



## Susceptibility to impact damage of apples inside ventilated corrugated paperboard packages: Effects of package design



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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. Ventilated corrugated paperboard (VCP) packages used extensively in the fruit industry are designed to minimize handling damage and to facilitate airflow around the produce to maintain the cold chain. During handling and transportation, both the package and contents experience a range of force loading conditions, including impact, compression and vibration which may result in bruise damage. The objectives of this study were to investigate the impact bruise damage susceptibility of apples packed inside two ventilated carton designs (one with fruit on tray layers and the other with fruit in retail polyethylene plastic bags). The spatial variation of bruise damage inside the packages and the incidence of physical damage of the packages were also investigated. Results showed that both the incidence and susceptibility to bruise damage of the apples were affected by package design and drop heights; with more than 50% higher incidence and 66% higher bruise susceptibility occurring on fruit packed in the bulk package design than on those packed in the layered package design. Irrespective of package design, both bruising incidence and susceptibility were highest at the bottom of the package, which increased significantly by about 50% when the package drop height increased from 30 cm to 50 cm.

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### 1. Introduction

Packaging fresh fruit and vegetables is an important step in the long and complicated journey from the grower to consumer. Bags, crates, hampers, baskets, cartons, bulk bins, and palletized containers are common forms of packaging used when handling, transporting, and marketing fresh produce. However, despite the availability and use of different packaging formats and designs in fruit handling, the occurrence of bruise damage is still a frequent quality problem (Lu et al., 2010a,b; Opara and Pathare, 2014).

Consumer perception of fresh produce quality is influenced by the appearance, shape and textural characteristics, and these in turn influence purchasing decisions. Consumers desire high quality produce that is free from bruise, cuts, punctures,

physiological disorders and pathogens (Matzinger and Tong, 1993; Timm et al., 1996). The presence of bruising and other types of physical damage reduce the aesthetic appeal of fresh produce. Previous studies have shown that bruising due to excessive compression, impact and vibration forces is the most common type of postharvest mechanical injury (Brown et al., 1993; Maness et al., 1992; Knee and Miller, 2002; Jarimopas et al., 2007; Opara, 2007; Lewis et al., 2008; Opara and Pathare, 2014). In addition to the loss of appearance quality, bruised fruit is also susceptible to high risk of fungal and bacterial contamination and excessive moisture loss, as high as 400 times more than that of intact fruit (Wilson et al., 1995). Several researchers have studied fruit bruising due to impact (Holt and Schoolt, 1977; Schoolt and Holt, 1980; Peleg, 1981, 1985; Jarimopas et al., 1984; Chen and Yazdani, 1991; Pang et al., 1992; Bajema and Hyde, 1998; Ragni and Berardinelli, 2001).

Peleg (1985) describes good interior packaging as that which treats individual fruits as separate units, avoids fruit-to-fruit contact, and absorbs the impact energy. Holt and Schoolt (1984) compared three different types of packaging for their protection

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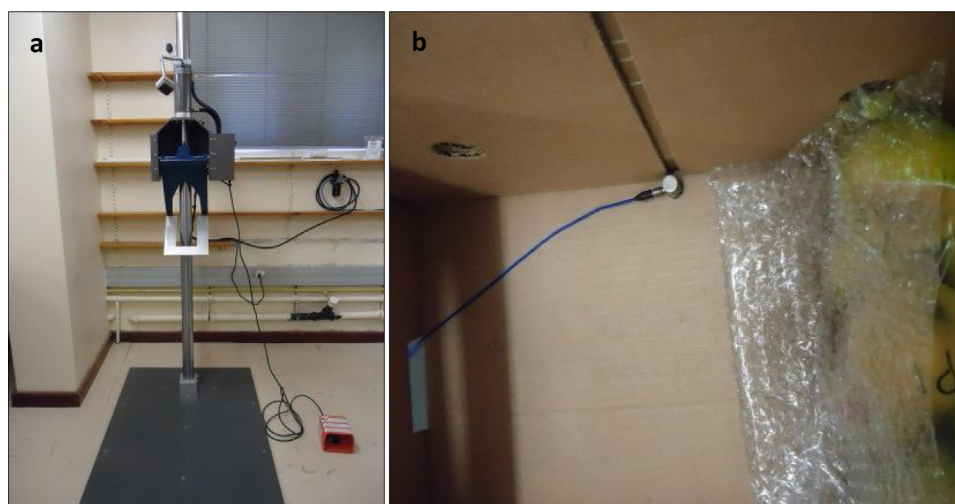
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**Fig. 1.** Packaging designs used: (a) MK4 box; (b) tray arrangement in MK4 box; (c) Econo box; (d) fruit packed in plastic bags arranged in bulk inside Econo box.

afforded to apples against damage due to impact. The authors found that wooden boxes afforded the least protection, followed by returnable crates and tray packs. In another study of apples in bulk bins during semi-trailer transport, [Timm et al. \(1996\)](#) found that fruit in plastic bins had less abrasion damage in comparison to those packed in hardwood and plywood bins. In contrast, [Accan et al. \(2007\)](#) studied the mechanical forces exerted on apples in wooden crates during transport from harvest to market under free fall, horizontal impact and vibration forces and found that the mechanical forces acting on the apples at the bottom of the crate was greater than those at the upper layer and that there was a significant difference between the damage at the lowest and the uppermost layers.

Ventilated paperboard carton is the most common type of packaging used for handling fresh fruit ([Pathare et al., 2012](#)). A wide range of ventilated package designs are used for handling produce in the fresh fruit industry ([Berry et al., 2015](#)); however, in the two main types of ventilated packaging designs, produce may be packed on tray layers or placed inside plastic bags each containing up to ten pieces of fruit. Both types of package design and multi-scale packing are used extensively in long distance (export) and local fresh fruit supply chains. Previous studies have reported the significant influence of package design on cooling performance of ventilated package designs used for handling fresh fruit, including energy efficiency ([Defraeye et al., 2014, 2013](#); [Delele et al., 2013a,b](#); [Zou et al., 2006a,b](#)). Although there is a vast



**Fig. 2.** Drop testing equipment used (a) Lansmont model PDT-56 drop tester (b) PCB model 353B15 accelerometer.

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