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Bruise damage measurement and analysis of fresh horticultural produce—A review

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ABSTRACT

Bruising is the most common type of mechanical damage affecting fresh horticultural produce, and reduces quality to the consumer and income to fruit and vegetable industries. Bruising can occur during harvest and at all stages of postharvest handling, especially during packhouse operations, transport and storage, and is one of the major physical defects contributing to downgrading and postharvest loss of fresh horticultural produce. Understanding susceptibility or resistance of produce to bruising is important in developing strategies for reducing the problem. Bruise quantification can be carried out using destructive manual measurements and subsequent analysis, or using a range of non-destructive techniques. Novel and emerging non-invasive technologies for bruise measurement of fresh horticultural produce include near infrared spectroscopy, hyperspectral imaging, thermal imaging and nuclear magnetic resonance imaging. Various mathematical models used to estimate bruise size are discussed, including the use of instrumented spheres to characterise the bruise potential of postharvest handling systems. A wide range of indices based on mathematical expressions of the physical and mechanical properties of fruit, the bruised portion and the energy of the handling system causing the damage have been proposed and applied to quantify the intensity or potential to damage for different commodities and even for the same commodity. Standardisation of bruise measurement and analysis methods is warranted to permit comparison of research results on the effectiveness of pre- and postharvest treatments to reduce bruising, as well as facilitate inter-laboratory traceability of data.

1. Introduction

Consumer satisfaction with product quality is the main objective of the production, handling, storage and distribution of fresh horticultural produce. Consumers primarily judge fruit quality based on appearance, and even a moderate amount of bruising can reduce consumer acceptance (Fig. 1). With the long marketing chain of many fruit and vegetables that is currently in place, bruising is a common problem (Sablani et al., 2006), and is one of the major physical defects contributing to downgrading and postharvest loss of fresh horticultural produce (Opara, 2007). According to Kader (2002), visual quality plays a vital role (up to 83%) in consumer choice, and it is highly affected by the presence of defects. In another study, bruising was found to be a more important barrier to purchasing than price (Harker, 2009). With regard to horticultural produce, bruising has been defined as damage to plant tissue by external forces causing physical change in texture and/or eventual chemical alterations of colour, flavour and texture (Mohsenin, 1986).

The presence of bruising and other types of mechanical damage (cuts, puncture, split, abrasion) causes significant economic loss of fresh produce due downgrading or rejection of the appearance quality by the consumer (Van Zeebroeck et al., 2007c; Prusky, 2011). In addition, researchers have also demonstrated that the presence of mechanical damage also accelerates physiological processes which lead to senescence and spoilage as well as loss of nutritional value. For instance, studies by Wilson et al. (1995) showed that a single bad bruise on an apple increased the rate of moisture loss by up to 400%. In another study, sweet potatoes showed a 72% increase in the respiration rate after physical impact (Saltveit and Locy, 1982), while bruised tomato tissue was reported to have lower vitamin C content than unbruised tissue (Moretti et al., 1998; Sablani et al., 2006). Furthermore, fruit affected by bruising easily ferment, rot, or get mildewed, and infect other undamaged fruit during storage (Opara et al., 2007; Prusky, 2011; Lü and Tang, 2012). Research on a wide range of fruit and vegetables has shown that up to 30–40% of produce may be affected by bruising and other types of mechanical damage from harvesting to market (Peleg and Hinga, 1986), amounting to significant financial losses in the fresh produce industry (Hyde et al., 1993; Funt et al., 2000; Storey, 2007). Given these substantial losses and potential

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Fig. 1. Different levels of bruising in avocado fruit (Gamble et al., 2010).

gains in developing measures to reduce the problem, it is important to have reliable methods to measure, analyse and detect bruise damage.

Despite the economic importance of bruise damage as a major quality problem in postharvest handling of fresh horticultural produce, there is currently no comprehensive review on the subject. The aim of this article is to provide a review of recent technological developments in bruise measurement, detection and analysis of fresh horticultural produce. Given the rising demand for rapid and accurate methods of quality measurement in the horticultural produce industry, special attention is given to the application of instrumented spheres for bruise detection, analysis and control during postharvest handling.

2. Bruise damage of fresh horticultural produce—an overview

2.1. What is a bruise?

A bruise is a type of subcutaneous tissue failure without rupture of the skin of fresh produce (Mohsenin, 1986), where the discolouration of injured tissue indicates the presence of a damaged spot. Depending on the extent of damage, the presence of a bruise may take up to 12 h of incubation period to become visible, which means that affected produce may not detected until they reach the consumer at the point of purchase or consumption (Van Linden et al., 2008).

Bruising results from excessive force on the surface of fresh produce; however, it is still not clear which factors determine the differences in susceptibility of produce such as fruit to a given force (Topping and Luton, 1986). Fruit are susceptible to bruising when they impact each other or a hard surface during picking and postharvest operations in the packhouse, during transport and at retail stores (Yurtlu and Erdogan, 2005). To reduce the incidence and severity of bruise damage, knowledge of the fruit properties and postharvest handling factors influencing bruise susceptibility is important (Ahmadi et al., 2010; Abedi and Ahmadi, 2013). Consequently, several researchers have presented bruise prediction models (details in Section 5.2) based on impact properties (peak contact force, impact energy or drop height) and fruit properties (temperature, stiffness, radius of curvature, etc.) which influence bruise sensitivity (Bajema et al., 1998; Bajema and Hyde, 1998; Van Zeebroeck et al., 2007a; Ahmadi et al., 2010; Zarifneshat et al., 2010, 2012; Ahmadi, 2012; Abedi and Ahmadi, 2013).

2.2. Factors influencing bruise damage

The incidence and severity of bruising is influenced by several preharvest and postharvest factors such as variety, maturity status, crop load, irrigation and temperature of produce (Mohsenin, 1986; Geyer and Herold, 1995; Studman, 1997; Opara, 2007). Research on fruit has also shown that external factors such as fruit size, shape, water status, firmness and internal factors, internal factors such as cell wall strength, elasticity, cell shape and internal structure (Studman, 1997; Van Linden et al., 2006b) affect the potential and severity of bruising. In apples, fruit texture was shown as a major contributor to bruise susceptibility and might vary considerably within the fruit (Khan and Vincent, 1993a,b). Fruit turgidity and firmness have also been reported to influence impact bruise susceptibility in apples and pears (Garcı′a et al., 1995). Temperature of the fruit at the time of bruise induction (Saltveit, 1984; Thomson et al., 1996; Baritelle and Hyde, 2001), and storage temperature after bruising (Saltveit, 1984; Thomson et al., 1996), affect bruise development. To date, produce type and cultivar differences account for most of the differences in bruise susceptibility; however, it is still not known which produce factors contribute most to the potential