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Optimum postharvest handling-effect of temperature on quality and shelf life of tropical fruits and vegetables

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Abstract

The challenge of high tropical temperature and chilling sensitive horticulture required an optimum postharvest handling to minimize the worldwide concern on the postharvest losses of tropical fruits and vegetables. To ensure the harvested produces achieves the consumer acceptability, the effect of temperature on the perishable produces along the integrated series of postharvest chain operations including harvesting, processing, storage and transportation must be crucially maintained. Even though the cooling process during the postharvest handling helps to reduce deterioration from high tropical temperature, the refrigeration storage temperature may also result in detrimental chilling injury. Quality of the produces reduced because of the development of symptoms include internal and external discoloration, abnormal fruit ripening, accelerated senescence, skin pitting, wilting, increase susceptibility to decay and loss of flavour. Optimum storage temperature for specific fruits and vegetables, temperature conditioning, intermittent warming technique, controlled atmosphere storage, chemical treatments and application of growth regulator can be applied either to retard the damaging symptoms or to increase the tolerance of the commodities towards chilling injury in order to extend fresh produces shelf life.

1. INTRODUCTION

Fruits and vegetables were identified to play a significant role in providing dietary fibre, essential vitamins and minerals to the world populations. According to FAO (2004), the international consumption of tropical produce has increased by approximately 40 percent between 1995 and 2004. Over the years, the demand for tropical fruits and vegetables has increased tremendously because attributed by the rising consumer incomes and increasing in consumer awareness of the health benefits of eating diets that are heavy in fresh produces (Nzaku and Houston, 2009; Nolasco *et al*., 2017). However, as the demand of world fresh produces increases, problems associated with postharvest losses became as worldwide concern (Kiaya, 2014; Kitinoja and Kader, 2015). Among the five principles outlined during the World Summit on Food Security, reducing postharvest losses is one of the resolutions endorsed during the assembly (FAO, 2009). In addition, Kusumaningrum *et al.* (2015) pointed out that barriers for international trade in tropical produce were postharvest losses that resulted from quality deterioration and the yield declination. The main cause of postharvest losses was identified because of limited shelf life of tropical produce (Amin and Hossain, 2012; Arah *et al.,* 2015). As a consequence, these losses have several adverse impacts on the sales of tropical produce farm, consumer prices, national income and nutritional quality (Wu, 2010). In developing countries, postharvest losses reported mostly occur during transportation, handling, storage and processing (Azizah *et al.,* 2009). According to Liu (2014), there was about 25 percent of the fresh produce become non-edible because they rot in storage and transportation process, whereas, up to 30 percent above is due to decay losses in some postharvest perishable produces. High tropical temperature with humidity and abundant of chilling injury sensitive horticulture are some of the challenges during postharvest handling in maintaining the quality of fresh tropical produces (El-Ramady *et al.,* 2015). Therefore, temperature should be considered as a very important factor for optimum postharvest handling of tropical fruits and vegetables throughout the chain and to minimize losses. Thus, postharvest handling-effect of temperature on tropical fruits and vegetables quality and shelf life is reviewed.

2. POSTHARVEST HANDLING CHAIN

Postharvest handling systems are required to ensure that harvested fruits and vegetable achieves the consumer acceptability (Ahmad and Siddiqui, 2016). The postharvest handling chain integrates a series of operations including; harvesting, processing, storage, transportation and ripening.

