Scientia Horticulturae 227 (2018) 154–161

Contents lists available at ScienceDirect

Scientia Horticulturae

journal homepage: www.elsevier.com/locate/scihorti

Research paper

Compression damage susceptibility of apple fruit packed inside ventilated corrugated paperboard package

Umezuruike Linus Opara[a,b,*], Tobi Fadiji[a,c]

[a] Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Sciences, Faculty of AgriSciences, Stellenbosch University, South Africa

[b] Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Food Science, Faculty of AgriSciences, Stellenbosch University, South Africa

[c] Department of Mechanical and Mechatronics Engineering, Faculty of Engineering, Stellenbosch University, South Africa

ARTICLE INFO

Keywords:
Ventilated packaging
Compression damage
Bruise
Apples
Package design

ABSTRACT

Ventilated corrugated paperboard (VCP) packages are used widely in the fruit industry cold chain and are designed to reduce produce damage while still maintaining adequate air distribution needed to ensure optimum heat transfer from produce to cold air. The packages may experience mechanical failure due to excessive compression load under such cold chain conditions, which may lead to bruising of the packed fresh produce, particularly apple fruit that are susceptible to mechanical damage during postharvest handling. The objectives of this study were to investigate the compression bruise susceptibility of apples packed inside two ventilated corrugated paperboard packages (MK4 and MK6). The MK4 package design has higher length-to-height, longer trays and higher vent area compared to the MK6 package design. Results showed that the susceptibility to bruise damage was affected significantly by package design. Fruit bruise damage inside the MK6 package design was more than the apple fruit bruise damage inside the MK4 package design, with differences of about 63% and 43% in apple bruise area and apple bruise volume, respectively. Irrespective of package design, fruit placed towards the bottom of the package incurred lesser damage.

1. Introduction

In the postharvest journey of fresh fruit from growers to consumers, packaging remains a vital step. Various types of packages and mode of transportation may be used in handling fresh fruit (Lu et al., 2012; Lu et al., 2010; Van Zeebroeck et al., 2007). Fruits and vegetables may experience various loading conditions during handling, transportation and storage and these loadings may be dynamic, static and mostly in real life conditions, a combination of both exist (Opara and Pathare, 2014; Lewis et al., 2008). These loading conditions usually lead to mechanical damage on the packed fruit in spite of the handiness and the use of different package designs used in handling fresh fruit (Berry et al., 2015), which consequently results in postharvest loss of fresh fruit (Knee and Miller, 2002) resulting in postharvest loss of fresh fruits (Fadiji et al., 2016a,b; Opara and Pathare, 2014; Prusky, 2011; Van Zeebroeck et al., 2007).

The main objective of the production, handling and storage of fresh horticultural produce is to deliver good quality product in sound condition, which is satisfying to the consumer (Opara and Pathare, 2014). However, mechanical damage is responsible for extensive rot or decay of fresh fruits and vegetables, which leads to about 30% to 40% produce loss (Barchi et al., 2002). A clear understanding of the interaction between package and produce under static and dynamic loading conditions provides useful information in minimising mechanical damage and ensuring the delivery of quality fresh produce to the consumers (Fadiji et al., 2016a,b; Opara and Pathare, 2014; Abedi and Ahmadi, 2014; Ahmadi et al., 2010; Dewulf et al., 1999; Roudot et al., 1991; Holt and Schoorl, 1984).

Several researchers have catergorised the loadings causing mechanical damage into compression, impact and vibration forces (Fadiji et al., 2016a,b,c; Opara and Pathare, 2014; Kitthawee et al., 2011; Lewis et al., 2008; Opara, 2007; Jarimopas et al., 2007; Robertson, 2005; Lee et al., 2005; Knee and Miller, 2002; Bollen et al., 1999; Brown et al., 1993; Vergano et al., 1991; Ruiz Altisent, 1991; Brusewitz et al., 1991; Armstrong et al., 1991; Holt and Schoorl, 1984). As noted by Brown et al. (1993), fruits are exposed to compression via forces applied through contact by the picker, tree limbs, fruit to fruit contact due to overfilled cartons or carton stack height or by an operator

* Corresponding author at: Postharvest Technology Research Laboratory, South African Research Chair in Postharvest Technology, Department of Horticultural Sciences, Faculty of AgriSciences, Stellenbosch University, South Africa.
E-mail addresses: opara@sun.ac.za, umunam@yahoo.co.uk (U.L. Opara).

http://dx.doi.org/10.1016/j.scienta.2017.09.043
Received 31 March 2017; Received in revised form 24 September 2017; Accepted 25 September 2017

