CHAPTER 2
LITERATURE REVIEW

Longan fruit (*Dimocarpus longan* Lour.) is a non–climacteric fruit with little change in soluble solid concentration (SSC) or titratable acidity (TA) after harvest. Longan fruit have a very short postharvest lives that limit consumption and marketing (Jiang, 1997; Pan and Zhang, 1999; Siripanich *et al*., 1999; Lin *et al*., 2001). The major factors, reducing the storage life of longan fruit, are exocarp browning and fruit decay. Longan fruit are susceptible to microbial decay. Fruit decay in longan exocarp usually caused by fungal spore, mycelium, yeast and bacteria. Fungi are reported as a major causes of posthavest disease such as *Lasiodiplodia* sp., *Phomopsis* sp., *Pestalotiopsis* sp., *Cladosporium* sp., *Penicillium* sp., *Fusarium* sp., *Curvularia* sp., *Colletotrichum* sp., and *Rhizopus* sp., (Nachaiweing, 1994; Rasrinaul, 1996 and Rimpranam and Sangchoted, 2002). For prolong the shelf life, sulfur dioxide fumigation has been the most effective practical postharvest treatment for controlling of color change (Tongdee, 1994; Li *et al*., 1999 and Pan *et al*., 1999). In recent years, there has an increasing in concerning about sulfur dioxide residues in fruit particularly as some people are sensitive to sulfur (Tongdee, 1994).

Using of Control Atmosphere in Longan

Oxygen is required for a normal respiration and growth due to effects of electron transport on the cytochrome system, although other oxidative enzyme systems, present in cell may also be suppressed by the low oxygen condition. Carbon dioxide is essential for the growth of many aerobic microorganisms, since it is fixed in lactic, fumaric, citric and other acids of the Kreb's cycle. Controlled atmosphere has been reported to modulate the rate of exocarp color change in longan fruit. Longan fruit were stored in controlled atmospheres of 4% oxygen plus 5 or 15% carbon dioxide or 70% oxygen at 2^{o}C. The result indicated that controlled atmosphere prevented exocarp browning and decreased fruit decay in comparison

with modified atmosphere packaging (MAP with 15-19% oxygen plus 2–4 carbon dioxide). Higher carbon dioxide atmospheres (4% oxygen and 15% carbon dioxide) are more effectively reduced decay and extended storage life of longan fruit when compared with other controlled atmosphere treatment (Tian *et al.*,2002). Su *et al.* (2005) reported that longan fruit could store for 6 days in pure oxygen atmosphere at 28°C. The experiments were also conducted to examine the changes in concentrations of adenosine triphosphate (ATP), adenosine diphosphate (ADP) and adenosine monophosphate (AMP), energy change levels and activities of polyphenol oxidase (PPO) and peroxidase (POD) in relation to exocarp browning of longan fruit. The result revealed the lowering of exocarp browning and higher ATP concentrations, low AMP concentrations and high respiration rates, compared to those stored in the ambient atmosphere. Enhanced respiration of longan fruit exposed to pure oxygen resulted in the production of ATP. However, fruit exposed to pure oxygen exhibited higher activities of PPO and POD, which was not associated with reduced exocarp browning inhibition. These results supported the hypothesis that exocarp browning of postharvest longan fruit may be a consequence of membrane injury caused by the lack of maintenance energy.

Browning of longan has been attributed to oxidation of phenolic by polyphenoloxidase, producing brown-color by products. Jiang (1998) reported that polyphenol oxidase (PPO) was isolated from longan fruit exocarp. The optimal pH for PPO activity was 6.5 with 4-methylcatechol. The enzyme had a remarkably optimum temperature at 35°C and was relatively stable, requiring a little more than 20 min at 50 °C for 50% loss of activity. Reduced glutathione, L-cysteine, thiourea, $FeSO_4$ and $SnCl_2$ markedly inhibited PPO activity, whereas $MnSO_4$ and $CaCl_2$ enhanced PPO activity.

