

Field and Post-Harvest Factors Affecting the Quality and Shelf Life of Soft Fruits

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Abstract

Soft fruit production is an economically important income for many producers all over the world. One of the main problems is the sensitivity of this small but very aromatic, health beneficial and desirable fruits. Despite the numerous benefits that soft fruits are valued for, post-harvest losses make its production in most parts of the world unprofitable and difficult to export. Soft fruits differ to most other fruits; they are so called non-climacteric fruit and are not able to ripen after they are harvested. Therefore, special pre-harvest and post-harvest treatments are necessary to reduce post-harvest losses in soft fruit, which, without special care can be as high as 40%. This study revealed that the post-harvest quality status of soft fruits partly depended on some pre-harvest practices carried out during production. Some of these factors are nutrient management, maturity stage, cultivar selection and irrigation. Using best post-harvest handling practices or factors such as temperature, relative humidity, storage in controlled atmosphere and physical handling procedures to maintain the quality after harvest was also critical. It was concluded by this study that understanding and managing both pre-harvest and post-harvest factors properly would reduce the post-harvest quality losses in soft fruit production.

Keywords: Soft fruits; Shelf life; Pre-harvest and post-harvest; Quality; Storage

Abbreviation: MA: Modified Atmospheres; CA: Controlled Atmosphere

Introduction

Soft fruits are one the most popular and extensively consumed fruits in the world [1]. Today's consumers are in demand of high quality, nutritionally versatile and safer fruits [2] throughout the year regardless of the season. Special interest in soft fruits is rising because they are a good source of natural antioxidants and beside the usual nutrients such as vitamins and minerals, soft fruits contain remarkably high content of phenolic compounds [3]. Soft fruits contain higher amounts of anthocyanins, a type of phenolic compounds that are beneficial in reducing the incidence of some chronic diseases [4]. Many researchers have shown a positive correlation between antioxidant activity and phenolic content especially anthocyanins [4]. Anthocyanins are responsible for the colour of the fruit [3] and among soft fruits; we can observe fruits in various different colours, from black and blue to yellow and red. World soft fruit production in 2018 accounts for about 750.000 hectares of harvested land area with an estimated production of 12 million tonnes [5]. Most economically important soft fruits in the world are strawberries and blueberries. Strawberries (*Fragaria×ananassa* Duch.) are the main soft fruits as they are cultivated commercially in 76 countries [6] on approximately 50% of total soft fruit production area with the production of 8.4 million tonnes. China leads world strawberry production with about 3 million tonnes followed by United States of America with 1.3 million tonnes [5]. Second economically most important soft fruits are blueberries (*Vaccinium* spp.) which became one of the crops with the highest production trends. Worldwide production of blueberries has grown by 72.11 % in last 20 years mostly in the United States of America, where 48% of the blueberries are harvested [5]. Soft fruit production is an important source of income for many producers all over the world [6]. Most of the soft fruit production is destined for the fresh market sector, which requires optimum pre-harvest production technology providing high-quality berries and post-harvest longevity [7]. Despite the numerous benefits that soft fruits are valued for, post-harvest losses make its production in most parts of the world unprofitable and difficult to export. Soft fruits

differ to most other fruits; they are so called non-climacteric fruit and are not able to ripen once they are harvested [8].

Therefore, special pre-harvest and post-harvest treatments are necessary to reduce post-harvest losses in soft fruit, which, without special care can be as high as 40 % globally [9]. These losses bring low economic efficiency to the producers as well as to the whole production country [6]. An investigation into the possible factors that can affect the post-harvest quality of soft fruits is therefore necessary to extend the post-harvest life of fresh soft fruits to further extend the marketing season and to reduce waste. The post-harvest qualities of soft fruits are dependent not only on post-harvest handling and treatment methods but also on many pre-harvest factors such as genetic and environmental conditions [10]. Production technology, such as fertilization [11], water supply [12], pest and disease management [13] and harvesting methods [14] are also believed to be factors influencing both pre- and post-harvest quality of soft fruits. Many post-harvest quality losses are a result of different pre-harvest factors and fruits that are infected by pest, diseased, inappropriately irrigated and fertilized can never be improved in quality by any post-harvest treatment [15]. The aim of this review therefore is to investigate the most important pre-harvest and post-harvest factors and its effect on post-harvest qualities and shelf life of soft fruits, mainly strawberries and blueberries.

