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Post-Harvest Handling Technologies of Tropical Fruits: A Review

Rossi Indiarto[1], Afifah Nurul Izzati[2], Mohamad Djali[3]
Department of Food Industrial Technology, Faculty of Agro-Industrial Technology, Universitas Padjadjaran,
Jl. Raya Bandung-Sumedang Km. 21, Jatinangor, Sumedang 40600, Indonesia.
[1]rossi.indiarto@unpad.ac.id; [2]afifah16003@mail.unpad.ac.id; [3]djali@unpad.ac.id

ABSTRACT

Tropical fruits are very susceptible to post-harvest damage, so appropriate handling methods are needed to maintain quality, extend shelf life, and minimize losses. This review aims to discuss post-harvest handling methods in various tropical fruits. The handling method consists of physical processes, which include manual cleaning, heat treatment, use of modified atmospheric packaging (MAP), UV-C treatment, and radiofrequency heating. Meanwhile, chemical methods can use 1-MCP, salicylic acid, methyl jasmonate, induction of γ-aminobutyric acid, or a combination of these methods. Technological developments show that the latest techniques such as ultrasonication, ozonation, and analysis of aspects of loss during the process using the e-nose method and the Taguchi approach can also be used to improve the quality of post-harvest tropical fruits.

Key words: Climacteric, post-harvest, shelf life, technology, tropical fruits

1. INTRODUCTION

Tropical fruits, like in Indonesia, are horticultural products from tropical climates with an average temperature of ±27 °C [1]. The fruit consists of various botanical families, including Anacardiaceae (mango, plum), Annonaceae (custard & sugar apple, soursop), Bromeliaceae (pineapple), Sapindaceae (rambutan, leaf, lychee, longan) and Passifloraceae (passion fruit). Tropical fruit is consumed in fresh form but can be consumed as processed products, such as canned fruit or juice, as technology develops [2]–[4]. Tropical fruits are more sensitive to a variety of damage than those growing in temperate climes. It causes a faster damage rate, even under optimum storage conditions [5]. The damage is caused by physical, mechanical, biological, chemical, and microbiological factors [6]. It results in a very short shelf-life of tropical fruit. Fruit damage factors initiate from the process of fruit maturation, the level of fruit maturity when harvesting, post-harvest handling, fruit storage and nutrition, cultivar species, and the place of growth [7]. The complexity of the cause of the damage is handled using specific methods for extending its shelf life. Several unexpected losses result from inappropriate post-harvest handling. Losses in horticultural products can reach 49-80%; in tomatoes, for example, losses of up to 50% can range from harvesting to consumption in the distribution chain, especially in tropical countries [8]. It is necessary to minimize these losses that proper post-harvest handling is essential. This study aims to review post-harvest handling methods on tropical fruits, so that it can be used as a reference to minimize damage generated from pre- to post-harvest and ready for consumption.

2. TROPICAL FRUIT HANDLING POST-HARVEST

Post-harvest fruits are a crucial step in determining commodity quality. The selection of handling methods must be adjusted to the characteristics of horticultural products, tools, materials, and techniques according to the goals to be achieved [9]. One of the parameters which determine the post-harvest characteristics of horticultural products is fruit maturity [10]. The ripening level can be physiological and horticultural distinguished. Physiologically, it is assessed from the consumer's acceptance of the fruit's characteristics, while horticultural in terms of respiration activity and ethylene gas production [11].

Physiological maturity can be obtained by determining parameters such as color, structure, shape, and development time [10], [12]. Meanwhile, the maturity level based on respiring activity and ethylene gas production can be divided into climacteric and non-climacteric [13]. The maturity level is influenced by the fruit respiration rate, production of ethylene gas, and internal ethylene concentration (IEC) [14]. Some tropical fruits can produce high IEC for rapid maturities such as durian, mangosteen, and papaya [3].

