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Application of Postharvest Technologies for Fruit Crops in Taiwan

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Introduction

Varied climatic conditions exist in Taiwan, where fruits of tropical, subtropical and temperate origin are cultivated. From an estimated production area of 188,000 ha, about 2,256 Mt of fruits are produced annually. Particularly, the tropical fruit crops such as banana, pineapple, mango, guava, waxapple, lychee, carambola, papaya, Indian jujube and sugarapple, etc. are favored by Taiwan and foreign consumers due to high quality by improved cultivation technologies and breeding. In the twentieth century, most tropical fruits were grown in small landholdings for local consumption. Due to inadequate availability of basic infrastructure for handling, storage, and transportation, and lack of postharvest knowledge, about 9-21% of the products was lost between the orchard and the consumer (Liu and Ma, 1983). The foreign market for tropical fruit is increasing rapidly because of increasing tourism, strangeness of exotic fruit and the trend to healthy diet. Improved postharvest technologies such as optimum condition for handling, refrigeration for cooling fresh fruit, modified atmosphere packaging for prolonging storage life, airfreight, and packaging development, which have been developed in recent years, have had an important role in enabling these change to occur. The export of Taiwan tropical fruit becomes more important day by day. This situation prompted research on postharvest aspects of fruit crops, the results of which are summarized in this paper.

Current Status of Export

Major countries that import fruits from Taiwan are Japan, Hong Kong, United States of America, Singapore, Canada, and China. According to the amount of export value, Japan's share is 35% of the total, followed by Hong Kong (20%) and USA (10%). In considering the factors of geography and consumption potential, Japan is still the most important market for Taiwan. Taiwan's fruits, including banana, lychee, guava, pineapple, carambola, and mango, are exported to foreign countries (Table 1). For a long time, banana was a major and important fruit for exporting to Japan, but the volume was in a decreasing trend in recent years. From 2003, the exporting volume was lower than 50% share in total (Table 1). In 1999, about 1000T of pineapple was exported to Japan and maintained between 400 to 950T in the following years (Table 1). The exporting status of guava, carambola, mango, and lychee was in an increasing fasion in volume. In addition, the Japanese government granted the permits of import for papaya and pitaya into the Japanese market in 2004 and 2010, respectively. The fruits with tropical flavor, long production season and high nutritional value also have a potential for future export.

Postharvest Physiology

The research of postharvest physiology for tropical fruits fell behind those of temperate fruit. Until now, knowledge of biochemistry and physiology in tropical fruit has not yet fully enabled the management of postharvest handling for commercial benefit.

1.Respiratory Behavior

Based on fruit respiration and ethylene production patterns during maturation and ripening, fruits are either climacteric or nonclimacteric (Table 2). Climacteric fruits show a large increase in respiration and ethylene production which coincides with ripening, while nonclimacteric fruits show no change in respiration and ethylene production. The deterioration is different between climacteric and nonclimateric during postharvest. Removing ethylene from the atmosphere around the climacteric fruits before-climacteric-rise is the preferred method of preventing deterioration and senescence of ethylene-sensitive fruits. In particular, some guava cultivars are climacteric such as ‘Bai Bar’, ‘Jong-Shan-Yueh Bar’, ‘Li-Tzy Bar’, and ‘Dar- Dih Bar’, and some cultivars are nonclimacteric such as ‘Tai-Kuo Bar’, ‘Shyh- Jii Bar’, ‘Jen -Ju Bar’, and ‘De-Wang Bar’ in Taiwan (Lin, 1998). The ripening of climacteric guava is faster than nonclimacteric guava. Nonclimacteric guava is preferred for export, instead of climacteric guava, due to poor storage potential of the later. As with guava fruit, the respiratory behavior of carambola fruit is not clear.

Table 1. Expor volume of Taiwan fruit crops. (tons)

Year	Mango	Guava		Pineapple	Banana	Lychee, Longan			Carambola		
	Japan*	Canada	China	Japan	Japan	Canada	Japan	USA	USA	Canada	China
1999	35.8	98.2	—	1007.6	44915	963	933	1191			
2000	101.2	94.9	—	835.5	42619	661	576	1910			
2001	109.1	117.5	—	946.2	25644	765	286	1959			
2002	124.2	365.0	4.0	368.6	24744	694	186	2570	203	24	0.1
2003	84.8	797.8	27.9	847.5	33129	753	79	2643	406	207	84.2
2004	502.3	1589.1	23.8	1000.1	18140	531	161	2717	497	393	105.3
2005	481.1	976.9	176.3	848.3	15218	278	198	1615	358	396	173
2006	429.9	1173.8	87.2	432.7	16022	50.2	108.5	1186	509	305	246.1
2007	786.8	1682.9	45.8	459.5	19142	296.4	102.2	1435	371	399	111.0
2008	838.1	1302.3	53.5	665.5	9154	235.7	124.0	624	297	337	150.9
2009	993.1	1254.7	208.1	866.1	8863	499.7	130.9	708	223	213	206.1

Table 2. Fruit classification by respiratory behavior.