OXYGEN TREATMENT

Application of high oxygen atmospheres to inhibit browning has been applied to sliced apple fruit (Lu and Toivonen, 2000) and shredded lettuce (Heimdal *et al.,* 1995): Super atmospheric oxygen**:** Oxygen concentration greater than 21 kPa (induced through high oxygen atmospheres or hyperbaric atmospheres) may influence posthavest physiology and quality maintenance of fresh horticultural perishables either directly or indirectly via altered carbon dioxide and ethylene (C_2H_4) production rates. Kader and Ben-Yehoshua (2000) reported that exposure to super atmospheric oxygen concentration may stimulate, did not effect, or reduced rate of respiration and ethylene production, depending on the commodity, maturity and ripening stage, oxygen concentration, storage time, temperature and concentration of carbon dioxide and ethylene present in the atmosphere. In some plant organs, cyanide-resistant respiration is enhanced by elevated oxygen atmospheres. Ripening of mature-green, climacteric fruit were slightly enhanced by exposion to 30-80 kPa retarded their ripening and caused oxygen toxicity disorders on some fruit. High oxygen concentrations improved some of the effects of ethylene on fresh fruit and vegetable, including ripening, senescence, and ethylene-induced physiological disorders (such as bitterness of carrots and russet spourting on lettuce). Escalona *et al*. (2006) reported that controlled atmospheres of 20 or 75 kPa oxygen with 0 or 10 kPa carbon dioxide showed a constant respiration rate during the first 2-4 days at different temperature (1, 5 and 9^{o}C) and suggested that 80 kPa oxygen must be used in modified atmosphere packaging (MAP) to avoid fermentation of fresh-cut butter lettuce in combination with 10-20 kPa carbon dioxide for reducing their respiration rate. Wszelaki and Mitcham (2000) noted about strawberry in USA that the commercially-used for carbon dioxide level was 15 kPa in air. In addition, its combination with 40 kPa oxygen was the most effective in suppressing mycelia growth *in vitro* following 7 days at 5^{o}C under this atmospheres.

Kaewsuksaeng (2008) reported that high oxygen atmosphere (HOA) (70 %) reduced rate of respiration of Longan fruit, inhibited the rise in ethylene production,

reduced weight loss and prolong storage for 20 days. However, the accumulation of ethanol content in aril occurred in high oxygen atmosphere showed similar effect as low oxygen treatment on inhibiting ripening, flesh softening and solute leakage (Solomos *et al*., 1997; Lu and Toivonen, 2000). High oxygen atmosphere may also inhibit enzymatic discoloration, anaerobic fermentation, microbial growth and fruit decay (Day, 1996). Contrasting results were obtained in other studies of which included exocarp browning or browning (Solomos *et al*., 1997; Whitaker *et al*., 1998). Techavuthiporn *et al.* (2006) noted that high oxygen (50-70 %) reduced browning, weight loss and exocarp anthocyanin content but stimulated respiration rate in litchi fruit cv. Hong Huaw. Seubrach *et al*. (2006) found that modified atmosphere by polyvinyl (PVC) and in linear low density polyethylene (LLDPE) at 4 ^{o}C and 90-95 % RH significantly reduced the weight loss and extended the shelf-life of longan fruit to 20 days compared to the fruit stored in the ambient air (16 days). However, PVC film packaging affected to reduce browning and achieved better overall customers's acceptance during storage in shelf.

Lu and Toivonen (2000) reported that apple slices from fruit previously exposed to 1 kPa O_2 or 100 kPa O_2 had also reduced respiration rate, surface browning and flesh softening as compared with pretreatment air (21 kPa O_2).

Poubol *et al*. (2008) studied the effects of low oxygen levels (0.5, 1 and 2%) on physiology and quality of 'Nam Dok Mai' mango cubes stored at 1^{o}C (5 days), 5^{o}C (4 days) and 13 ^{o}C (2 days). Temperature of 1 and 5 ^{o}C were recommended for holding 'Nam Dok Mai' mango cubes without risking the development of chilling injury. Low oxygen atmospheres had a beneficial effect on attributes including development of browning, water soaking at all temperatures and respiration rates at 13^{o}C as well as extended the shelf life by 1 day at all temperatures. However, low oxygen atmospheres of less than 2% storage should be avoided when mango cubes were held at 13^{o}C.

CARBON DIOXIDE TREATMENT

The effect of high carbon dioxide on fruit ripening

High carbon dioxide concentrations at 20^{o}C delay or inhibit ripening and senescence in fruit and vegetables, but the mode of actions is still not clearly understood. Although most of the ripening-associated changes caused by high carbon dioxide involved inhibition of ethylene production and action, high carbon dioxide may regulate other independent processes (Rothan *et al*., 1997).