Climacteric fruits are a group of fruits that mature in line with an increase in the production and respiration rate of ethylene gas. In contrast, non-climacteric fruits do not experience an increase in the respiration rate at maturity [15]. However, Paul et al. [16] research show the possibility of deviations from climacteric and non-climacteric groupings like guava, melon, Japanese plum, Asian pear, and paprika. These fruits can also have climacteric and non- climacteric characteristics. It is influenced by the cultivar or genotype and occurring water loss process. The following examples include several tropical fruits, shown in Table 1.

Table 1: Examples of tropical climacteric and non-climacteric fruits

Climacteric fruits	Non-climacteric fruits
Avocado, apple, apricot, cantaloupe, blueberry, broccoli, stone melon, cherimoya, durian, feijoa, guava, kiwi, mango, mangosteen, passion fruit, jackfruit, nectarines, papaya, persimmons, pear, banana, plantain, plum, quince, sapodilla, sapota, santol, soursop, sugar-apple, breadfruit, tin, tomato	Grape, berry, carambola, citrus, cashew apple, jujube, peas, cocoa, date palm, pumpkin, lychee, longan, longkong, loquat, melon, dragon-fruit, pineapple, okra, paprika, pomegranate, pomelo, prickly pear, rambutan, bark, watermelon, snap bean, summer squash, tangerine, eggplant, dutch eggplant, cucumber, olive

[3], [15], [16]

2.1 Traditional post-harvest handling

Post-harvest handling methods are used to improve product quality from harvesting to storage [8]. Improving product quality is achieved using artificial ripening such as calcium carbide (CaC_2), ethylene gas, or ethephon (2-chloroethyl phosphonic acid), increased activity of functional fruit compounds such as antioxidants [17]–[19], increased physical quality such as hardness, color, and maintained texture [20], [21]. Quality improvement is accomplished by applying the handling method according to fruit characteristics [3], [22].

Most non-climacteric fruits can be handled with simple handling methods, although the same process can also handle climacteric fruits [23]. Physical methods can do the simple technique, i.e., manual cleaning followed by direct storage in containers (e.g., handling pineapple, star fruit, watermelon and soursop), wet cloth (e.g., handling breadfruit), heat treatment, modified packaging, and ultraviolet C (UV-C) [24]. Furthermore, chemical methods can also be applied by spraying fungicides (e.g., in the handling of avocados, bananas and papayas, the use of artificial ripening on mangoes) and the use of 1-methylcyclopropene (1-MCP), salicylic acid or methyl jasmonate [25], [26]. In general, the use of physical methods is relatively higher than in chemistry. It is because non-chemical methods are considered safer for materials, humans, and the environment [27], [28]. Heat treatment is the most used physical method [22], [29], [30]. In addition to being safe, heat treatment is deemed to be effective and easy to use to maintain material quality so that it can extend its shelf life [31]–[33].

Fruit heat treatment at 37-65 °C may take several seconds to days with a batch (intermittent), continuous, or drainage system. However, intermittent heat treatment is of better quality than continuous heat [34]. The heat treatment consists of brief hot water rinsing and brushing, hot air, hot water, and steam heating. The hot water rinsing and brushing method is a short treatment that lasts 15-25 seconds at 45-63 °C. Hot air is a steam blanching method that can be either dry or wet steam regulated by adding controlled air or steam. The hot water method is the immersion in hot water, lasting from a few minutes to hours [35]. They are commonly used in industry, this method. In addition to the heat treatment method, other methods for post-harvest handling of fruits such as electromagnetic radiation (microwave and radiofrequency energy) and heating with far-infrared light were also used [36]–[38]. Heat treatment processes and other handling methods, like heat treatment-culture inoculation or chemical-heat treatment, can also be combined [39].

The post-harvest process is then equipped with suitable packaging and storage, such as heat treatment followed by MAP storage [7], [8]. MAP packaging is a conditioned packaging containing O_2 and CO_2 components. The component comes from adding or removing gases found in food packaging (active MAP) or respiration process of packaged material (passive MAP) to some degree [40]. Modified packaging is used to regulate fruit respiration rates [41]–[43].