Climacteric	Non-climacteric
Avocado	Carambola **
Banana	Lychee
Cherimoya	Longan
Guava *	Pineapple
Mango	Waxapple
Papaya	Guava *
Indian jujube	
Passionfruit	

*"Li-Tzy Bar","Jong-Shan-Yueh Bar", "Bai Bar",and"Dar-Dih Bar"are climacteric, "Jen-Ju Bar", "Shyh-Jii Bar", "Tai-Kuo Bar", "Shui-Jing Bar",and "Di-Wang Bar"are nonclimacteric fruit respectively (Lin,1998).

**，"Ruen-chii"and "Er-lin"may be climacteric fruits (Shiesh,1986).

Shiesh (1987) and Mitchan and McDonald (1991) suggested that carambola fruit is climacteric based on rising respiration, but Oslund and Davenport (1981) indicated that the respiration rise was induced by infection from microorganisms. They suggested that carambola fruit is nonclimacteric. It is necessary to do further research on carambola respiration behavior.

2.Respiration and Ethylene Production

In general, the rate of deterioration of harvested fruits is proportional to their respiration rate. Some tropical fruits are classified according to their respiration rate in Table 3. The respiration rate is affected by cultivation condition, maturity and climacteric status, and is also cultivar specific.

As a plant hormone, ethylene regulates many aspects of growth, development, ripening and senescence. It also plays an important role in fruit abscission. Fruits are classified by respiration in Table 3 according to their ethylene production rate. There is no consistent relationship between the capacity of ethylene production and the perishability of a given fruit; however, the exposure to ethylene accelerates ripening or senescence in most fruits. Ethylene-sensitive fruits should not be mixed with ethylene-producing fruits during long-distance transport.

3.Chilling Injury

Controlling product temperature is the most important method of slowing quality loss in perishables and extending the shelf life of fruits. Exposure to undesirable temperatures results in many physiological disorders, such as chilling injury. Chilling injury occurs in some fruits (mainly those of tropical origin) held at temperatures above their freezing point and below 15℃, depending upon fruit kind. Chilling injury symptoms become more serious and noticeable upon transfer to higher temperatures. The most typical symptoms are surface and internal discoloration (browning), internal breakdown, pitting, scald, uneven ripening or failure to ripen, off-flavor, and surface decay (Table 4). Fruit maturity and cultivars may influence the susceptibility to chilling injury. Partial to complete control of chilling injury symptom development have been achieved by temperature conditioning, intermittent warming, heat treatment, polyethylene bagging, and waxing (Table 4).

Table 3. Tropical fruits classified according to the respiration and ethylene production rate at 20℃.

Group	Respiration rate		Ethylene production rate	
	Level (mg/kg/hr)	Fruit	Level (μl/kg/hr)	Fruit
Very low	＜35	Pineapple, Carambola	＜0.1	Waxapple
Low	35-70	Banana（green）, Lychee, Papaya, Passionfruit	0.1-1.0	Pineapple, Carambola
Moderate	70-150	Mango、Guava、Indian jujube	1.0-10.0	Banana, Mango, Guava
High	150-300	Avocado, Banana(yellow)	10-100	Avocado, Papaya,Indian jujube
Very high	＞300	Sugarapple	＞100	Passionfruit, Sugarapple

(Kader et al.,1985；Paull,1994；Postharvest project report 1993-1998)

Table 4. Optimal storage temperature, approximate storage life, and CI symptom for some fruit in Taiwan

