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Vibration Damage to Kiwifruits during Road Transportation

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Abstract

A serious problem in the transportation is the bruise of the fruit due to vibration. In this research, the effects of road transportation factors such as vibration frequency, acceleration, size and stack height in the bin were investigated on the kiwifruit damage. A laboratory vibrator was used to simulate the road transportation. Rate of damage was based on the bruise depth of kiwifruits. The obtained data were statistically analyzed using randomized complete block design based on a factorial experiment with four factors; vibration frequency (7.5 and 13 Hz), vibration acceleration (0.3g and 0.7g), size (small and large), and stack height (11, 23 and 34 cm) on the percentage of damage to the kiwifruits. Analysis of data indicated that size and stack height, frequency and acceleration had significant effect on the percentage of total damaged fruits and percentage of fruits with a bruise depth higher than 2 mm ($P< 0.01$). The mechanical damages considerably increased by increasing the vibration frequency and acceleration. The larger kiwifruits were more prone to damage than the smaller ones during transportation. The total damage considerably increased by increasing the stack heights of fruits inside the bin. The maximum damage to kiwifruits happened in vibration frequency of 13 Hz, vibration acceleration of 0.7 g, stack height of 34 cm and large size of kiwifruits.

Keywords: Kiwifruit; transportation; vibration; frequency.

1. Introduction

Kiwifruit is considered as an important commercial fruit in Iran with a mean annual production of 34000 tones. Iran ranked sixth producer of kiwifruit in the world (FAO, 2011) and part of production are exported. Kiwifruit cultivars such as Hayward, Bronut, and Manti are widely grown in Iran.

Mechanical damage which can occur during different stages of fruit harvest and post harvest represents a serious hazard to quality and has the potential to significantly reduce the value of product (Van Zeebroeck et al., 2007). Among different causes of damage to fruits, vibration generated by vehicles during road transport has an important roll on the damage process to the agricultural products, particularly soft fruits (Acican et al., 2007). The occurrence of damage to kiwifruits in transport is related to a number of factors, out of which the most important is the fruit resistance to mechanical damage due to vibration. The vibrations due to transportation are influenced by road roughness, distance, speed, packaging and some characteristics of the truck suspension and the number of axles (Vursavus and Ozgoven, 2004).

There is no reported data on vibration damage of kiwifruit. Therefore, the objectives of the present study were to simulate the transport vibration under laboratory conditions and to investigate the effects of mechanical parameters such as vibration frequency, vibration acceleration, stack height and size of kiwifruits in the bin on the damage during the transportation.

2. Materials and Methods

The kiwi variety Hayward is one of the common commercial varieties grown in Iran and all over the world was used in this study. Samples were carefully harvested from an orchard in the Northern region of Iran. To minimize any bruising before testing, it was placed in the corrugated containers and carefully handled up to the laboratory and stored at 25^{o}C, 89.7% humidity until testing. The vibration simulator used to provide amplitudes and frequencies on trucks, which were similar as described by Shahbazi et al. (2010). Figure 1 shows the laboratory vibration simulator.

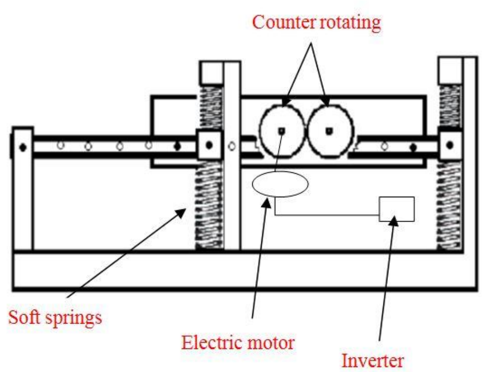

Figure 1: Vibration simulator.

Four different variables including vibration frequency (7.5 and 13 HZ), vibration acceleration (0.3 and 0.7 g), fruit size (46.58 ± 4.47 and 65.83 ± 2.98 mm), and stack height (11, 23, and 34 cm) were used in this study. The acceleration of vibration was directly measured using an acceleration simulator table and a piezoelectric accelerometer. A wooden bin (30 cm by 40 cm by 35 cm) with kiwifruits was placed on the vibration table as same as truck transportation.

3. Results and Discussion

3.1 Effects of acceleration and frequency on the bruise depth

The effects of vibration frequency and vibration acceleration (0.3 g and 0.7 g) on bruise depth of kiwifruits were studied at 34 cm stack height and the results are shown in Figures 2 and 3. The results indicated that the number of un-bruised kiwi fruits decreased by increasing in vibration acceleration from o.3 g to 0.7g. It shows the negative effect of acceleration in transportation of kiwifruits.