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Fresh postharvest produce must be harvested at suitable stage of maturity. According to Mohammad Nasir (2006), non climacteric tropical fruits such as rambutans (*Nephelium lappaceum*) must be harvested during ripe stage, while climacteric mangoes (*Mangifera indica*) can be harvested at green-matured stage and can be either artificially or naturally ripened. The principles in dictating at which stage of maturity of fruit or vegetable should be harvested are crucial to its subsequent storage and marketable life and quality (Mishra and Gamage, 2007). Some of the typical maturity indexes criteria include; fruit ripening colour changes, shape and size during maturation, ripe fruit aroma, vegetable leaf changes, abscission and fruit firmness (FAO, 1989). Besides that, appropriate methods and harvesting tools such as secateurs and knives, depending on the type of fruit or vegetables must be taken under consideration in order to minimize mechanical injury during harvesting. Moreover, Barbosa-Canovas *et al.* (2003) in their report has mentioned that mechanical damages such as tissue wounds, squeezing, and breakage of fresh produces is caused by inappropriate methods and techniques used during harvesting which increase the susceptibility of the produce to microorganisms growth and decaying process. Practical harvesting containers should be considered by handlers to pick the fruit and vegetables in the field to provide protection for the fresh produce against rough handling and transport deterioration (Arah *et al.,* 2016).

Packing house serves as a venue for the preparation of the fresh produce prior transportation for wholesaling and retailing (El-Ramady *et al.,* 2015). In tropical country, for instance Malaysia, the common packing house operations for fruit and vegetables reported contain various sections and sub-sections such as sorting and trimming, washing and fungicide treatment, drying, grading, cooling and packing (Azizah *et al.,* 2009). The packages such as corrugated fibreboard cartons, wooden or plastic crates, plastic or bamboo basket, pallet boxes, and nets, should have sufficient mechanical strength to protect the fresh produce during handling, transport and stacking. A study by Azizah *et al.* (2009) reported that rough handling during preparation for the market will increase the bruising and mechanical damage, and limits the benefits of cooling. The cooling process is necessary in ensuring the freshness and extending the shelf life of tropical fruit and vegetables. The delay between harvesting and cooling processing will result in direct losses because of water loss and decay, and indirect losses because of reduction in nutritional quality and flavour (Kader, 2002). According to Barbosa-Canovas *et al.* (2003), there were several methods such as precooling, air precooling, icing, room cooling, forced air cooling, hydro cooling and vacuum cooling that can be applied in extending the shelf life of tropical postharvest fruits and vegetables.

Fruits and vegetables are highly perishable and can be stored only for limited days under normal tropical ambient condition. The complexity and variety impact factors such as temperature dependent respiration rate and different optimal storage temperatures affect the quality during postharvest storage (Lange and Cameron, 1994; Thompson, 2010). According to Snowdon (2010), the simplest type of storage involves shading from direct sunlight in order to prevent undue temperature rise or excessive moisture loss. In conventional chilling storage, air is cooled to desired air temperature by directing it over pipes through which refrigerants such as chlorofluorocarbon compounds are circulated. Limited time of storage is generally sufficient for delivery and distribution of produce that are marketed locally, exported by air or shipment by sea. During transportation, the principle of refrigeration with ventilation and modified atmospheres applied must be similar to storage in minimizing the postharvest losses (El-Ramady *et al.,* 2015).

The final operation in the postharvest handling chain is ripening. It can be carried out either by induction or by natural means (Mishra and Gamage, 2007). According to Mohammad Nasir (2006), induced ripening is normally carried out to overcome the uneven ripening of certain type of produce. Chemical such as calcium carbide is the most commonly used for chemical artificial ripening of fruit. Upon contact with moisture, calcium carbide will produce acetylene gas, which has almost similar effects as the natural ripening agent, ethylene. Acetylene mimics ethylene and accelerates the ripening process. Controlled ripening rooms and ethylene gas are applied to fresh produce for export.

3. EFFECT OF TEMPERATURE ON QUALITY AND SHELF LIFE OF TROPICAL FRUITS AND VEGETABLES

Temperature plays an important role in the determination of postharvest quality and shelf life of tropical fruit and vegetable. Different level of temperature subjected to different postharvest deterioration (Kader, 2013).

