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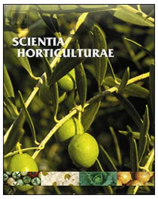

Review

Preharvest factors influencing bruise damage of fresh fruits – a review

Zaharan Hussein[a], Olaniyi Amos Fawole[b], Umezuruike Linus Opara[a,b,*]

[a] *Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Food Science, Faculty of AgriSciences, Stellenbosch University, Private Bag X1, Stellenbosch, South Africa*

[b] *Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Sciences, Faculty of AgriSciences, Stellenbosch University, Private Bag X1, Stellenbosch 7602, South Africa*

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ABSTRACT

Bruise damage of fresh fruits is a major problem in the horticultural industry, potentially occurring during preharvest, harvest and at all stages of postharvest handling chain. This damage can cause considerable postharvest and economic losses, reduce produce quality and result in serious food safety concerns. Understanding the factors influencing susceptibility or resistance of produce to bruising is important in developing strategies for reducing the problem. This review discusses main preharvest factors that could be manipulated by producers prior to harvest in attempts to reduce bruise damage of fresh fruits during postharvest handling. These factors include: (1) genetic (species/genotype); (2) climatic and environmental; (3) seasonal variation; (4) orchard management practices; and (5) effect of fruit properties. A critical discussion of these factors and their relative influence on bruise susceptibility of fresh fruits is presented. Among other factors, orchard management practices such as irrigation and fertilization could be an important strategy to manipulate fruit mechanical strength to enhance resistance to bruising. Future research directions are discussed.

1. Introduction

Fruits play an important role as essential part of human diets, providing essential macro and micronutrients, vitamins, dietary fibres and phytochemicals to the world's population (Li and Thomas, 2014; Hussein et al., 2015). The close association between the consumption of fresh fruits with many nutritional and health benefits has made produce highly recommended as health diet to fight against sedentary life style and degenerative diseases such as cancer, high blood pressure, cardiovascular diseases and ageing (Viuda-Martos et al., 2010; Fawole et al., 2012a,b; Mphahlele et al., 2016). Hence, the perceptions of health benefits coupled with a change in consumers' life style and increase in consciousness of healthy diet have heightened the global demand for fresh fruits and vegetables (Li et al., 2011; Li and Thomas, 2014). In the quest to satisfy this demand, the rapid expansion of mechanized horticulture industry to multiple digit growth has been evident (Montanez et al., 2010; Siddiqui et al., 2011). Hence, large-scale mechanization which involves large-scale planting and mechanical handling (e.g. harvesting, packaging and transport) of fruits has been necessary (Li et al., 2011).

Fruits have high potential to be mechanically damaged during their developmental stages and/or before harvest (Kays, 1999; Lurie, 2009). Generally, the chances that fruit can be damaged while still on the tree are quite substantial, and this can happen from a variety of sources. Several ways in which fruit can be mechanically damaged whilst on tree include (i) forceful contact of fruit with other fruit or parts of the tree such as branches during growth which may cause abrasion, puncture and bruising, (ii) predation by slugs, insects, birds and mammals can also puncture the skin and consume a portion of the tissue, and (iii) effect of weather, such as wind and hail that can aggravate damage caused by contact of fruit with other parts of the tree, causing mechanical injury such as bruising, cleavage, slip and buckling (Kays, 1999; Van Zeebroeck et al., 2007a). For instance, Kumar et al. (2016) reported an average preharvest loss of up to 30.4% in litchi fruit during sorting at harvest, which mainly comprised losses due to sunburn, cracking, bruising anthracnose, and fruit borer infestation, among others.

The most common type of mechanical damage to fruits is bruising, commonly occurring during harvesting, handling and transport (Ahmadi et al., 2010; Tabatabaekoloor, 2013). Bruise damage is a type of subcutaneous tissue failure without rupture of the skin of fresh produce resulting from the action of excessive external force on fruit surface during the impact, compression or vibration against a rigid body or fruit against fruit which result in cell breakage (Kitthawee

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[*] Corresponding author at: Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Science, Faculty of AgriSciences, Stellenbosch University, Private Bag X1, Stellenbosch, South Africa.