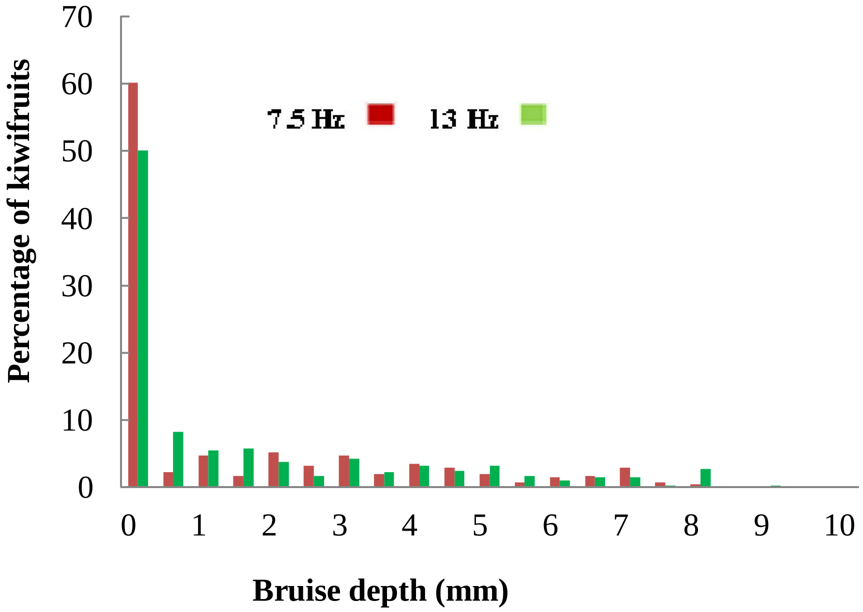

Figure 2: The effect of frequency on bruise depth of kiwifruits in vibration acceleration of 0.3 g.

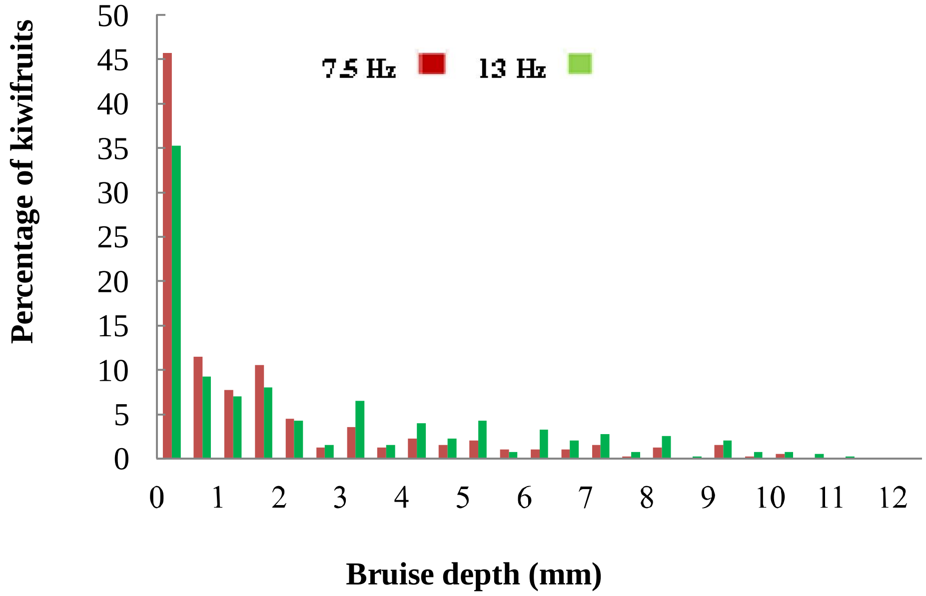

Figure 3: The effect of frequency on bruise depth of kiwifruits in vibration acceleration of 0.7 g.

Table 1 shows that there is no significant difference between frequencies of 7.5 and 13 Hz at acceleration of 0.3 g, but it showed the significant difference at acceleration of 0.7 g. Based on the above findings, by increasing of vibration acceleration the mechanical damages to kiwifruits increased in the road transport due to increasing the power and intensity of received forces. As a result, the size and intensity of acting forces on the kiwifruits that are in the shape of repetitive forces increased. These factors become the cause of destruction of tissues of kiwifruits. The test results in this study were similar to those obtained by other researchers (Van Zeebroeck et al., 2006; Shahbazi et al., 2010).

Table 1: Mean comparison of interaction between vibration frequency and acceleration.