3.1. Effect of high temperature

High temperature and relative humidity are known to be significant factors for biological and chemical degradation of fruits and vegetables especially for tropical countries due to their geographical position. In addition, respiration is undoubtedly one of the contributing factors to the deterioration of fresh produce after harvest since fruit and vegetables continue to respire even after been detached from the plant. At high temperature, fresh produces will increase ethylene production which promotes respiration rates and the metabolic process (Liu, 2014). According to Silva (2008), every 10°C increment in temperature, the respiration rate will increase at least by two fold. The

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temperature will induce rapid utilization of stored carbohydrates and produce energy during respiration. Energy released upon postharvest respiration in fruit and vegetable will affect the sweetness, flavour, weight, turgor and loss of nutrition value of the fresh produce (Silva, 2008). A study by Proulx *et al.* (2005) pointed out that high postharvest storage temperature on papayas (*Carica papaya*) led to accelerated water loss and subsequent shrivelling and softening of the fruit. Moreover, Barbosa-Canovas *et al.* (2003) also reported that high temperature together with long exposure to tropical sun after harvest would lead to heat injury and severe loss of water from leafy vegetables.

High tropical temperature was identified to provide a conducive atmosphere for the growth and multiplication of tropical insects that contribute to postharvest deterioration (Teygeler, 2001). Some insects begin the infestation in the field and continue until postharvest storage (de Lima, 2011). The insects cause damage to the fruits and vegetables mainly by direct feeding (White and Elson-Harris, 1992). In poor storage management at stores and warehouses, the quality and shelf life of fruit and vegetables reduces due to damaging loss caused by insects. According to Santos *et al.* (1990), some insect species feed on the endosperm causing loss of weight and quality, while other species feed on the germ, resulting in poor seed germination and less viability which subjected to grains lose value for marketing.

3.2. Effect of low temperature

Low temperature storage is considered as an effective method in optimizing the quality of most fruit and vegetables and extending the postharvest shelf life. In preserving quality, low storage temperature is used to delay ripening and senescence process, reduce water loss, retards respiration, decrease metabolic rate and lessen decay incidence (Wang, 1994; Yahia, 2011). A study by Junmatong *et al.* (2012) shows that low temperature is useful to reduce ripening and maintain general perishability of mangoes (*Mangifera indica*) during postharvest handling, storage, and long distance transportation. According to Liu (2014), low temperature affects the maturing process of fruits by preventing the generation of ethylene that acts as plant hormone which promotes the respiration. In term of shelf life, a study by Paull *et al.* (1997) stated that papayas (*Carica papaya*) able to maintain shelf life up to 3 weeks at lower temperatures (10 to 12°C), compared to exposure under ambient tropical temperature (25 to 28°C) with shelf life of between 4 and 6 days.

During postharvest handling, cooling process is essential in ensuring the freshness of the fruit and vegetable as it has various beneficial effects in maintaining the quality (Morris and Brady, 2005). The cooling methods for fruit is recommended by using various methods such as precooled either by cold air, cold water, direct contact with ice, or by evaporation of water from the product under partial vacuum until the temperature is reduced to 3 to 6°C (Barbosa-Canovas *et al.,* 2003). In vegetables, it involves combination of cooled air and water in the form of a mist (Teruel *et al.,* 2004). Another method is icing method where the ice slurry containing 60 percent finely crushed ice, 40 percent water, and 0.1 percent sodium chloride to lower the melting point, is commonly added by placing a layer on the top of the fresh produce inside the containers (Barbosa-Canovas *et al.,* 2003). Those suggested cooling methods are very good in preserving the freshness of produce. However, the cooling process may lead to chilling injury for tropical fruits and vegetables as most tropical postharvest commodities are chill sensitive. The shelf life of chill sensitive crops increases at lower postharvest storage temperature down to a certain point which is known as critical chilling temperature. Further decrease in temperature will shorten the shelf life. The critical chilling temperatures usually occur between 10 and 13°C (Wang, 1994).

