J. Appl. Environ. Biol. Sci., 4(11S)68-73, 2015

ISSN: 2090-4274
Journal of Applied Environmental and Biological Sciences
www.textroad.com

Effect of Storage Period on Some Orange Mechanical Parameters (*cv.* Valencia)

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Received: October 29, 2014
Accepted: December 31, 2014

ABSTRACT

External and internal changes in fruits during storage time are affected by the various factors. Some of these changes can be studied by measuring the mechanical attributes. In this research, the effects of storage time on some mechanical properties of Valencia orange were investigated. Analysis of experimental results showed that storage time and fruit size have significant effect(at level 1%) on the rupture force and deformation. The resistance of orange fruit in order to applied forces firstly decreased and then increased with increasing time. Rupture force and deformation values were increased by increasing fruit size. Also rupture force affected by load direction so that this value is significantly lower in the longitude direction than the transverse direction.
KEYWORDS: orange, mechanical properties, storage period, static load, load direction.

INTRODUCTION

Large quantities of fruits are wasted each year due to mechanical damage and bruise from field to consumption. Fruit bruising occur during handling, transportation and storage. It is invisible in many cases of fruits such as oranges. To avoid mechanical damages the magnitude the applied forces is required to be less than the failure forces which cause internal damages in oranges. Orange production of Iran during the 2004 to 2012 reduced from 2129 tons to 1285 tons and this is the result of dropping from sixth to thirteenth ranked the countries among this fruit world's producing countries [5]. Most of Iran orange exports in 2004 are to the North coastal countries of Caspian Sea, Turkey and the United Arab Emirates [13] .Unfortunately its lower firmness with respect to the mechanical damaged orange fruit results in large deformation, especially after long-term shipping, this frequently causing the rejection of the entire fruit stock.

Singh and Reddy (2006), studied the effect of storage time on physical and mechanical properties of Nagpur Mandarin orange varieties and also reported that the oranges had 19.4% and 7.3% weight loss after 17 days of storage at ambient (58% RH and 28^{o} C) and refrigerator (78% RH and 7^{o} C) conditions respectively.

Henriod (2006) studied the characteristics of the Navel oranges after harvesting, during storage period and transporting, in high relative humidity condition and express that the weight loss of oranges in high relative humidity conditions (98%) with the temperature less than 5°C in 55 days storage is 3% which in compare with the results of Singh et al (2006) shows a much smaller amount.

Naturally, there is dispersion in the properties of an agricultural product. These differences can show different mechanical behavior of the number of samples collected from the same farm.

According to literature review was conducted, there is little research on the effect of storage time on mechanical properties of the Valencia orange is made. So the aim of this present study was to investigate the changes of the mechanical properties of the Valencia orange fruit during storage period that including the information needed to design and optimize storage and transportation systems in order to reduce waste, thereby optimizing above systems. For this purpose, the effect of storage period, fruit size and load direction on some mechanical properties of complete orange fruit such as failure force and failure deformation were studied.

MATERIALS AND METHODS

To prepare complete samples without any damage, small, medium and large sizes of samples provided directly from a garden that located in Shahsavar city of Iran.

And immediately transported to a GLSZ98V8FWO refrigerator type, and stored at 5 ° C and relative humidity of 90%-85% condition. They were examined in a laboratory at 20 ° C after 2, 32 and 62 storage days. samples were regularly reviewed and if illness or injury were observed they immediately transferred out of the refrigerator.

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Table 1. the mass average of used orange samples						
	2 days after harvesting		**32 days after harvesting**		**2 days after harvesting6**	
	Number of samples	Average± standard deviation	Number of samples	Average± standard deviation	Number of samples	Average± standard deviation
Small	32	103.73±18.06	32	99.675±19.90	32	81.230±18.43
Medium	32	161.311±12.83	32	141.244±14.10	32	128.590±12.94
Big	32	205.868±22.61	32	193.961±28.24	32	167.378±25.72

a) Statistical Analysis:

To provide information on the physical properties of whole orange fruit during storage, a series experiment was performed to determine mechanical properties of orange. Factorial experiment in the form of randomized design with 8 replications was used and the effects of size in three levels (small, medium and large), load direction in two levels (longitude and transverse direction groups) and storage time in three levels (2 days, 32 days and 62 days after harvesting) on the mechanical properties of orange such as failure force and failure deformation were studied. All calculations, data analysis and Duncan test comparison was performed with MSTATC software.

b) Mechanical properties

To determine force–deformation behavior of orange fruit, force was applied to fruit by two flat plates in two longitudinal and transverse directions. The purpose of longitudinal loading in this test is to align the force vector in direction of stem to blossom. Transverse loading of sample was performed in perpendicular direction to longitudinal loading. For loading the samples, German manufactured model 250- Z tension – pressure device with one fixed and one movable grips was used. The lower grip was a 30 cm diameter flat circular plate of the device and upper grip was a similar plate with a diameter of 10 cm, parallel and movable. In a quasi static loading, the loading rate is low enough to obtain the more accurate results and scientific observations (especially for softer materials such as agricultural products and especially orange with a lower modulus of elasticity).

