Sustainable Postharvest Handling of Horticultural Products

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*Abstract***:**

Sustainable commercial horticultural success depends on satisfying consumer requirements. Fresh fruits and vegetables are important components of human food. However, horticultural products are highly perishable and losses can be of great importance if postharvest correct measures are not provided. Quality of fresh horticultural products can not be improved by postharvest technologies, only can be maintained, what means horticultural products must be of high quality at harvest. There is a worldwide trend to explore new alternatives to increase storage life, giving priority to methods that reduce horticultural product decay avoiding negative effects to human health and environment. The objective of our research was to apply environmental and human health friendly techniques to preserve fresh fruit quality through storage. Figs, apricots, oranges, pomegranates and kiwifruits were treated with sodium bicarbonate, calcium chloride, acetic acid or subjected to modified atmosphere packaging to increase their storage life with minimal quality loss, as well as damage to human health and environment. The use of these treatments and techniques gave a great performance in the reduction of fruit losses, weight loss and fruit softening. Postharvest techniques such as modified atmosphere and calcium, sodium bicarbonate and acetic acid treatments, when applied in adequate concentrations, help to keep fruit quality through storage, without damaging the environment and human health. The benefit of each treatment depends on the type of fruit.

Key-words: Food safety, storage, human health, sustainability, postharvest technologies.

1 Introduction

Agriculture has economically challenged due to globalization of the markets, reduced returns and increased cost of inputs [5]. Profitable agriculture depends on adequate postharvest technologies which provide good quality products for as longer as possible in order to decrease price fluctuations.

Sustained commercial horticultural success depends on satisfying consumer demands. Appropriate product quality for a particular use must be attained if continued repeat purchases are to be made and if producing enterprises are to remain profitable [12].

Fresh fruits and vegetables are important components of human food, occupying the second place in the food pyramid. The increased market demand for food may exert pressure on the environment through intensive farming [18] and postharvest technologies. However, horticultural products are highly perishable and losses can be of great importance if postharvest correct measures are not provided. Losses include partial or total loss, loss of quality, water loss, rots and physical damage.

In countries less developed where postharvest technologies are poor, losses (in value) average 50% in marketing chain. High losses mean small margins and high prices, which in turn lead to lower consumption.

Quality of fresh horticultural products can not be improved by postharvest technologies, only can be maintained, what means horticultural products must be of high quality at harvest [12]. To have a high quality product at harvest, it is of major importance to ensure that preharvest conditions are optimised.

Quality is difficult to define; it is the product state that meets the expectations of the consumer [12]. Quality is characterised by intrinsic and extrinsic factors which vary depending on the expectations and memory of the consumers [15]. Intrinsic factors include external attributes, such as, color, shape, size and freedom from defects and internal attributes which are texture, sweetness, acidity, aroma, flavour, shelf-life and nutritional value [12]. Extrinsic factors refer to production and distribution systems which include cultural practices during production, package types and their recycling capacity, management and postharvest practices, being of major importance the sustainability of production and distribution in relation to energy utilization.

Sustainable development has been defined as development which meets the needs of the present without compromising the ability of future generations to meet their own needs [25], and integrates economic, social and environmental factors. Sustainability requires that standards of living and production capabilities do not decline over time and that the natural environment is not damaged or degraded [20].

The benefits of increased food supplies at reasonable prices are important, but there may also be social and environmental costs, such as for example health or safety risks [18]. As a consequence, individuals or society make responses to exploit positive or mitigate negative impacts.

Since fresh horticultural products are removed from their source of carbohydrates, water or nutrients at harvest, the eating quality of fresh horticultural products is already determined at harvest and can be only maintained, not improved, with postharvest techniques [12]. Additionally, climate changes can cause decrease in product quality at harvest [8].

In fact, even with the best postharvest technologies available, the best we can do is to reduce the rate at which horticultural products deteriorate as they proceed through their normal ripening and senescense.

This fact emphasise the importance of high quality product at harvest. Also, the maturity at harvest has a very important influence on subsequent storage life and eating quality. There are different ways to measure maturity and literature refers best maturity indices for harvest of most fruits and vegetables. For these indices to be useful, they must be objective, easy to use, measure what is important and the data obtained can be compared between farms, regions and years [12].

There is a worldwide trend to explore new alternatives to increase storage life, giving priority to methods that reduce horticultural product decay avoiding negative effects to human health and environment.

The pre and postharvest application of calcium salts has been used successfully in many fresh fruits to reduce loss of firmness and to slow down the ripening process [23]. Calcium alters intracellular and extracellular processes which retard ripening exemplified by lower rates of colour change, softening, CO_2 and ethylene production, increase in sugar, and a reduction in total acid content [9].

It is known that calcium deficiency can induce a range of postharvest disorders in many fruits and vegetables [13]. Calcium deficiency can be overcome by calcium salts spraying during fruit development and/or by postharvest dip or drench treatments after harvest [14].