Chilling injury may occur in certain fresh produce at the range of 0 to 15°C and this phenomenon greatly dependent on the species and cultivars, types of tissues, stage at maturity and other environmental factors including storage humidity (Snowdon, 2010). At these temperature ranges, the tissues become weakened because they are unable to carry on normal metabolic processes (Wang, 1989). The severity of damage is determined by the temperature at which the fresh produce is held and by the duration of exposure (Wang, 1990; Watkins, 2003; Snowdon, 2010). The postharvest produces would start to show alterations such as internal or external discoloration, skin piking, abnormal fruit ripening, accelerated senescence, wilting, loss of flavour and increase susceptibility to decay (Barbosa-Canovas *et al.,* 2003; Wang, 2009). The most common form of chilling injury and symptoms in many of tropical horticultural commodities includes failure to ripe which is common in bananas (*Musa spp.*), papayas (*Carica papaya*), sapodillas (*Manilkara zapota*) and tomatoes (*Solanum lycopersicum*), and pitting, circular or irregular-shaped pits on fruit surface in cucumbers (*Cucumis sativus*), aubergines (*Solanum melongena*), melons (*Cucumis melo*), okra (*Abelmoschus esculentus*) and sweetpotatoes (*Ipomoea batatas*) (Wang, 1990). The symptoms often appear only after the commodity is returned to warmer temperatures, as when marketed. The minimal safe temperature for selected tropical fruit and vegetables together with other symptoms of chilling injury is presented in Table 1.

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Table 1: The minimal safe temperature for selected tropical fruits and vegetables and the chilling injury symptoms for storing at low temperature from published literatures (Kitinoja and Kader, 1995; Hardenburg *et al.,* 1986).

Tropical Commodities	Minimal Safe Temperature (°C)	Chilling Injury Symptoms (Between 0°C to Safe Temperature)
Aubergines *(Solanum melongena)*	7	Surface scald Alternaria rot Blackening of seeds
Bananas *(Musa spp.)*	nv (11.5-13)[b]	Dull colour upon ripened
Cucumbers *(Cucumis sativus)*	7	Pitting Water-soaked spots Decay
Guavas *(Psidium guajava)*	nv (4.5)[b]	Pulp injury Decay
Lemons *(Citrus limon)*	nv (11-13)[b]	Pitting Membranous staining Red blotch
Limes *(Citrus aurantiifolia)*	7-9	Pitting Turning tan with time
Mangoes *(Mangifera indica)*	nv (10-13)[b]	Grayish scald-like discoloration of skin Uneven ripening
Okra *(Abelmoschus esculentus)*	7	Discoloration Water-soaked areas Pitting Decay
Papayas *(Carica papaya)*	7	Pitting Failure to ripen Off flavour Decay
Peppers *(Piper nigrum)*	7	Sheet pitting Alternaria rot on pods and calyxes Darkening of seed
Pineapples *(Ananas comosus)*	nv (7-10)[b]	Dull green upon ripened
Sweet potatoes *(Ipomoea batatas)*	13	Decay Pitting Internal discoloration
Tomatoes *(Solanum lycopersicum)*		
mature-green	13	Poor colour upon ripe Alternaria rot
ripe	nv (7-10)[b]	Watersoaking and softening Decay
Watermelons *(Citrullus lanatus)*	4.5	Pitting Objectionable flavour

*The value in brackets is those given by second reference if they differ from the first reference
**nv Indicates no value given and single value indicates agreement in the recommendations
***[b] Indicate the value of Hardenburg *et al.* (1986)

4. MINIMIZING POSTHARVEST LOSSES FROM THE EFFECT OF TEMPERATURE ON TROPICAL FRUITS AND VEGETABLES

In minimizing postharvest losses associated with the effect of temperature on tropical perishable produces, the identified approach are; several postharvest technique in reducing chilling injury and management of optimum storage temperature.

