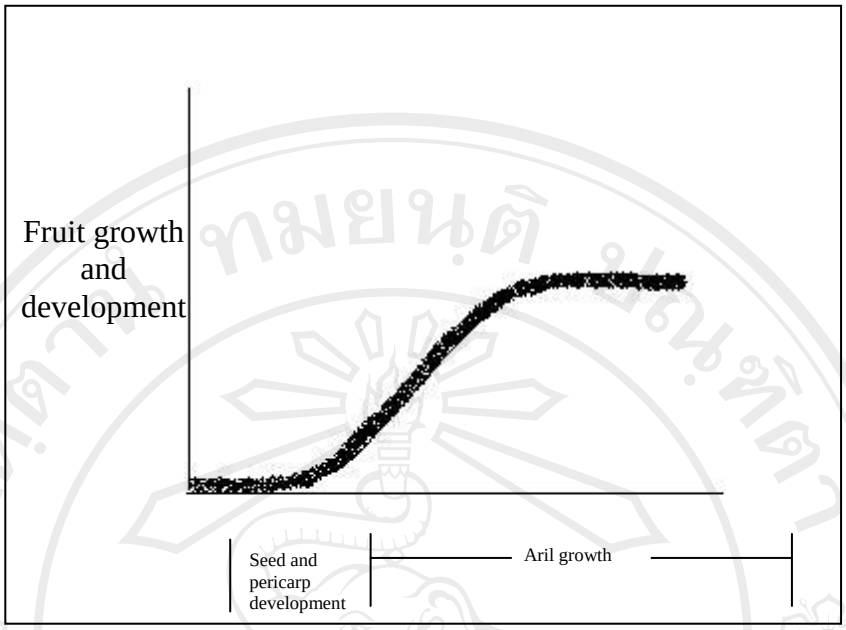

Figure 2.1 sigmoid curves of longan fruit growth and development (Li and Li, 1999)

2.3 Longan cultivars

Longan was originated in northeastern India, Burma and southern China. However, Thailand, China and Taiwan are now the main centers of commercial productions. In Thailand, main production is centered in the tropical monsoon areas of Chaing Mai, Lamphun and Phrae Provinces in the north, at the elevations between 300 and 600 m above sea level (Fletcher, 1995). There are over 5 cultivars for longan cultivated in Thailand. Longan cultivars can be divided by characterized shapes as follows.

1. Daw cultivar
2. Haew cultivar
3. Chompoo cultivar
4. Black leaf cultivar
5. Biew Kiew cultivar

However, according to commercial concept, longan cultivars which are preferable for cultivation in Thailand can be divided into 5 groups of cultivars as follows (Saranrom, 1989).

1. Kra Loke longan

Kra Loke cultivar longan is the most popular in Thailand because of its large fruit size with thick aril and sweet taste. The example cultivars, by Thai names, include Daw, Dang, Haew, Chompoo, Bai Dum and Biew Kiew

a. Daw cultivar

Daw cultivar longan is the most popular in northern Thailand because of its eary variety which promising higher selling price in early fruit season. This cultivar is normally harvested during June and July. The character of this cultivar is the leaf which is rather large, tapering at both leaf-ends, and curl at margin. The veins on 3-pair compound leaves are obviously prominent. This Daw cultivar longan is normally easy to flower and fruit without alternate bearing. The fruit of this cultivar is comparatively medium in size and rounded, slightly askew. The fruit skin is brown with deep brown spotting. The fleshy aril is thick and sweet wrapping a medium single seed.

b. Daeng cultivar

This cultivar includes of 2 types, thick peel Daeng and thin peel Daeng. Thick peel Daeng has large leave with curly blade, smooth margin and dark green in color often with 3-pair compound leaves. Thin peel Daeng's leaf is medium in size with long and smooth blade. The leaf-base end is more tapering than the leaf-tip end with mostly 4-pair compound leaves. The thin peel Daeng's fruit is smaller than the

fruit of thick peel Daeng. The peel appears thin as its name with rough skin. The fleshy arils of both types are white in color, while thick peel Daeng's fruit has more juice and stronger odor. Seeds of both types are also the same appearances.