Modified atmosphere packaging (MAP) alone or in combination with refrigerated storage, has been known to maintain quality and reduce postharvest losses of fruits and vegetables [16]. The objective of MAP is to create a reduction of O_2 and increase in CO_2 satisfactory to reduce fruit respiration. The use of polyethylene films allowing some gas exchange, depending on respiration rate of each horticultural product, gives a suitable modification of the atmosphere composition around the fruits. Besides, MAP reduces water loss of horticultural products. Sodium bicarbonate (BCS) is often used in food industry and is known to be efficient to a large scale in reducing microbial activity [7]. Treatments with BCS have reduced fungi activity in some fruits through storage [4, 7, 19].

Acetic acid is acting mainly in bacteria than in fungi [24]. In banana, 0.2% acetic acid increased storage life of banana with significantly good quality [10].

The objective of our research was to apply environmental and human health friendly techniques to preserve fresh fruit quality through storage.

2 Materials and methods

2.1 Plant material and treatments

Experiments focused fruit of significant importance in Portugal, either for export or national consumption. Commercial mature fruits were harvested from orchards in Portugal. Recommended harvest practices were followed, to reduce decay through storage. Those included harvesting during the coolest time of the day and shade of fruits; careful handling of the fruits to avoid wounding, bruising, crushing, or damage from humans, equipment, or harvest containers; use of clean and sanitized tools, packing or transport containers; and good means and rapid transportation from the orchard to the cold storage facility or packhouse.

After selection for uniformity of size and freedom from defects, some fruits were used directly for quality analyses. The remaining fruits were submitted to postharvest treatments with sodium bicarbonate (SBC), acetic acid or calcium chloride ($CaCl_2$). Other fruits did not have any treatment and were placed in storage under modified atmosphere (MAP) or just in normal atmosphere (control). Postharvest treatments consisted of dipping fruits in solutions of SBC, acetic acid or $CaCl_2$ of different concentrations, for 2 minutes. After that, fruits were allowed to dry at ambient temperature for 1-2 hours, and then placed in single layer alveolar boxes.

The trays were placed in storage rooms at the recommended storage temperature for each fruit species: 2ºC for figs, 3ºC for apricot, 5ºC for pomegranate, 0ºC for kiwifruit and 7ºC for oranges. Relative humidity was maintained at 90-95%. Fruits were analysed at harvest and at regular intervals through storage. Measurements of weight loss, firmness, and loss of fruits were performed.

2.2 Measurements

Weight loss was expressed as a percentage of the initial fruit weight. Loss of fruits (rotten; overripe) was calculated as percentage of total initial fruit number. Firmness was measured with a TCD200 Chatillon pressure tester, John Chatillon & Sons, Inc. U.S.A., and expressed in Newtons. For kiwifruit the penetrometer was fitted with a flat 8mm tip. The tip was inserted after skin removal, at the fruit equator to a depth of 7mm for flesh firmness measurements.

For apricots the penetrometer was fitted with a conical plunger of 6.5 mm diameter and 2.4 mm height. The tip was inserted with fruit skin to a depth of 12 mm.

For oranges, firmness was determined by compression with the same Chatillon TCD200 texture meter fitted with a plate of 92 mm diameter. The necessary force to move the fruit 10 mm was recorded.

2.3 Statistical analysis

Statistical analyses were carried out with a SPSS statistical package. Two-way analyses of variance (ANOVA) tests and Least Significant Difference (LSD) Tests at (P<0.05) for comparisons between treatments over time were conducted.

3 Results and discussion

3.1. Fruit loss

Loss of fruits (rotten; overripe) was significantly reduced by the use of sodium bicarbonate (BCS) or acetic acid (Table 1). In fig fruit, either the use of 0.5% SBC or 1% acetic acid kept fruits health during 20 days storage at 2ºC while not treated fruits (control) had 25% losses.

For apricot fruits 0.5% SBC was very efficient in reducing fruit loss which was only 8% after 28 days storage at 3ºC, when compared to control fruits.

Acetic acid and SBC are known to be efficient to control microbial activity [7, 10, 19]. Reduction of fruit loss by using SBC or acetic acid was also observed by Antunes et al. [4, 6]. The important finding was that low concentrations such as 0.5% SBC and 1 % acetic acid can have a great effect in reducing fig and apricot decay through storage.

Table 1. Loss of fruits (rotten; overripe) as % of total fruit, through storage, subjected to different postharvest treatments

Fruit	Storage days/ Temperature	Treatment	Fruit loss (%)
Fig	20 days / 2ºC	Control	25
		0.5% SBC	0
		1% AceticAc	0
Apricot	28 days / 3ºC	Control	30
		0.5% SBC	8

3.2. Weight loss

Weight loss was significantly reduced by the use of modified atmosphere in apricot and pomegranate fruits (Table 2). Apricot had only 3% weight loss of the fruits after 18 days storage while control fruits (no MAP covering) lost 8% of their weight. Pomegranate had a reduction in fruit weigh of 7% after 60 days storage under MAP, while control fruits reduced their weight in 13%.