4.1. Postharvest technique in reducing chilling injury

The right chilling temperatures were identified to prevent or minimize chilling injury on postharvest produces (Wang, 1989; Karel and Lund, 2003). Chilling injury can be defined as the visual manifestation of cellular dysfunction in crops exposed to chilling temperatures (Watkins, 2003). In order to minimize chilling injury of chill sensitive tropical produces, Hatton (1990) and Paull (1990) has recommended on multiple temperature conditioning by exposing the postharvest commodities to temperature slightly above the critical chilling range. Low temperature conditioning has been recognized to be effective in treating tropical produce such as aubergines (*Solanum melongena*), cucumbers (*Cucumis sativus*), limes (*Citrus aurantiifolia*), lemons (*Citrus limon*), papayas (*Carica papaya*), mangoes (*Mangifera indica*) and tomatoes (*Solanum lycopersicum*). It has been associated with the increasing degree of unsaturation in membrane fatty acids, maintaining high level of phospholipids in membrane and suppressing the increase in the sterol that contribute to reduce chilling injury (Zheng *et al.,* 2011). Another technique is by interruption of low temperature storage with one or more period of warm temperature, also known as intermittent warming. The warm temperature treatment during intermittent warming process is able to increase the storage life of some chilling-sensitive fruits and vegetables (Biswas, 2012; Kluge *et al.,* 2003).

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Warming of chilled tissues for short periods helps to repair damage to membranes, organelles or metabolic pathways (Patel *et al.,* 2016). According to Cohen *et al.* (1990) and Wang (1994), the treatment must be applied before chilling injury become irreversible and has been used successfully in commercial operation of lemons (*Citrus limon*).

Table 2: The storage period of some selected tropical fruits and their recommendation for optimum storage temperature and relative humidity from published literatures (Snowdon, 2010; Mohammad Nasir, 2006; Paull, 1999).

Tropical Fruit	Temperature (°C)	Relative Humidity (%)	Storage Period (days)
Babacos *(Vasconcellea heilbornii)*			
green	10	90	150-180
turning	7	90	120
Bananas *(Musa spp.)*			
green	13 (13-14)[c]	85-90	10-20 (7-28)[c]
coloured	13-16	85 - 90	5-10
Breadfruit *(Artocarpus altilis)*	13	95	7-21
Cape Gooseberries *(Physalis peruviana)*	14	80	nv
Carambolas *(Averrhoa carambola)*	5-10 (9-10)[c]	90 (85-90)[c]	21-28
B 10	nv (5)[b]	nv (85-90)[b]	nv (35-63)[b]
B 17	nv (5)[b]	nv (85-90)[b]	nv (42)[b]
Cherimoyas *(Annona cherimola)*	8-9	90	7-14
Cherries *(Prunus spp.)*			
sour	0-1	90-95	7-14
sweet	-1-0	90-95	14-21
Coconut *(Cocos nucifera)*	0-1.5	90-95	30-60
Custard apples *(Annona reticulate)*	5-7	85-90	28-42
Dates *(Phoenix dactylifera)*			
fresh	0	85-90	30-60
dried	≤ 0	70-75	365
Durians *(Durio zibethinus)*	4-6	85-90	30-60 (42-56)[c]
Granadillas *(Passiflora ligularis)*	7-10	85-90	21-35
Guavas *(Psidium guajava)*	5-10	90	14-21 (21-28)[b]
Horned melons *(Cucumis metuliferus)*	10	90	nv
Jackfruits *(Artocarpus heterophyllus)*	13	95	7-21
Lemons *(Citrus limon)*			
green	10-14	90	60-150
yellow	11	90	90-180
Limes *(Citrus aurantiifolia)*	9-10	90	30-60 (42-56)[c]
Litchis *(Litchi chinensis)*	5-10	90-95	120-180
Longans *(Dimocarpus longan)*	4	90	nv
Mangoes *(Mangifera indica)*	12-14	90	14 (14-21)[c]
Mangosteens *(Garcinia mangostana)*	10	90	21-28
Melons *(Cucumis melo)*	4-5	90	7-21
Naranjillas *(Solanum quitoense)*	7-10	90	28-42
Nectarines *(Prunus persica var nucipersica)*	-1-0	90-95	14-49
Oranges *(Citrus sinensis)*	2	90	90
Papayas *(Carica papaya)*			
green	10	90	21-28 (14-21)[b]
turning	7	90	14-21 (7-21)[c]
Passion fruits *(Passiflora edulis)*	7-10	85-90	21-35
Peaches *(Prunus persica)*	-1-0 (-0.5)[c]	90-95	14-42 (14-28)[c]
Pineapples *(Ananas comosus)*			
mature green	10-13	90	21-28
turning	7-10	90	21-28
ripe	7	90	14-28
Prickly pears *(Opuntia spp.)*	8-10	90	14
Pummelos *(Citrus maxima)*	10-15 (7-9)[b]	90 (85-90)[b]	nv (84)[b]
Rambutans *(Nephelium lappaceum)*	10-12	95	7-14
Sapodillas *(Manilkara zapota)*			
turning	20	90	14-21
ripe	0	90	14
Watermelons *(Citrullus lanatus)*	10-15	90	14-21