c. Chompoo cultivar

This cultivar is also popular for cultivation in Thailand; however, it does not adapt well in arid condition and tolerate the drought during dry season. The branches on the tree are also fragile and easy to drop off. This cultivar's fruits are normally harvested during July and August. The leaf is medium in size with thick blade. Petiole is large and strong. The fruit of this cultivar is large and rounded and slightly askew. The fruit peel is smooth and thick with red-brown skin color. The fleshy aril is juicy and crispy with pink color wrapping around a single seed which is quite small in size.

d. Haew cultivar

This cultivar is easy to cultivate since it is more tolerated to arid condition. There are 2 types of the cultivar divided by the character of shoot apex, the red-shoot apex Haew cultivar and the green-shoot apex Haew cultivar. This longan cultivar is more difficult to bear flower and fruit. The fruit size is large, rounded and askew. It is normally concave at the bottom. The fruit skin is thick and rough with dark brown color. The fleshy aril is thick with off-white color and is very sweet and very crispy. Seed is rather small. With its thick peel, this cultivar's fruit can be stored for comparatively longer time making it preferable for canning.

e. Biew Kiew cultivar

In Thailand, the fruit of this cultivar reaches mature-phase later than other cultivars. The leaf is long, like a mango leaf, smooth and thin with dark green blade.

There are also 2 types of the cultivar, strong-inflorescence Biew Kiew cultivar and soft-inflorescence Biew Kiew cultivar. The fruit of strong-inflorescence Biew Kiew cultivar is normally larger than the one of the soft-inflorescence Biew Kiew cultivar. On the other hand, the soft-inflorescence Biew Kiew cultivar is more fruitful with larger fruit-cluster. Fruit of both cultivars is comparatively large, rounded and obviously askew. The peel is thick and tough while the skin is smooth with brown-green color. The fleshy aril is thick with off-white in color. It is very sweet and crispy with preferable odor while the seed is rather small.

f. Bai-dum cultivar

This cultivar has small, narrow and short leaf with smooth blade and green to black in color. The leaf-base end is more tapering than the leaf-tip end. The cultivar's fruit is large, rounded and slightly askew. The peel is thick and rough with brown color. The fleshy aril is tough and very sweet while the seed is small.

2. Kra-Dook longan

This longan group is indigenous. The fruit is normally smaller than Kra-Loke longan. The fleshy aril is thick aril and juicy with large seed. This grouop of longan is generally unprofitable to cultivate for commercial production. However, its seeds have been cultivated for the seedlings and young tree to be use for cross-over grafting of other cultivars with more preferable or profitable characteristics.

3. Pseudo-Kra Loke longan

This longan cultivar has a medium fruit size ranged between the fruit sizes of Kra Loke longan and Bai-Dum longan. The fleshy aril is juicy and crispy. The tree of this cultivar is fruitful with large fruit-cluster.

4. Sai Nam Peung longan

Most of the characteristics of this longan cultivar are the same as the Pseudo-Kra Loke longan except its aril is pale yellow in color. The fruit has a very preferable taste and the seed is comparatively small.

5. Other longan cultivars

There are some other indigenous longan cultivars locally grow in Thailand. An example is a climber longan cultivar which has the same characteristics as a climber or vine. Because of some of its leaves are modified to be part of its flower-base, this longan cultivar is more preferable for decorative purpose.

2.4 Postharvest disease of longan

In general, longan fruit is sufficiently sweet with high sugar content (Table 2) and it is very susceptible to postharvest pathogens of both bacteria and fungi (Table 1). In Thailand, fruit rot-disease has caused major problem of losses in longan production after being harvested. Tongdee (1997) had reported 3 causing factors of fruit rot-disease: microorganisms, temperature during storage, and wound and contusion during transportation and storage. Details of each causing factor are as follows.