Table 2. Weight loss of fruits (% of total weight) through storage, subjected to different postharvest treatments.

Fruit	Storage days/ Temperature	Treatment	Weight loss (%)
Apricot	18 days / 3ºC	Control	8
		MAP	3
Pomegranate	60 days / 5ºC	Control	13
		MAP	7

Weight loss is mostly dependent on the relative humidity surrounding the fruit, but can be also associated with a slight reduction in flesh firmness [1, 11]. Weight loss is of great importance because it can cause fruit shrivelling and advance senescence.

The use of MAP significantly reduced weigh loss in apricot and pomegranate since it is known to be efficient in reducing water loss by fruit as well as respiration rate [21].

This work suggests that the use of MAP in apricots during 18 days at 3ºC and on pomegranate during 60 days at 5ºC benefits storage life capacity.

3.3. Firmness

Firmness is an important indicator of the stage of ripening and senescense of most fruits. For this reason is used as maturity index to indicate time to harvest or when fruits are eating ripe.

Calcium is an important nutrient for keeping firmness through storage since it is responsible for cell cohesion [17].

Oranges treated with 3% $CaCl_2$ showed a significantly higher fruit firmness than non treated fruits through 45 days storage at 7ºC (Table 3). At this temperature, even after only 15 days storage, fruits not treated with calcium showed significantly lower firmness that oranges treated. Fruits treated with calcium had better quality presenting significantly higher values of firmness after 30 and 45 days storage.

Table 3. Firmness (N) of oranges cv. 'Navelina' treated with 3% $CaCl_2$ postharvest or control through 45 days storage at 7ºC.

Storage days	Control	3% $CaCl_2$
0	89.2 ± 5.6	89.2 ± 3.6
15	77.8 ± 5.5	84.6 ± 3.7
30	74.1 ± 4.9	84.0 ± 5.4
45	70.0 ± 6.0	82.1 ± 5.2

Apricot fruits treated with 3% $CaCl_2$ concentration had similar pattern as oranges, showing 20N firmness after 21 days storage at 3ºC while control fruits had 12N flesh firmness (Table 4). Apricots treated with calcium had better quality presenting significantly higher values of firmness after 14 and 21 days storage than fruits not treated.

Table 4. Firmness (N) of apricot cv. 'Lindo' treated with 3% $CaCl_2$ postharvest or control through 21 days storage at 3ºC.

Storage days	Control	3% $CaCl_2$
0	16.6 ± 3.1	16.6 ± 3.1
6	17.1 ± 3.0	20.0 ± 2.5
14	13.9 ± 2.8	18.6 ± 3.0
21	12.1 ± 4.1	19.7 ± 2.3

Kiwifruit also showed significantly higher firmness (28N) after 120 days storage at 0ºC when treated with 2% $CaCl_2$, while control fruit were softer showing 17N flesh firmness (Table 5). After 60 days storage at 0ºC, fruits not treated with calcium showed already significantly lower firmness than treated fruits.

Table 5. Firmness (N) of kiwifruit cv. 'Hayward' treated with 2% $CaCl_2$ postharvest or control through 120 days storage at 0ºC.

Storage days	Control	2% $CaCl_2$
0	58 ± 4.6	58 ± 4.6
60	29 ± 3.2	41 ± 3.1
120	17 ± 0.5	28 ± 2.8

It is known that calcium ions make bridges between peptic molecules in the middle lamella being responsible for cell cohesion. So, softening can be the result of the loss of calcium from the middle lamella and/or a loss of its place in the connections between the peptic molecules [17].

Calcium infiltrations pre and postharvest in fruit tissues, delays softening rate and ripening, by retarding the loss of disintegration of cell walls [22]. Reduction of fruit softening was also observed for those fruits by Souty [23] and Antunes [2, 3, 4].

This work suggests that immersion of oranges and apricot in 3% $CaCl_2$, and kiwifruit in 2% $CaCl_2$ postharvest benefits storage life capacity.

5. Conclusions

Horticultural products are highly perishable. To make sustainable horticultural production postharvest handling is of great importance. Postharvest technologies should avoid negative effects to human heath and environment.

Preharvest adequate cultural practices are very important to give a quality product which keeps better in postharvest life. Also, correct maturity at harvest for each product is of relevant importance for subsequent storage life and eating quality. In addition, correct harvest measures provide reduction of postharvest losses.

Postharvest techniques such as modified atmosphere and calcium, sodium bicarbonate and acetic acid treatments, when applied in adequate concentrations, help to keep fruit quality through storage, without damaging the environment and human health.

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