The effect of high carbon dioxide on fruit softening

Carbon dioxide treatments also prevented fruit softening and modified the activity and content of cell wall degrading enzymes (Del Cura *et al*., 1996). However, the levels and activities of polymer degrading enzymes in cell walls are not always consistent with the rate of fruit softening. Furthermore, fruit texture can be modified by the presence of many sclereids in mesocarp tissues of some fruit, such as cherimoyas which become highly lignified and hard (Schroeder, 1951). These cells contain substantial quantities of lignin, a hydrophobic polymer or p-hydroxycinnamyl, conferyl and sinapyl alcohols, some of which are bound to the polysaccharide of the cell wall. The density and extent of development of the sclerenchyma may be associated, to some extent, with the observed texture. Lignin and tannins are widespread phenolic compounds with several functions, including the strengthening of cell walls. Tannins are also responsible for astringency in many fruit, affecting palatability and the nutritional value (Singleton, 1981). Harker *et al*. (2000) reported that strawberry fruit were exposed to 5-40% carbon dioxide for 3 days, followed by normal cold storage at 0^{o}C for up to 3 weeks. Strawberry fruit were firmer in ambient atmosphere storage at 0 ^{o}C. Firmness was further enhanced by carbon dioxide treatment. Carbon dioxide-treated strawberry fruit were firmer than air-stored fruit and had lower susceptibility to decay, resulting in extension of postharvest life (Harris and Harvey,1973; El- Kazzaz *et al*.,1983). Siriphanich (1998) found that carbon dioxide treatment reduced the amount of water soluble

pectin and increased the amount of pectin extracted in a 1,2-cyclohexalenediaminetetraacetic acid (CDTA). Cherimoya fruit were kept at 20^{o}C in air and 20% carbon dioxide for 3 days after that they were transferred to the air. The high carbon dioxide treatment inhibited flesh softening and maintained lignin at level found in fresh harvested fruit. The fruit exposed to 20% carbon dioxide also improved internal color and increased the non-tannin polyphenol fractions, but it prevented the decline in the tannin fractions (Assis *et al*., 2001).

The effect of high carbon dioxide on fungal growth

High concentrations of carbon dioxide may directly suppress fungal growth by retarding various metabolite functions, so causing lowered respiration (Sommer,1985). Exposure to high carbon dioxide level have been shown to affect fruit respiration and fungal growth during the postharvest period (Wells and Uota, 1970; El-Goorani and Sommer 1979; Prusk *et al.*,1991). The exposure to high carbon dioxide concentration for short periods (pulsing) immediately after harvesting has extended storage life and frequently improving quality at outturn in a number of fruit (Meiburg *et al.*, 1998).

High carbon dioxide pressure treatments

Tiwong (2006) reported that high carbon dioxide pressure treatments; 2 kg-cm^{-2} for 1, 2 and 4 hours could prolong the shelf-life of strawberry fruit to 12 days at 10^{o}C while the control fruit had only 8 days of shelf-life. The results showed that all carbon dioxide treated fruit had higher firmness, total titratable acidity, pH and total sugar contents than the control (untreated). Nevertheless, the fruit treated with high carbon dioxide pressure 2 kg-cm^{-2} for 2 hours had the highest total soluble solids and the lowest weight loss.

High carbon dioxide atmosphere storage

A high carbon dioxide atmosphere during cold storage is useful for improving fruit shelf life. It may bring a two-fold effect which are reducing water loss and hence

desiccation-induced browning. Generally, it is known to increase stomatal resistance, to gas exchange including water vapor, and inhibiting phenolic metabolism particularly the activities of PPO (Rhodes *et al*., 1981) and POD which are the main enzymic processes involved in fruit browning. High carbon dioxide (9-12%) storage was also found to retard browning and extend rambutan shelf life for 4-5 days (O' Hare *et al.*, 1994). Additionally high carbon dioxide atmosphere (10-15%) reduced weight loss, respiration and ethylene production and delayed the increase in soluble solid contents of rambutan fruit cv. Rong-rein (Sopee *et al*., 2006). It was illustrated that high carbon dioxide could retain firmness of fruit such as strawberries (Kader, 1992). Smith (1992) also reported that high carbon dioxide as much as 40% could enhanced the firmness of strawberries. Siriphanich (2008) also noted that firmness of strawberries increased under high carbon dioxide (20%) treatment.