1. Disease-causing microorganisms

Many kinds of microorganism are responsible for plant diseases. Among those, fungi have been reported as a wide cause of plant disease (Arios, 1969). Longan fruits are very susceptible to postharvest decay as a result of both bacterial and fungal infections. The most important disease-causing microorganisms include *Laiodiplodia* sp. and *Geotrichum candidum* (Sardsud *et al*., 1994a; Jiang, 1997; Tsai and Hsieh, 1998; Li abd Li, 1999). Many studies in Thailand on both pre-harvest and post-

harvest disease of longan, in Daw cultivar, had found many genera of fungi in the infected fruits, such as *Alternaria*, *Asp ergillus*, *Botrytis*, *Cephalosporium*, *Chaetomium*, *Cladosporium*, *Colletotrichum*, *Curvularia*, *Fusarium*, *Gloeosporium*, *Lasiodiplodia*, *Mucor*, *Nigrospora*, *Paecilomyces*, *Pestalotiopsis*, *Rhizoctonia*, and *Rhizopus* (Choomsan, 1987; Chaiwangsri, 1992; Nachaiwiang, 1994).

2. Storage temperature

The visual appeal of a longan fruit can deteriorate rapidly under ambient conditions within just 3 or 4 days following harvesting (Tongdee, 1997; Jiang and Li, 2001). Deterioration is associated with skin desiccation, color loss and disease development; however, it can be delayed by low temperature storage (Prapaipong and Rakariyatham, 1990; Kader and Arpaia, 1992; Jiang, 1999).

3. Wound and contusion during transportation and storage

Wound and contusion during transportation and storage can also be major cause of longan fruit decay (Tongdee, 1997).

Table 2.1 Major postharvest pathogens of longan fruit

Pathogens	**References**
Bacteria	
Enterobacter sp*, Acinetobacte* sp.	Lu *et al*. (1992)
Mold	
Botryodiplodia sp.	Jiang (1997)
G. candidum Link ex Pers.	Tsai and Hsieh (1998)
Penicillium sp., *Rhizopus* sp., *Alternaria* sp.	Lu *et al.* (1992)
Aspergillus sp., *Fusarium* spp., *Lasiodiplodia theobromae*	
Pestalotiopsis sp. *Cladosporium* spp.	Sardsud *et al.* (1994b)

Table 2.2 Longan Fruit Composition at Harvest.

Constituent	Approximate value
Aril (% dry weight)	16.5±0.7
Pericarp (% dry weight)	35.6±0.4
Soluble solids (%)	18.3±0.2
Total sugars (mg/g)	154.0±11.0
Sucrose (mg/g)	29.0±3.0
Glucose (mg/g)	17.0±1.0
Fructose (mg/g)	23.0±1.0
Titratable acidity (meq/ g)	2.1±0.1
PH	6.4±0.1
Citric acid (meq/ g)	0.12±0.01
Malic acid (meq/ g)	0.35±0.07
Succinic acid (meq/ g)	1.15±0.11
Ascorbic acid (meq/ g^{1})	1.40±0.2
Total phenols (mg/g)	0.5±0.1

Source: Paull and Chen (1987)

2.5 Fruit infection

Fruit decay from microorganism might have been infected from the flowers and/or young or immature-fruit, which no sign or symptom is normally appeared at the firstly infected time or even several days after that. On the other hand, the

infection during postharvest management can also be another major cause. The microorganism may get into the wound of cut surface resulting from contusion or wound of insect (Boonyakiat, 1988; Wara-Aswapati, 1989). The infection of microorganism on host has been very specific (Agrios, 1969; Hasan, 2000). Pathogens may have entered plants through wounds, natural opening such as stoma, lenticels and hydathodes. Some of them can even penetrate directly through plant surfaces. Some pathogens could also enter into the host plants through more than one channel (Agrios, 1969). For fungal infection on plant tissue, spores adhere to the surface, germinate produce structure and breach the cuticle or penetrate directly through wounds and activate pathogenic factors, in order to achieve decay development (Agrios, 1969; Prusky, 1997; Wills *et al*., 1998). Postharvest rot on fruit can be caused by either pre-harvest or post-harvest infections with microorganism. The infection symptom developed when fruit resistance decreased during senescence.