E-mail address: opara@sun.ac.za (U.L. Opara).

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et al., 2011; Li and Thomas, 2014; Opara and Pathare, 2014; Stropek and Gołacki, 2015). The physical evidence of bruising onto a produce is usually indicated by discolouration of injured tissue which marks the damaged spot (Blahovec and Paprštein, 2005; Opara and Pathare, 2014).

Mechanical impact or compression (due to loading) onto a biological produce provokes mechanical stress that induces cell wall and membrane rupture and hence bruising (Ahmadi, 2012). Bruise susceptibility (BS) is the measure of produce response to external loading (Opara and Pathare, 2014; Van Linden et al., 2006; Van Zeebroeck et al., 2007b; Ahmadi, 2012). Hence, the extent of dynamic or static loading onto a produce is considered the most important bruise factor, usually expressed in terms of loading or absorbed energy (Blahovec and Zidova, 2004; Blahovec, 2006). The former comprises all impacts likely to occur during harvesting and handling operations such as fruit dropping into the picking buckets or during sorting, or a vibration, mainly occurring during transportation (Komarnicki et al., 2016). On the other hand, static or compression loading can occur during harvesting, transportation or storage when poorly designed bins are overfilled and stacked such that the produce in the lower bins support the weight, which possibly causes damage (Thompson, 2003; Lewis et al., 2007; Komarnicki et al., 2016).

In agreement with the above hypothesis, several authors have stated that irrespective of differences both in preharvest and postharvest factors, the amount of mechanical energy applied and absorbed by produce during impact, compression or vibration is a major deciding factor on the severity of damage that occurs (Blahovec and Paprštein, 2005; Opara, 2007; Zarifneshat et al., 2010). Hence, this clearly shows that impacts, compressions or vibrations on produce during mechanical handling should be avoided to prevent damage (Li and Thomas, 2014). Nonetheless, while the mechanical force in contact with produce has been identified as obvious factor affecting bruising, this phenomenon is dependent on a number of other factors relating to physiological and biochemical properties of the produce on one hand, and growing environmental conditions on the other hand (Van Linden et al., 2006; Strehmel et al., 2010; Ahmadi, 2012).

Bruising of produce at preharvest stage is uncommon and usually not easily controlled (Van Zeebroeck et al., 2007a). Traditionally, produce that is physically damaged before or at harvest or those with various defects are usually discarded either on the field or in the packhouse (Knee and Miller, 2002). This further exacerbates the problem as it virtually becomes difficult to quantify losses due to such damages. However, it remains pertinent to understand distinctively the difference between preharvest and postharvest mechanical damages. This could be helpful as a tool to reduce harvest losses resulting from such damages, and possible measures to alleviate the problem.

Previous research has indicated that among other factors, the agricultural production practices greatly affect the overall quality of fresh produce at harvest, after harvest and even during shelf life storage (Prusky, 2011). This could imply that, to a large extent, the quality of fresh produce depends on various factors prevailing during their growth, mainly including climate, seasonal variation and orchard management practices (Opara, 2007; Tahir et al., 2007; Prusky, 2011). In view of that, limited studies have been conducted to ascertain the effects of preharvest factors on bruise damage of fresh fruit using different simulated impact and compression loadings.