Percentage of kiwi fruits with a bruise depth > 2 mm			Percentage of total damaged fruits	
	Acceleration (g)			
Frequency (Hz)	0.3	0.7	0.3	0.7
7.5	22.3 [a]	21.45 [a]	40.3 [a]	45.54 [a]
13	22.34 [a]	30.71 [b]	41.3 [a]	57.51 [b]

Means with the same letter have no significant difference at 5% level of confidence.

3.2 Interactions of vibration frequency, stack height and size on kiwifruit damage

Table 2 shows the percentage of total damaged fruits due to different frequencies, sizes and stack heights. At frequency of 7.5 Hz, only the difference between stack height of 11 and 34 cm was significant, while for the same condition at vibration frequency of 13 Hz the difference between all three stack heights were significant ($P < 0.05$). It shows that the amount of total damages increases by increasing of vibration frequency and stack height, simultaneously. Therefore, most of damages (about 61.5%) were in vibration frequency of 13 Hz and stack height of 34 cm.

Table 2: Mean comparison of interaction between vibration frequency and size of fruit at different stack heights on percentage of total damaged fruits.

		Frequency (Hz)		Size (mm)	
		7.5	13	46.6 ± 4.47	65.8 ± 2.98
Stack height (cm)	11	34.19 [a]	37.15 [a]	7.82 [a]	16.64 [c]
	23	43.08 [ab]	49.5 [b]	17.48 [b]	32.87 [d]
	34	51.48 [bc]	61.53 [c]	26.74 [b]	43.64 [e]

Means with the same letter have no significant difference at 5% level of confidence.

Table 3 shows the effect of frequency, size and stack height on the percentage of fruits with a bruise depth higher than 2 mm. Based on the Duncan's multiple range test results, increasing the frequency had significant effect on percentage of fruits with a bruise depth higher than 2 mm at stack height of 11 cm. Also, increasing the stack height increased significantly the percentage of fruits with a bruise depth higher than 2 mm at both frequencies. Fruit size had significant effect on damage with a bruise depth higher than 2 mm. In vibration frequency of 7.5 Hz, the amount of bruise depth higher than 2 mm increased due to increase of stack height and fruit size (Table 3). It could be concluded that the mechanical damage of kiwifruit increased by increasing vibration frequency and fruit size during the road transportation. The results are similar to those obtained by Van Zeebroeck et al., (2006) to study of vibration damage during apple bulk transport.

Table 3: Mean comparison of interaction between vibration frequency and size at three stack height of kiwifruit on percentage of fruits with a bruise depth higher than 2 mm.

		Frequency (Hz)		Size (mm)	
		7.5	13	46.6 ± 4.47	65.8 ± 2.98
Stack height (cm)	11	7.85 [a]	16.61 [d]	7.82 [a]	16.64 [c]
	23	25.03 [b]	25.31 [b]	17.48 [b]	32.87 [d]
	34	32.72 [c]	37.66 [c]	26.74 [b]	43.64 [e]

Means with the same letter have no significant difference at 5% level of confidence.

In general, the reasons for mechanical injuries are numerous, and are often broadly grouped as impact, abrasion, compression and vibration damage, based on the type of force acting on the fruit (Sitkei, 1986). For this reason, increasing of fruit size could be increased the mass and porosity. Therefore, the bigger size has more freedom during the transport and the damaged fruit could be increased. Also, it can be concluded that by increasing of stack height, the mechanical damages to kiwifruits increased during the transportation and it was confirmed by some researchers (Mohsenin, 1986; Ogut et al., 1999; Van Zeebroeck et al., 2006; Nicolai & Tijsknes, 2007).

Indeed, a high vibration frequency (13 Hz), vibration acceleration (0.7 g), and stack height (34 cm) affects damage to the fruit and leads to deterioration in kiwi quality during the transportation. Mechanical forces acting on the kiwifruit at the base of the package are of greater values than those on the upper layers. To decreasing the freedom and suspension of kiwifruits during the transport, the sorting of kiwifruits are necessary before any acting and also minimum layer of fruit is suggested. Eventually, to minimization the percentage of damage during the transportation, the effects of mechanical parameters, stack height and size of fruit should be minimum which is keeping the quality of kiwifruit.

4. Conclusion

This paper involved a case study to investigate the effect of vibration frequency, vibration acceleration, stack height and size of kiwifruit on the percentage of damaged kiwifruits during transportation. Laboratory studies indicated that the higher damage occurred in bigger size of kiwifruits. Increasing the vibration frequency and acceleration increased the total percentage of damage to kiwifruits. The most damage to kiwifruits was occurred in vibration frequency of 13 Hz, vibration acceleration of 0.7 g, stack height of 34 cm and big size of kiwifruits. The effect of frequency and acceleration were more critical when the stack height increased.

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