Discussion

Pre-harvest factors affecting the post-harvest quality

The following describes some of the most important field factors and production technologies affecting the shelf life and post-harvest qualities of soft fruits.

Nutrient management: When we say nutrient management, we first think about fertilization with nitrogen, being indispensable element for the development of the plant [16]. Producers all over the world often use high doses of N with the belief that it promotes vegetative development and higher fruit yield [17]. Deficiency of nitrogen in strawberry (content of nitrogen in leaves 1.9%) causes chlorosis of the leaves and a significant decrease in leaf area, yield and root size [18]. However, an excess of nitrogen (content of nitrogen in leaves 4%) promote vegetative growth, delays maturation, increase susceptibility to diseases and pathogen attack and causes a loss of firmness in the fruit [19,20]. Because of the general decrease in fruit quality, post-harvest handling could easily be affected. Higher concentration of nitrogen significantly reduces post-harvest life probably due to calcium deficiency in fruit [21]. Calcium deficiency represents one of the most common issues for strawberry growers. Calcium plays a role in cell division and the maintenance of cell permeability and cell integrity, all of which directly influence factors such as firmness and shelf life [22].

Therefore, many researchers have shown that calcium application had positive influence on different quality parameters. For instance, Ca application in blueberry production has recently been studied and found to be useful to delay post-harvest softening and decrease weight loss of blueberry fruits [11]. Foliar calcium application in strawberry production had a positive effect on the

prevention of post-harvest rots [23] and increases fruit firmness [22]. Among microelements, boron has a direct effect on fruit quality. For example, boron deficiency causes partial flowers and deformed fruits, reduces yield, and increases defect [17]. Post-harvest calcium application can also have a positive storage effect on strawberry fruits. Dipping the fruits in 1% CaCl₂ solution is an effective treatment for increasing the calcium content of the fruits, for controlling their post-harvest decay, and for maintaining their firmness and soluble solids content [24].

Maturity stage: The maturity stage of soft fruits at harvest is probably one of the most critical elements of many quality traits and shelf life. Soft fruits, being a non-climacteric fruit, cannot be harvested before they are fully red and reach at 7-8% °Brix value to guaranty the fruit quality (Figure 1). Thus, this may extend its shelf life on the cost of flavour and nutritional value. Harvesting strawberries at the fully ripe stage is preferred to maximise nutritional value but limiting shelf life, because of fruit softening and increased susceptibility to physical injuries [25]. Unripe fruits are more prone to shrivelling and physical injuries, and have poor flavour quality when ripe [26]. Fruits either picked too early or too late in their season are more susceptible to post-harvest physiological disorders than fruits picked at the proper stage of maturity [27]. Decay incidence was found higher at fully ripe fruits than three-quarter ripe fruits [28].



Figure 1: Properly mature strawberry fruits for harvest.

Cultivar: The potential quality of fruit is very dependent on the cultivar. Different cultivars are characterised by different quality parameters making some more desirable to the producers and consumers than others. Post-harvest life based on appearance and on changes in flavour components and sensory characteristics of different strawberry cultivars during storage showed significant differences in fruit firmness and flavour quality during storage [29]. Cultivar selection is therefore an important factor to consider also depending on the market distance.

Irrigation: A deficiency or excess of water can affect the quality of crops if they are consume immediately or stored [30].

Management of water frequently poses a dilemma between yield, fruit quality and shelf life. Extreme water stress will reduce yield and quality of the fruit, but may benefit some taste related compounds [30,31]. If strawberry plants are over-irrigated, especially at harvest time, the fruits have a sour taste; they are softer and more susceptible to bruising and decay [32]. According to [12] the effect of irrigation intervals on the quality and storage performance of strawberry fruit is also important. They concluded that while 4 days irrigation interval may be optimum for fresh fruit consumption, irrigation interval of 10 days is appropriate for retaining quality during storage or distant marketing.