The Combination between Oxygen and Carbon dioxide

Jiang and Fu (1999) suggested that storage litchi at 1^{o}C under controlled atmosphere (3-5% oxygen and 3-5% carbon dioxide) with 90% RH gave good browning control and fruit quality maintenance. The reason was oxidation of both phenol and anthocyanins by PPO activity seem to affect the response of litchi fruit to water loss in terms of browning, and suggested that substrate-enzyme contact should be emphasized as this could promote enzymatic reaction leading to browning.

Storage of Fuji apple fruit in a high carbon dioxide (3 kPa) and low oxygen (1.5 kPa) controlled atmosphere reduced firmness and titratable acidity losses during long term storage (Argenta *et al*., 2002). The effectively of carbon dioxide-enriched atmosphere on decay control of *Botrytis cinerea*–grown in table grapes was evaluated during storage at 0^{o}C. High-carbon dioxide controlled atmosphere resulted in as good control of *Botrytis* sp. as using metabisulphite pads (Wszelaki and Mitcham, 2003). Controlled atmosphere including 12 – 15 kPa carbon dioxide are used commercially for both transportation storage of strawberries. Carbon

dioxide was effectively suppressed mycelia growth, spore germination, and germ tube elongation of *B. cinerea* and it was defined as fungistatic to most fungi.

Hess *et al.,* (1993) studied about the effect of brief exposure of mass avocado fruit dices to low oxygen and /or high carbon dioxide concentrations (0.25 %-O_2, 20%-O_2+ 80%-CO_2, 0.25%-O_2+ 80%-CO_2) on cytophasmic pH, ATP levels and activities of phosphofructokinase (PFK) and Pyrophosphate:fru-6-P phosphotransferase (PFP). The results showed that cytoplasmic pH values of avocado fruit dices kept in natural air, 0.25%-O_2, 20%-O_2+80%-CO_2 and 0.25%-O_2+80%-CO_2 were 6.9, 6.7, 6.3 and 6.3 respectively. The combination of 0.25%-O_2+80%-CO_2 treatment could reduce ATP level about 64% because of synergistic effect on inhibiting phosphorylation. However, a decrease in pH from 6.9 to 6.7 or to 6.3 caused a reduction in PFK activity about 9, 15 and 23 % respectively, whereas PFP became inactive between pH 6.9 and 6.3. Exposure of low oxygen or high carbon dioxide may change intracellular pH, which is important in the regulation of metabolism of fruit and vegetables. Previous works on lettuce (Siriphanich and kader, 1986) and pears (Nanos, 1994) indicated that exposure to low oxygen or high carbon dioxide concentrations generally reduced cytoplasmic and vascular pH and ATP levels.

PFK and PFP are important enzymes of glycolysis. In ‘Bartlett’ pears, exposure to 10 % carbon dioxide enriched air decreased PFK and PFP activities (Kerbel *et al.,* 1988). On the other hand, exposure to 0.25 % O_2, the activities of these two enzymes were increased (Nanos, 1994).

Hypobaric of low–pressure (LP) storage

Basically, modified or controlled atmosphere storage is designed to delay ripening and senescence processed in fruit and vegetables, and to extend their postharvest life. In this procedure, the commodity is maintained in a vacuum–tight and refrigerated container, hold at sub-atmospheric pressure and continuously ventilated with humidified air at relative humidity (RH) of 80 – 100% (Dilley *et al*., 1982; Burg, 1990). The reduction in the atmospheric pressure beneath 760 mmHg,

the oxygen level in the atmosphere is reduced. Under continuously ventilated partial pressure, carbon dioxide, ethylene and various volatile by–products of metabolism rapidly diffuse out of commodity and are flushed from the storage chamber. As a consequence of the low partial pressure of oxygen and the low levels of ethylene in the atmosphere, ripening and senescence of fresh fruit and vegetables are delayed and storage life are extended. Hypobaric pressure has direct fungistatic effects on fungal spore germination and mycelium growth of various storage fungi such as *Penicillium digitatum*, *Botrytis cinerea*, *Alternaria alternata* and *Geotrichum condidum* (Apelbaum and Barki–Golan,1977). Beneficial effects of hypobaric storage have been reported for various fruit: apple, mango (Spalding and Reeder, 1977) and papaya (Alvarez, 1980).