*The value in brackets is those given by the second and/or third reference if they differ from the first reference
**nv Indicates no value given and single value indicates agreement in the recommendations
***[b] Indicate the values of Mohammad Nasir (2006)
****[c] Indicate the values of Paull (1999)

Besides that, depending on the commodity, various strategies for reducing the likelihood of injury at chilling temperatures can be done such as; minimization of moisture loss by using semi permeable packaging, use of certain postharvest fungicide treatments, controlled atmosphere storage, chemical treatments and application of growth regulator (Wang, 1990, 1994; Snowdon, 2010). Semi permeable packaging of fruits and vegetables helps to maintain high relative humidity and modify the concentrations of oxygen and carbon dioxide in the surrounding atmosphere (Siracusa, 2012). The proper semi permeable packaging has been shown to delay chilling injury in bananas (*Musa spp*), apricots (*Prunus mume*) and lemons (*Citrus limon*). For controlled atmosphere storage, most commodities are responding favourably to a decrease in oxygen level and increase in carbon dioxide concentration (Kader *et al.,* 1989). The effectiveness is varies with commodities. But, this process is beneficial to prevent chilling injury in pineapple (*Ananas comosus*) and okra (*Abelmoschus esculentus*). However, in tomatoes (*Solanum lycopersicum*), papayas (*Carica papaya*) and lemon (*Citrus limon*), these produces are less susceptible to chilling injury (Wang, 1994). Calcium is one of the chemical treatments used apparently to strengthen the cell walls and cell membranes in order to withstand the chilling stress in okra (*Abelmoschus esculentus*), papaya (*Carica papaya*), peach (*Prunus persica*) and tomatoes (*Solanum lycopersicum*) (Madani *et al.,* 2016; Sohail *et al.,* 2015). Growth regulator, such as abscisic acid (ABA) is used to alter the chilling tolerance of tissues by inducing stomatal closure, reduce water loss, and prevent chilling-induced wilting of seedlings (Tijero *et al.,* 2016). ABA has been proven to reduce chilling injury in zucchini (*Cucurbita pepo* var cylindrical) and pineapple (*Ananas comosus*) (Wang, 1991, Zhang *et al.,* 2015).

Table 3: The storage period of some selected tropical vegetables and the recommendations for optimum storage temperature and relative humidity from published literatures (Snowdon, 2010; Paull, 1999; Hardenburg *et al.,* 1986).