The storage is done at low temperatures after the fruit has been packed. The optimum storage conditions for tropical fruits are generally around 13±1 °C [44]. Low-temperature storage is an efficient method of maintaining post-harvest fruit quality by inhibiting metabolism [23]. So that a series of ripening processes related to respiration rate, weight loss, softening, and other damage indirectly inhibited [45]. However, there is still the possibility of cold damage to tropical fruit like chilling injuries. Chilling injury is the physiological damage to the material's low-temperature storage [46]. In chilling injury, changes in the integrity of the cell wall indirectly change the physical fruits. Physical changes occur in the form of uneven maturity, a holey surface, damaged or softened that may result in microorganism damage [3], [37], [47]–[49]. The following are some post-harvest studies on the handling of tropical fruits.

Post-harvest handling in Table 2, shows fruit quality is maintained. It can be seen from the firmness and chilling injury. Firmness is used to determine the quality of horticultural products closely related to product moisture and freshness [50]. Although firmness has decreased in normal conditions, the change is not significant. It was due to the cold tolerance of good material. Cold material tolerance increases due to heating. For example, catalase in tomatoes, certain temperatures may be precursors for activating or increasing antioxidant enzymes. The increase in antioxidant activity is consistent with the decrease in ion damage that occurs so that the formation of cold tolerance in the material and chilling-injury may be inhibited [37], [47].

Table 2: Post-harvest handling of tropical fruits and their efficacy

Fruit	Post-harvest handling	Efficacy	Ref.
Apple	Hot water treatment (45 ºC, 10 minutes) and inoculation of *Penicillium expansum* spore suspension (inoculation-heat treatment, heat treatment-inoculation; 1, 4, 24 hours), storage T= 20 ºC)	Increased thermotolerance of apple genes, affecting fruit resistance to blue mold infection	[41]
Peach	Steam blanching (T= 38 ºC, t= 3 hours), hot water blanching (T= 48 ºC, t= 10 minutes) and cold storage (T= 4 ºC)	Steam and hot water blanching can maintain firmness, increase antioxidant activity and slow down the damage. Whereas hot water blanching is more efficient to prevent internal browning of the material	[25]
Papaya	Hot water (T= 48 ºC, t= 20 minutes) followed by soaking in 1% Ca (heat treatment-Ca) solution	Inhibits anthracnose and damage	[51]
	Hot water control, hot water solution of salicylic acid (T= 42 ºC, t= 40 minutes) followed by (T= 49 ºC, t= 20 minutes)	Both solutions can inhibit mold growth during storage	[52]
Tomato	Hot water blanching (T= 40 ºC, t= 10 minutes)	Slows damage and extends shelf-life	[47]
Cherry	Hot water (T= 44 ºC, t= 114 minutes) and storage (T = 20 ºC)	Inhibits blue mold decay by increasing resistance to disease and slowing cell softening	[53]
Kiwi	Hot water (T= 45 ºC, t= 10 minutes), storages (T= 4 ºC and 25 ºC)	Inhibiting damage by inhibiting the growth of *B. cinerea* and *P. expansum* spores and increasing the antioxidant activity of catalase and peroxidase enzymes	[54]
Lemon	Hot water treatment (non-chemical, kinetin and potash alum (chemical), MAP: polyethylene	Extend shelf life. Hot water treatment is more effective than kinetin and potash alum	[43]
Melon	Hot water dipping (50 ºC, 30 minutes), MAP (Oriented polypropylene) and biodegradable film (polylactic acid), cold storage (T= 6 ºC)	Decreased fruit respiration rate. Oriented polypropylene MAP packaging is more effective than polylactic acid. The combination of heat treatment with MAP is effective in reducing browning and other quality degradation, as well as increasing beta carotene levels	[42]
Paprika	Hot water dipping (T= 45 ºC, t= 3 minutes), cold storage (T= 4 ºC)	Reduces mechanical damage, slows pectin solubilization and softening, extends shelf life	[55]
Sweet orange	Heat treatment (T= 50 ºC, t= 0-20 minutes), Cold storage (T= 5 ºC)	Firmness and weight loss are maintained at a certain storage time limit, then after that, it decreases	[56]
Cucumber	Short hot water dipping (45 ºC, t = 5 minutes), cold storage (T = 4 ºC)	Firmness, color, and taste of cucumber are maintained and prevent chilling injury.	[57]
	Hot water treatment (55 ºC, t = 5 minutes), cold storage (T=	Inhibits the decline in texture quality, preserves color, inhibits damage in	[50]