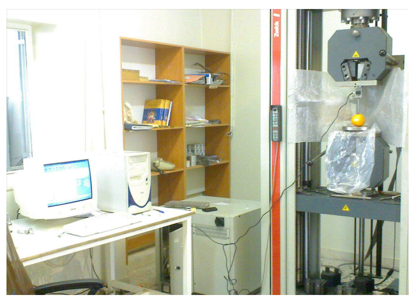

Fig.1. Picture of the experimental apparatus equipped with fixed (lower) and moving (upper) grips. (Diameter of pressure plate is 15 cm and the speed of upper grip is 10 mm/min)

Based on the standard of American Society of Agricultural Engineers, loading rate of 10 mm per minute was selected (ASAE, 2006). Low loading rate (0.1 mmd^{-1}-6 mm/min) is also used in other studies (Bentini *et* al, 2009). However, the loading speed of 15 mm/s, in other studies such as Pallottino et al (2011) have been used.

The application of pressure force in this experiment continued until the first crack in fruit shell was observed. In all experiments force-deformation curves were nonlinear as shown in Figure2. This nonlinear behavior is due to fruit geometrical deformation in compression test which is one of factors of nonlinear behavior of structures [11]. Every mechanical structure such as cylindrical bar, affected by uniaxial pressure (or tension), have changes in section area and therefore its geometrical shape will be changed. This geometrical deformation causes the original assumption of fixed section area to be violated. The stress- strain curve which is linear for lower stresses , to become nonlinear. The force-deformation curve for small forces is similar to stress-strain curve if the section area and length of the material are constant but for large forces to become nonlinear because of changing in area and length. As shown in figure 2, the maximum force in diagram is failure force (F_u) and the deformation of this force is called failure deformation (D_u).

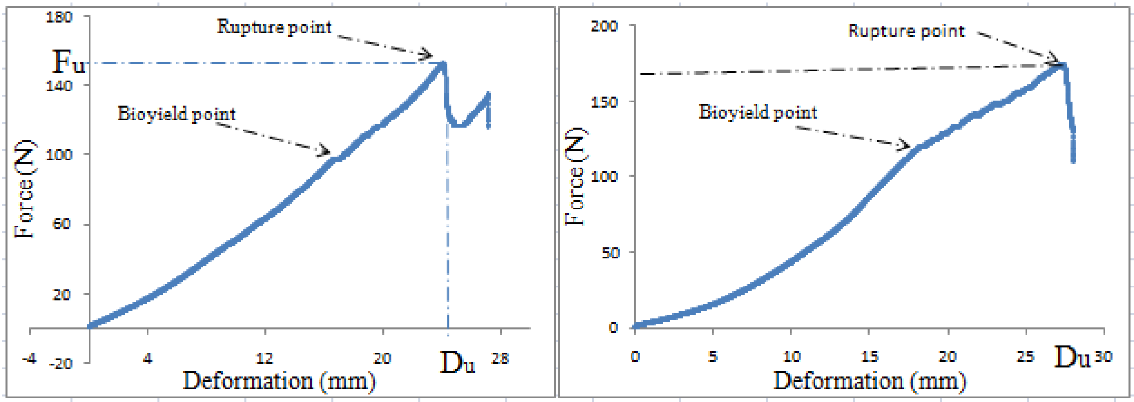

Fig2. Force-deformation curves in static load (loading at longitude (right) and transverse (left)

RESULTS AND DISCUSSION

Magnitudes of failure forces (F_u) and failure deformations (D_u) in fruit loading at longitude and transverse directions are shown in table 2.

As shown in table 2, the mediume size of oranges after 62 days storage in transverse direction loading has the highest failure force with magnitude of 305.887 N and the small size of oranges after 32 days storage in transverse laoding direction has the lowest failure force with magnitude of 110.020 N. The highest failure deformation belongs to big size of oranges after 62 days storage in transverse direction of loading with magnitude of 32.128 mm and the lowest failure deformation belongs to small size of oranges after 32 days storage in longitude direction of loading with magnitude of 17.338 mm.