Over the past decades, manipulation of preharvest factors had largely been the unexplored option for orchardists to reduce bruise damage, in spite of the presence of a considerable number of preharvest factors that could potentially influence the susceptibility of many horticultural produce to bruising (Shewfelt and Prussia, 1993; Mowatt, 1997). Fig. 1 conceptualizes the effects of preharvest factors on the susceptibility of fruits to bruising. Instead, most efforts to reduce bruise damage by orchardists or packhouse operators revolved around improving handling techniques from harvest, through postharvest handling activities to final retail points (Shewfelt, 1986; Mowatt, 1997). Nonetheless, there are several preharvest factors that could be manipulated quite easily by both orchardists and packhouse operators in a quest to reduce bruising of fresh fruit produce (Fig. 1). While research has put much attention on the postharvest factors that potentially influence bruising, little is known about the preharvest factors affecting bruising of horticultural fruits. This current review presents the discussion of previous research that explored various preharvest factors and their relative influence on bruise susceptibility of various fresh fruits.

2. Fruit bruising: causes and effect on fruit quality

Application of impact or compression forces directly to the surface of fruit can cause external (surface) and/or internal bruising (Li and Thomas, 2014; Opara and Pathare, 2014). External bruising is usually described by the presence of any defect(s) such as skin rupture and/or manifestation of browning in the exocarp surface of a fruit (Li and Thomas, 2014). On the other hand, internal bruising involve either damage of fruit tissues beneath the exocarp or tissues not in contact with the exocarp (Vursavus and Ozguven, 2004; Li and Thomas, 2014). External bruising of fruit is visible and therefore can be quantified either as diameter by assuming the circular shape of the visible bruise damage (Vursavus and Ozguven, 2004) or as an area that assumes circular or elliptical shape of the bruise (Pang et al., 1996; Bollen, 2002). Fruit defects due to external bruising might be eliminated during sorting and grading or processing, hence leading to rejection and price adjustment requests by buyers and receivers in both domestic and export markets (Grant and Thompson, 1997).

The formation of external bruising is associated mainly with the breakage of cell structures and the failure of membranes (Lee et al., 2005; Rinaldo et al., 2010). Damage of cells and fruit tissue initiates the contact between polyphenol oxidase (PPO) and peroxidase (POD) cytoplasmic oxidizing enzymes and phenolic contents originally stored in the vacuole (Billaud et al., 2004; Jiménez et al., 2011). In the presence of oxygen, the enzymatic oxidation in the damaged cells transforms phenolic substances into quinones, which polymerize to form dark/brown pigments on damaged part of the fruit (Lee et al., 2005; Franck et al., 2007; Holderbaum et al., 2010). The formation of brown pigment on the surface of the damaged region provides the external sign of an impact or compression bruising (Van Linden and De Baerdemaeker, 2005; Opara and Pathare, 2014). The difference in the concentration of phenolic contents and the activity of oxidizing enzymes between the fruit exocarp, mesocarp and endocarp tissues makes the browning inhomogeneous (Rinaldo et al., 2010; Li and Thomas, 2014). For instance, in fruits such as litchi, the phenolic content and oxidizing enzymes (PPO and POD) activity are higher in external tissues, and hence the browning predominantly occurs on the external surface of the fruit's bruise damaged region. On the contrary, other fruits such pear, tomato and longan, the phenolic content and PPO and POD activity are lower in the external tissues and therefore browning occurs internally (Casado-Vela et al., 2005; Quevedo et al., 2009).

Unlike external bruising, the internal bruising on fruit is characterised by hidden damage and hence easily overlooked and difficult to measure. Shewfelt (1986) described internal bruising as ‘latent damage’ suggesting that damage is usually incurred at one step in a postharvest system but not apparent until a later step in the handling chain. Internal bruising is traditionally estimated or measured by assuming a non-visible shape of an internal damage (Li and Thomas, 2014). The shape for an internal bruising is either assumed as spherical (Ahmadi et al., 2010; Ahmadi, 2012), an elliptical cone (Bollen, 2002; Shafie et al., 2015), or an ellipsoidal shape (Lu and Tang, 2012; Kitthawee et al., 2011). Measurement of such dimensions as diameter, width and depth of the bruised tissues using digital callipers is usually followed by calculation of the bruise volume (BV) or bruise area (BA) of an internal bruising (Ahmadi et al., 2010; Kitthawee et al., 2011; Shafie et al., 2015).