2.6 Changes in ultrastructure

The cuticle layer of the fruit pericarp is thin. Underlying tissues consist of the undeveloped cork layer, some stone cells and parenchyma cells with large intercellular spaces (Pan, 1994). Differences in storability among cultivars of langan fruits: ‘Shixia’, ‘Chuliang’ and ‘Tuzhong’, were found correlated with their pericarp structure. Enhanced storability was associated with a continuous thick cork layer, groups of stone cells in close arrangement, a well developed vasculature and a thick cuticle (Qu *et al*., 2001). At ambient temperature, there is a gradual breakdown of the cellular ultrastructure resulting in loss of compartmentalization of enzymes such as

PPO, and their substrates (Qu *et al*., 2001). The microstructure may also affect disease incidence due to the decreased resistance of the fruit to pathogens.

There have been many attempts to decrease the loss of postharvest longan fruit using different of methods. Developed techniques to control postharvest decay and to reduce browning, and also to extend the fruit storage life of longan include fungicide dips, waxes and chitosan coatings, application of plant growth substances, use of microbial antagonists, sulfur dioxide fumigation, irradiation and heat treatments. Of these, only sulfur dioxide fumigation and fungicide dipping have been used commercially (Jiang *et al*., 2002). Following information give more details for some of these techniques.

Sulfur dioxide (SO_2) treatment has been used to control saprophytic fruit-surface fungi and prevent peel-browning (Underhill *et al*., 1992; Han *et al*., 1999; Tongdee, 1994; Li *et al*., 1999; Pan *et al*., 1999). Browning has been attributed to oxidation of phenolics by polyphenol oxidase, producing brown-colored by-products (Mayer and Harel, 1979; Ferrar and Walker, 1996; Walker and Ferrar, 1998). Sulfur dioxide interacts with the membranes making the rind pliable and leaky to solutes. It also directly reacts with anthocyanins, rendering them colorless and stabilizing them against degradation (Timberlake and Bridle, 1975). Recommendations for the application of this method vary slightly; fumigation is achieved by burning sulfur powder at ambient temperature for 20 to 30 minutes with no humidity control (Cai, 1988; Han *et al*., 1999); vaporizing liquid sulfur dioxide held in a pressurized cylinder, or dissociation of sulfite compounds (Neamprem, 1992). Dipping the fruits in sodium metabisulfite is also effective against pericarp browning if followed by an acid dip (Xu *et al*., 1998; Zhang *et al*., 1999), however, sodium metabisulfite is

comparatively less effective and more variable than sulfur dioxide treatment. Fumigated fruit absorb about 30-50 % of the sulfur dioxide dosage applied. Fruit sulfur residues were maximal at 150-300 ppm immediately after fumigation (Ji *et al*., 1999) and they were found higher in the pericarp than in the aril. Additionally, these residues can decrease rapidly during the first few days after fumigation (Pan *et al*., 1999). Some pre-fumigation and post-fumigation treatments, including aeration and washing, had little effect on sulfur dioxide residues in longan fruit (Tongdee, 1992; Sardsud *et al*., 1994a). However, major limitation to use of sulfur dioxide is the health concerns associated with the sulfite residues remaining in the fruit-peel or aril (FDA, 1986). The FDA (1986) banned the use of sulfating agents on fresh fruit and vegetables, with grape being the only exception. Sulfating agents are defined as a salt or esters of sulfurous acid (SO_3), sulfur dioxide, sodium sulfite, and potassium and sodium metabisulfite. Internationally, various levels of sulfating agents are allowed on fresh fruit from 0 to 100 mg kg^{-1}. In recent years, there has been an increasing concern about sulfur residues in fruit, particularly as some people are sensitive to sulfites (Tongdee, 1994). European countries, Australia and Japan have set a maximum sulfite residues limit in fruit of 10 ppm. In the Unite States of America, sulfur is only registered for postharvest used on grape (Paull *et al*., 1995). In Thailand, Udomchote (1994) presented sulfite residue in longan fruit and its represents health risk for allergic people (Taylor, 1993).