Commodity	Storage temp. (℃)	Approximate storage life (day)	CI symptom
Avocado	6-9	14-28	Browning, decay, abnormal ripening
Carambola	1-5	21-28	Rib browning
Atemoya	13	7-14	Peel browning, hardening
Guava			
Nonclimacteric	1-5	28-35	Scald, vascular browning
Climacteric	10	14-21	Abnormal softening
Lytchee	4	21-28	Decay, browning
Mango(Hard mature)	8-12	14-21	Scald, abnormal ripening
Mango(Ripe)	1-4	28-35	Off-flavor, peel browning
Papaya	12	14-21	Scald, abnormal ripening
Pineapple	10	14-28	Internal browning
Banana	14	14-28	Peel browning, abnormal ripening
India jujube	5	10-24	Off-flavor, peel browning

Storage Potential

Normally, storage potential is given as the storage life of a fruit held at its optimum storage condition. The storage potential is dependent on variety, pre-harvest condition, culture practice, maturity at harvest and storage environment. The storage life or potential of tropical fruits is shown in Table 4. Most tropical fruits only have a 7 to 35 day life after being harvested. The storage life of fruits such as carambola, nonclimacteric guava, and ripe mango exceeds 24 days, and makes them suitable for long distance export.

Controlled Atmosphere Storage and Modified Atmosphere Packaging

In modified atmosphere or controlled atmosphere, gases are removed or added to create an atmospheric composition around the fruit. Usually this involves reduction of oxygen and elevation of carbon dioxide concentration. Two methods differ only in the degree of control. The beneficial effects of modified and controlled atmosphere include reduction respiration rate, inhibition of ethylene production and action, retardation of ripening and senescence, and maintenance of nutritional quality (Kader, 1994). The controlled atmosphere is not commonly used due to its high cost, and currently, there is no controlled atmosphere storage room in Taiwan. The modified atmosphere packaging is used commonly in contrast to controlled atmosphere (Lange, 2000). The oxygen and carbon dioxide concentration in packaging bag are adjusted by selection in the package materials (Beaudy, 2000; Watkins, 2000). In Taiwan, carambola, guava and waxapple are usually applied with modified atmosphere packaging during transportation (Table 5).

Heat Treatment

Pre-storage heating of fruits can prevent the postharvest deterioration of commodities. The benefits obtained by a long-term (12h to 4 days) heat treatment at 38 to 46^{o}C are superior to those obtained by short-term (up to 60 min) heat treatment at 45 to 60^{o}C. Heat treatment before storage protects against pathogens and reduces decay. For example, the anthracnose in mango can be controlled by dipping fruit into 55^{o}C hot water for 5 minutes (Shiesh, 1990). Heat also protects

Table 5. Controlled atmosphere conditions of tropical fruits.

Commodity	O_2（%）	CO_2（%）
Avocado	2-5	3-10
Banana	2-5	2-5
Mango	5-7	5-10
Papaya	2-5	5-8
Pineapple	2-5	5-10
Atemoya	5	5-10
Lychee	5	3-5

(Kader,1994)

against physiological disorder, especially chilling injury (Klein and Lurie, 1992) in fruits like avocado (Nishijima et al, 1995). Heat treatment can regulate postharvest fruit ripening while maintaining the fruit quality when shelved in ambient temperature. Finally, heat enhances the effectiveness of calcium treatment. Pre-storage heating of fruit shows promise as a nonchemical method of maintaining fruit quality.

Quarantine Disinfestations of Tropical Fruits

Most tropical fruits are hosts of fruit flies or other insect pests that are subject to specific prohibitions by quarantine authorities of import countries. The purpose of disinfestations treatment is to provide an assurance to the authorities of an importing country that the commodity will be free of pests. There are many methods for insect disinfestations, including heat treatment, cold treatment, irradiation, fumigation and controlled atmosphere (Paull, 1994). A proper quarantine treatment must meet the standard of Probit 9, causing no heat injury to the commodity, and is safe to human. Some quarantine disinfestation conditions are shown in Table 6.

Table 6. Quarantine disinfestations schedules of various fruit in Taiwan.

Fruit	Import	Method
Mango	Japan, Korea, USA, New Zealand	VHT (46.5℃, 30min)
Lychee	Japan	VHT (46.2℃, 20min) + CT (2.0℃, 42hr)
Lychee	USA	CT (1℃,15days or 1.39℃, 18 days)
Carambola	USA	CT (32, 33, 34, 35°F for 10, 11, 12 and 14 days, respectively)
Papaya	Japan	VHT (47.2℃)
Ponkan	Japan, Korea	CT (1℃, 14 days)
Pitaya	Japan, Korea	VHT (46.5℃, 30min)

VHT=vapor heat treatment ; CT=cold treatment (Bureau of Animal and Plant Health Inspection and Quarantine)

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