Fruit	Post-harvest handling	Efficacy	Ref.
	4 °C)	general	
	Induction of γ-aminobutyric acid, cold storage	Increased antioxidant activity	[58]
Valencia orange	Heat treatment, cold storage (T= 4 °C)	Firmness is increased, and chilling injury can be inhibited	[59]

2.2 Modern post-harvest handling

Even though damage can be prevented, further handling is needed to optimize it. Modern methods of handling have been implemented to improve the quality of post-harvest products. These methods include an ultrasound method equipped with controlled atmospheric storage (5% O_2; 2% CO_2; 93% N_2). It might maintain overall quality attributes and reduce the redistribution of water in cucumbers [60]. Ozone methods also can improve the quality and shelf life of cucumbers for up to 22 days without cold storage [61]. It is also necessary not only to maintain or enhance the quality of the product through post-harvest handling methods but also to analyze food quality damage and control that occurs during the process of obtaining better quality horticultural products. e.g. electronic nose (e-nose) and nuclear magnetic resonance (NMR) [62]. Its method has been used to analyze the quality of fruit and vegetables during storage, such as bananas, tomatoes, etc. [60], [63], [64], besides measurements using the Taguchi approach to measure and analyze losses based on quadratic functions. It's used to identify external factors that have the most significant impact on material quality, such as losses that are not noticeable in post-harvest handling. Furthermore, these approaches can also function to minimize product response to external factors to optimize post-harvest handling and already applied to cucumbers [65].

3. DEVIATIONS DURING POST-HARVEST HANDLING

The handling process by any method must be carried out carefully because if method incompatibility occurs, the product may be damaged. The damage can occur as physical changes such as browning, alterations in texture, hole formation, and black spots. Also, internal changes, like a deviation from the maturation process, can occur [33]. One form of damage was seen on mangoes using post-harvest methods in the way of aqueous 1-MCP, without- and with the addition of quarantine hot water treatment (QHWT) [66]. The order of treatment is crucial as QHWT, followed by 1-MCP, shows a negative interaction compared to QHWT, followed by the immediate 1-MCP treatment. It can be seen from the appearance of spots on the surface, and lenticel damage that continues to occur during the distribution process. In this case, heat treatment use does not provide a significant benefit where the use of 1-MCP without QHWT is considered to offer better benefits for mangoes [67]. Therefore, the use of heat treatment or other methods must be adjusted to the characteristics and objectives to be achieved to avoid irregularities and maintain the product quality.

4. CONCLUSION

Tropical fruits, both climacteric and non-climacteric, are easily damaged, requiring proper post-harvest handling. Physical methods such as manual cleaning, heat treatment, modified packaging (MAP), ultraviolet light and radiofrequency heating are simple methods that can be used for fruit after harvest. Additionally, chemical methods can be performed by adding 1-MCP, salicylic acid, methyl jasmonate, and γ-aminobutyric acid induction. New methods were also developed for post-harvest fruit handling such as ultrasound and ozonation and analysis by e-nose method and Taguchi approach, or by combining treatments or techniques. It produces fruit with excellent properties and a long shelf-life.

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