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Susceptibility of apples to bruising inside ventilated corrugated paperboard packages during simulated transport damage

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ABSTRACT

The incidence of fruit postharvest losses and waste due to mechanical damage during handling is a major problem in the fresh produce industry Among the various range of force loading conditions experienced during handling and transportation, vibration is one of the key factors which may result in fruit bruise damage and the type of package used during handling of fruit could significantly affect the physical quality of the fruit. A simulated transport study was used to assess the susceptibility of apple fruit inside two ventilated corrugated paperboard (VCP) packages (MK4 and MK6) commonly used in fresh produce industry for packing apple fruit. An electro-dynamic shaker was used to excite vibrations at three frequencies (9, 12 and 15 Hz) and 0.9 g amplitude for four hours, which is usually adopted for truck transport simulation. Packaging transmissibility and incidence of bruise damage were measured at different frequencies. Results showed that both the incidence and severity of apple bruising were affected by package design and frequency. For both package designs at the three vibration frequencies investigated, packaging transmissibility ranged from 100 to 250%, with the highest transmissibility observed on the MK6 package with a lower length–to–height ratio at 12 Hz compared to the MK4 package. Apple fruit inside the MK4 package with higher length–to–height ratio had less damage than fruit inside the MK6 package. Irrespective of the package design, apple fruit on the top layer were more susceptible to bruising and the range of the proportion of bruised apples was between 50 and 74% at all the three frequencies, which are rather extreme conditions that usually occur when loads of packed fruit damage during transport.

1. Introduction

Horticultural products, especially apples are highly susceptible to damage during transportation and postharvest handling (Sittipod et al., 2009; Eissa et al., 2012). The need to provide high quality products without blemish, cuts, bruises, physiological disorders and pathogens is important, which is emphasised and insisted on by consumers (Timm et al., 1996; Remón et al., 2003; Eissa et al., 2012). Various studies have been conducted which indicate that impact, compression and vibration forces account for the majority of the mechanical damage of horticultural products (Idah et al., 2007; Jarimopas et al., 2007; Opara et al., 2007; Van Zeebroeck et al., 2007a,b; Chonhenchob et al., 2009; Lu et al., 2010; Ahmadi, 2012; Babarinsa and Ige, 2012; Eissa et al., 2012; Lu et al., 2012; Fadiji et al., 2016). Transportation is important in the distribution process of horticultural products, however, vibration during transportation causes critical damage to packages and produce (Sittipod et al., 2009). Mechanical damage is responsible for the deterioration in the quality of fresh produce. Disposed produce due to mechanical damage is estimated to be about 40% (Barchi et al., 2002; Vursavufi and Özgüven, 2004). Cautious handling and proper packaging have shown to minimise the losses

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of fruits due to mechanical damage (Singh et al., 1992; Chonhenchob and Singh, 2003; Chonhenchob et al., 2009). Evidence of severe problems of mechanical damage is on the increase and is affecting the trade in fruits and vegetables (Okhuoya, 1995), giving a clear indication of the need to improve the handling methods, particularly optimising the packages to provide better protection.

Several studies have been reported investigating the effects of vibration during transport on different horticultural products such as peaches (O'Brien et al., 1969; Vergano et al., 1991; Oeguet et al., 1999), loquats (Barchi et al., 2002), pears (Slaughter et al., 1993; Jancsók et al., 2001; Berardinelli et al., 2005; Zhou et al., 2007), tomatoes (Olorunda and Tung, 1985; Singh and Singh, 1992; Babarinsa and Ige, 2012a, 2012b; Idah et al., 2012; Bello et al., 2013), kiwifruit (Tabatabaekoloor et al., 2013) and apples (Timm et al., 1996; Vursavufi and Özgüven, 2004; Van Zeebroeck et al., 2006; Acıcan et al., 2007; Eissa et al., 2012). Hinsch et al. (1993) studied the vibration of cherries, nectarines and pears on semi-trailers with steel spring suspension systems. The authors reported that the highest Power Spectral Density (PSD) levels occurred at the rear of the trailer at a frequency of 3.5 Hz. Also, frequencies of 3.5, 9, 18.5, and 25 Hz were the most frequent during transportation. Vertical acceleration was much higher than the horizontal acceleration with similar observations reported by Singh and Marcondes (1992). Similar to these findings, Slaughter et al. (1993) found the most severe damage at frequencies of 3.5 and 18.5 Hz in transit damage of Bartlett pears. Chonhenchob and Singh (2005) performed an actual shipment and vibration test in order to compare the packaging performance and the effects on quality of two cushioning systems; foam nets and paper-based wrap materials for exporting papaya fruit. The authors reported that although the paper-based cushions provided a similar protection as to the plastic foam nets materials, the paper-based cushions offered a better ripening response for papayas. In another study by Park et al. (2011), the authors evaluated the vibration transmissibility of corrugated paperboard with corrugation shape and equilibrium atmospheric conditions by a sinusoidal sweep vibration test. Vursavus and Ozguven, 2004 studied the effects of vibration parameters and packaging methods on mechanical damage in apples. The volume packaging method had the highest packaging transmissibility as compared to the pulp tray packaging and pattern packaging methods. For all the packaging methods used in the study, packaging transmissibility was at similar high levels at a vibration frequency interval of 8–9Hz. The authors concluded that the equivalent severe bruise index was affected significantly by vibration frequency, vibration acceleration, packaging methods and vibration time. In a recent study by Eissa et al. (2012), the authors compared the package cushioning materials for apples to vibration damage using an exciter vibration Table and a force transducer to evaluate the damage on the apple. Three types of cushioning materials (foam-net, paper-wrap and without (control)) were used. The foam-net package was concluded to be the most suitable for packaging and it reduced the percentage of fruit damage by 50–63%.