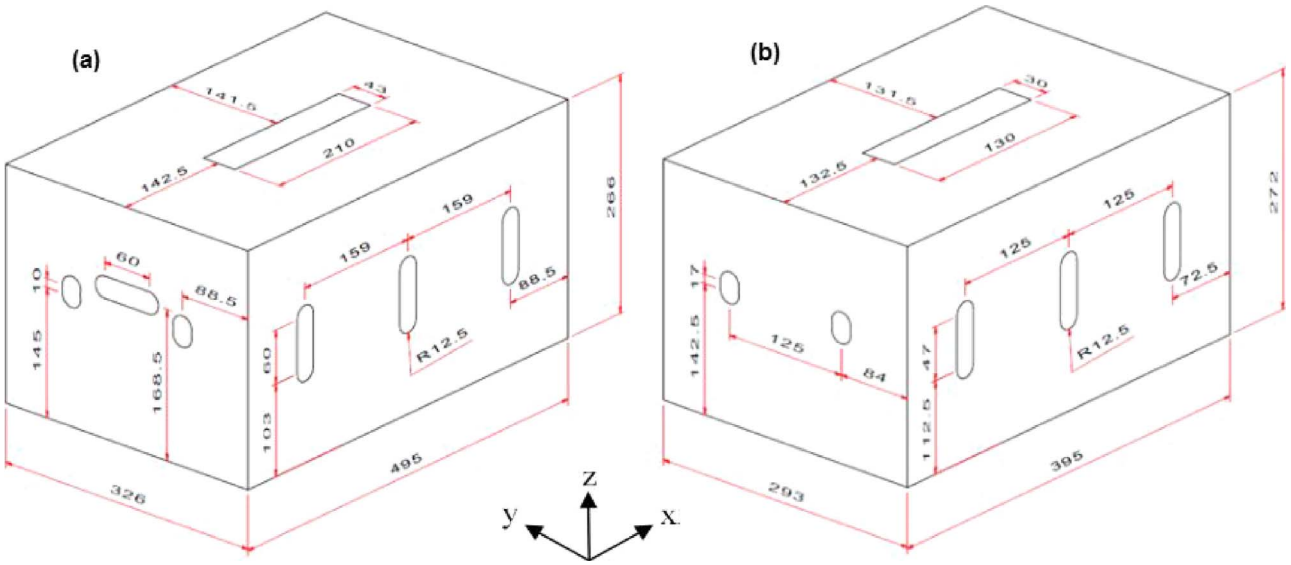

Fig. 1. Geometry and dimensions (mm) of the (a) MK4 and (b) MK6 packages. Both package designs have three oblong shaped vent holes oriented vertically on the long side of the package and the total vent area were 5007 mm^2 and 4241 mm^2, respectively. MK6 package has lower length–to–height ratio of 1.45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

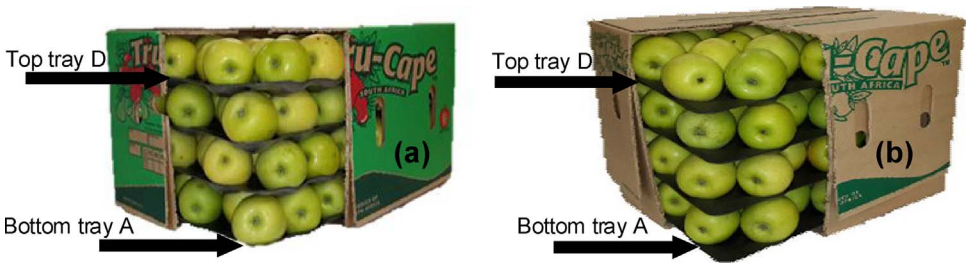

Fig. 2. (a) Placement of apple fruit inside MK4 package using the tray arrangement and (b) Placement of apple fruit inside MK6 package using the tray arrangement.

Fig. 3. Lansmont compression tester (Lansmont Corporation, Monterey CA, USA).

forcing cartons into a tight spot, among others. Vibration forces occur during transportation and are difficult to avoid (Fadiji et al., 2016b; Opara and Pathare, 2014). When the cartons reach resonance (their natural frequency equals the forcing frequency of the conveyance), severe mechanical damage is inherent. Impact forces are usually high, occurring in an extremely short duration and impact results from dropping produce or packed produce on an insufficiently cushioned surface during mechanical handling of fresh produce. Bruise damage which reduces the overall quality and economic value of affected produce are the results of impact forces (Eissa et al., 2012). The incidence of these forces are difficult to eliminate during extensive production and distribution of horticultural produce (Fadiji et al., 2016a; Gołacki et al., 2009).

The mechanical properties of fruit and vegetables affect the response of packaged produce under applied forces during transportation and handling (Babarinsa and Ige, 2012). Studies have been done on the mechanical damage of horticultural produce due to compression loading (Kılıçkan and Güner, 2008; Khan and Vincent, 1993; Holt and Schoorl, 1977) such as apricots (Vursavuş and Özgüven, 2004a) and tomatoes (Babarinsa and Ige, 2012). One of the major requirements of good packaging, especially for fresh horticultural produce, is the ability to prevent mechanical damage, particularly that which results from compression loading (Robertson, 2005). Therefore, in designing better and more effective package, understanding the performance of a package under static loads (compression) is crucial.

Among different and convenient forms of packaging such as bags, crates, hampers baskets, cartons, bulk bins, and palletized containers which exists for handling fresh produce, ventilated corrugated paperboard (VCP) package is the most commonly used type of package for the packaging and distribution of a wide variety commodities ranging from fruits and vegetables, industrial products and consumables (Fadiji et al., 2016c; Berry et al., 2015; Pathare et al., 2012). During transportation and storage, packages are stacked on top of each other causing the package at the bottom to experience the greatest load (Fadiji et al., 2016c). Therefore, the bottom package must have adequate and sufficient stacking strength to withstanding the load without collapsing (Fadiji et al., 2016c; Daxner et al., 2007). While several studies have reported on the potential of fruit to bruise due to impact (Komarnicki et al., 2016; Lu et al., 2012; Lu et al., 2010), compression (Kılıçkan and Güner, 2008; Timm et al., 1998) and vibration (Eissa et al., 2012; Zhou et al., 2007; Vursavuş and Özgüven, 2004b) forces, little is known about fruit bruising incidence under impact, compression and vibration inside ventilated paperboard cartons commonly used in fresh fruit industry. In recent articles, we reported the incidence of