Post-harvest factors affecting the post-harvest quality

Post-harvest handling and storage techniques have one main goal, to maintain the maximum quality of fruits from harvesting to consumer. With prolonged shelf life and retained consumer appeal, the grower will receive the highest market price at the time for sale. This chapter is devoted to provide information on quality retention in fresh soft fruits through proper post-harvest handling and storage.

Temperature: Low temperature is the most common method used to extend storage life [29]. All soft fruits must be chilled immediately after harvesting, so called precooling, in order to maximize the shelf life [33]. For example, strawberries rapidly cooled down to 0 °C showed threefold the storage life of those fruit maintained at 10 °C [34]. Temperatures around 0 °C are considered the best for strawberry [35], 2-5 °C for blueberry and raspberry [36,37] storage because they cause few changes in quality. However, the commercialization and post-market storage usually occur at higher temperatures. These higher temperatures can affect not only the strawberry shelf life, but also its nutritional value, in terms of soluble sugars, vitamin C and antioxidant compounds [35]. Temperature management during storage is the single most important factor in minimizing the deterioration of fruit quality and extending the shelf life of strawberry. Not only that we lower the temperature of the atmosphere around the fruits, it is also important how. The aim of the research carried out by Allais [38] was to assess the impact of mist-chilling on high-grade strawberry. Mist-chilling had reduced weight loss by 20-40% in comparison to air-chilling. Beside air and mist chilling, it is also used hydro cooling to lower the temperature of the fruits. Emond [39] studied the feasibility of hydro cooling for strawberries and it resulted not suitable for strawberry.

Relative humidity: High humidity is essential for stored soft fruits; moisture promotes the growth of disease-causing organisms. This can be offset by maintaining adequate air circulation and applying the coldest storage temperature allowable for each fruit without causing any injuries. Berries are mostly water and soluble solids such as sugars and acids that depress the freezing point below 0 °C. Optimum humidity for soft fruit is between 85-95% [40].

Combination gases: The primary purpose of modified atmospheres (MA) and controlled atmosphere (CA) storage is to lower the respiration rate to slow biochemical changes in fruits

and slow the ripening process. With this modification of storage conditions, beside the basic temperature and humidity demand, shelf life of soft fruits can be significantly extended [40]. CA and MA technologies can reduce the need for post-harvest pesticides and allow fully ripe fruit to be harvest. Controlled atmosphere demand for non-climacteric soft fruits is different than most of other climacteric fruits. The main difference is in low O₂ and high CO₂ levels that cause the disruption of the enzyme system in the ethylene production pathway. Strawberries, blackberries and raspberries have especially high rates of respiration, so the optimal CA is consist of 5-10% O₂ and 10-20% of CO₂ [41].

Physical handling: Physical handling can have a drastic effect on the post-harvest quality or life of harvested fruits. As the term itself suggests, soft fruits are delicate and do not tolerate rough handling at any stage, resulting in mechanical injuries which decrease the quality and shelf life.

Conclusion

Post-harvest quality management of soft fruits starts in the orchard and continues until it reaches the final consumer. Many post-harvest quality losses are a result of different pre-harvest factors and fruits that are infected by pest, diseased, inappropriately irrigated and fertilized can never be improved in quality by any post-harvest treatment. Understanding and managing the various roles that pre-harvest factors like nutrition management, harvest, cultivar selection, and irrigation can play the main role. Soft fruits are highly delicate and are subjected to rapid quality loss after harvest. Using best post-harvest handling practices or factors such as optimum temperature, right relative humidity, optimal gases concentrations in storage and the best physical handling procedures to maintain the quality after harvest is also critical. It can be concluded by this study that pre-harvest and post-harvest factors must be managed properly in order to reduce the quality loss to minimum.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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