Vibration due to transportation is influenced by the road roughness, distance, traveling speed, truck suspension, load and number of axles (Berardinelli et al., 2003; Vursavus and Ozguven, 2004; Idah et al., 2012; Pathare and Opara, 2014). Although, damage caused by vibration on different species of fruits and vegetables such as apricot, tomatoes, grapes and pears etc. have been assessed by several authors as reported by Berardinelli et al. (2005), very little knowledge is available on package and fruit interaction when subjected to vibration. A clear understanding of the behaviour of package and produce under static and dynamic loads provides information in minimising the mechanical damage to packaged produce and enhancing the quality of fresh horticultural produce (Jarimopas et al., 2005; Idah et al., 2012; Eissa et al., 2012). Careful handling and proper packaging have been reported to reduce mechanical damage (Singh et al., 1992). Minimised mechanical damage would ensure that the produce gets to the ultimate users in a desirable condition.

As reported by Pathare et al. (2012), ventilated paperboard carton is commonly used for handling fresh fruit and Berry et al. (2015) also described a wide range of ventilated package designs for handling different produce in the fresh fruit industry. Previous studies have demonstrated the significant effect of package design on the cooling performance of ventilated package designs used in handling of fresh fruit, including energy use and efficiency (Zou et al., 2006a,b; Delele et al., 2013a; Delele et al., 2013b; Defraeye et al., 2013, 2014; Han et al., 2015). A recent study by Fadiji et al. (2016) reported the significant influence of package design in protecting apple fruit subjected to impact. Although, there exist a vast knowledge on the preharvest and postharvest factors contributing to fruit bruising especially when subjected to mechanical loadings (Opara, 2007; Van Zeebroeck et al., 2007a, b; Opara and Pathare, 2014). Little is known about the bruise of fruit packed inside ventilated paperboard carton during simulated transport damage. The objective of this research was to simulate the transport damage on ventilated paperboard packages and evaluate the susceptibility of packed apples inside the packages to vibration bruise damage, including the spatial variability and severity of bruise occurrence inside the package.

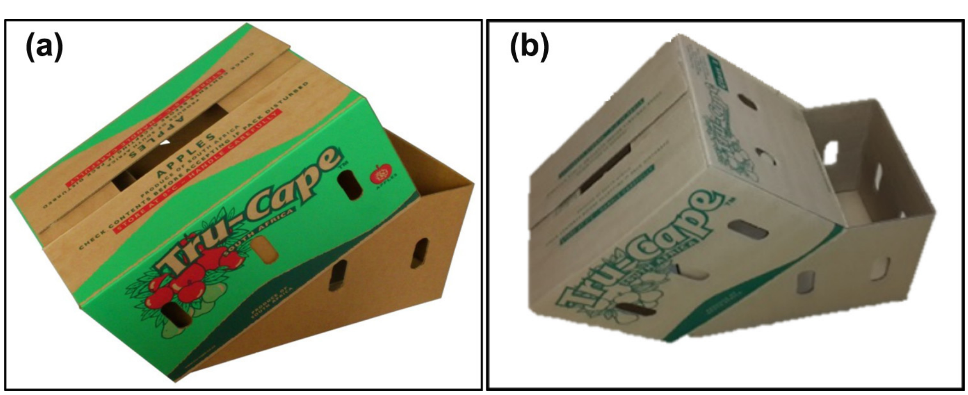

Fig. 1. (a) MK4 package and (b) MK6 package. Both MK4 and MK6 package designs have three oblong shaped vent holes oriented vertically on the long side of the package and the total area of the vent were 5007 mm^2 and 4241 mm^2, respectively. MK6 package has a lower length-to-height ratio of 1.45 and shorter trays, compared to the length-to-height ratio of 1.86 for MK4 package with longer trays.