Tropical Vegetable	**Temperature (°C)**	**Relative Humidity (%)**	**Storage Period (days)**
Amaranth *(Amaranthus spp.)*	0-2	95-100	10-14
Aubergines *(Solanum melongena)*	8-12	90-95	7-14
Bell peppers *(Capsicum annuum)*	nv (7-13)[b]	nv (90-95)[b]	nv (14-21)[b]
Cabbages *(Brassica oleracea var capitata)*			
green	0-1	95-100	90
white	0-1	95-100	180-210
Cassava *(Manihot esculenta)*	0-2 (0-5)[b]	85-90	150-180
Capsicums *(Capsicum annuum)*	7-10	90-95	7-21
Chinese cabbages *(Brassica rapa subsp pekinensis)*	0-1	95-100	30-60 (60- 90)[b]
Chillies *(Capsicum spp.)*	7-10	90-95	7-21
Cucumbers *(Cucumis sativus)*	8-11 (10-13)[c]	90-95	7-14
Endive *(Cichorium endivia)*	0-1	95-100	14-21
Lettuce *(Lactuca sativa)*	0-1	95-100	7-28 (14-21)[c]
Okra *(Abelmoschus esculentus)*	7-10	95-100	7-14
Peppers *(Piper nigrum)*	7-10	90-95	7-21
Radishes *(Raphanus raphanistrum subsp sativus)*	0-1	95-100	7-28
Sweet corn *(Zea mays)*	0-1	95-100 (90-95)[b]	4-8
Sweetpotatoes *(Ipomoea batatas)*	13-16	85-90	120-210
Tomatoes *(Solanum lycopersicum)*			
mature green	12-15 (18-22)[c]	90	7-14 (7-21)[c]
turning	10-12	90	7-14
ripe	8-10	90	7
Zucchini *(Cucurbita pepo var cylindrical)*	8 - 10	90 - 95	7 - 14

*The value in brackets are those given by the second and/or third reference if they differ from the first reference
**nv indicates no value given and single value indicates agreement in the recommendations
***[b] Indicate the values of Paull (1999)
****[c] Indicate the values of Hardenburg *et al.* (1986)

4.2. Optimum storage temperature for tropical fruits and vegetables

Low temperature postharvest storage is often more detrimental than beneficial for tropical chill sensitive produces (Saltveit, 2002; Znidarcic *et al.,* 2010). The fresh produces do not always benefited from cooling process. However, if the produces are not refrigerated, they tend to deteriorate and have a limited storage life because of high temperature effect (Wang, 1989). Therefore, ascertain the critical temperature and keeping fruits and vegetables within their optimum ranges of temperature is the most important factor in maintaining their quality and minimizing postharvest losses (Kader, 2002). Various studies have been done in obtaining the optimum temperature for postharvest storage of tropical fruits and vegetables to maintain the quality of the produces and extend the shelf life (Hardenburg *et al.,* 1986; Paull, 1999;

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Mohammad Nasir, 2006; Snowdon, 2010). The optimum storage temperature, relative humidity and potential duration of storage on selected tropical fruits and vegetables are respectively presented in Table 2 and Table 3.

5. CONCLUSION

Postharvest precooling process is necessary in reducing the detrimental effect of high tropical temperature on the fruits and vegetables. However, most of the tropical horticulture is categorized as chill sensitive commodities. In order to maintain the quality and extend the shelf life of the produces, several approaches can be taken to minimize the problems. Postharvest storage at optimum temperature, temperature conditioning, intermittent warming technique, controlled atmosphere storage, chemical treatments and application of growth regulator can reduce the chilling injury either by increasing the tolerance of commodities to chilling or by retarding the development of injury symptoms. Besides the effect of temperature, other factors such as tropical humidity, level of oxygen and carbon dioxide need to be taken under consideration in limiting the postharvest losses. Species and cultivar selection, breeding benefits and avoiding rough handling by trained handlers along the entire postharvest chain also may contribute to the fresh-like quality and extended shelf life of the tropical fruits and vegetables.

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