Table 2. Orange mechanical parameters after three storage times after harvesting

Failure Deformation (mm)	Failure Force (N)	Fruit size	Load direction	Storage Time (days)
21.963	182.193	Small	Longitude	2
25.668	208.516	Medium		
27.834	216.832	Big		
25.155	202.514		Average	
21.887	172.587	Small	Transverse	
27.099	210.764	Medium		
29.496	245.391	Big		
26.161	209.581		Average	
25.658	206.047			**Average**
17.338	119.879	Small	Longitude	**32**
20.911	123.556	Medium		
23.523	149.784	Big		
20.591	131.073		Average	
19.837	110.020	Small	Transverse	
25.144	151.904	Medium		
28.339	182.673	Big		
24.44	148.199		Average	
22.515	139.636			**Average**
20.319	207.801	Small	Longitude	**62**
26.405	232.190	Medium		
29.693	238.885	Big		
25.472	226.292		Average	
22.438	241.759	Small	Transverse	
28.312	305.887	Medium		
32.128	292.868	Big		
27.626	280.171		Average	
26.549	221.072			**Average**

To investigate the effects of factors of orange size, storage period and load direction on orange failure force and failure deformation, analysis of variance was performed and the results are reported in Table 3. Analysis of variance showed that the effect of the fruit size, storage period and load direction factors on the magnitudes of orange failure force and deformation, were significant at 1% level.

Since the effects of factors interaction on the failure force and the failure deformation are not significant, so by comparing the means of these mechanical properties, it can be concluded that the orange after 62 days storage is more resistant than this fruit after 2 days and 32 days storage (see Figure 3). The existence of factors interaction (storage period × load direction) effect on failure force shows that the load direction is affected with storage period on failure force, so as shown in figure 3 it can be concluded that the effect of direction load in 62 days storage on failure force is more than this factor effect on failure force in other storage times.

The effect of load direction on failure deformation is significant at 1% level and interactions effects of factors do not show significant differences, it can be concluded that in all three storage periods, the effect of load direction on failure force is independent of other factors. In other words, the results showed that the factor of load direction in all three sizes has similar effects on failure force and oranges are more resistant in transverse direction loading than the longitude one. Failure deformation averages compared with Duncan test show that in all three storage periods transverse direction loading oranges have the higher failure deformation than the longitude direction loading ones (Fig.3). This result may be due to thickening of the rind in orange blossom and also due to small contact area between the upper loading plate and fruit. This status can increase the stress due to uneven distribution of force in the load point; this reason with the existence of direct relationship between stress and strain cause the higher stresses; in other words increase in failure deformation, may be increasing stress due to discussed reasons.

Assessment by analysis of variance also shows that the effect of fruit size on failure deformation is significant at 1% level; therefore, from given values of failure deformation it can be concluded that in both directions, the failure deformation increased with increasing the fruit size (Fig 3). Pallottino et al (2011) presented similar results by investigating the mechanical properties of a specific orange. This result is agree with findings of many researches on mechanical properties of agricultural products [11]. So we can generally express that the failure deformation increased with increasing the fruit size. The direct relationship between failure deformation and orange size may be because of porous texture of orange, it means that while loading under pressure the pores of orange must be filled and after that the compressive load to the point of rupture disrupts the orange fruit. It is obvious that bigger oranges have more porous than smaller ones, so deforming is continued up to filling these porous and other deformation to fruit rupture will occur. Therefore the failure deformation in bigger sizes of oranges should be bigger than the smaller ones.

Table3. The results of ANOVA analysis showing the effects of size and storage period after fruit harvesting on orange mechanical parameters

Means of squares		**Degree of freedom**	**Source**
Failure deformation	**Failure force**		
215.53**	156326.90**	2	Time A
760.34**	29683.20**	2	Size B
196.48**	24381.04**	1	Load direction C
8.91 ns	1165.70 ns	4	B*A
24.57ns	7286.84*	2	C*A
6.69ns	4083.84ns	2	C*B
1.49ns	613.46ns	4	C*B*A
****significant difference at level 1% , * significant difference at level 5% , ns means no significant.**			

Conclusion

Force-deformation curves in both direction loading test were nonlinear. The magnitudes of orange failure force and deformation were investigated in quasi static load. Results showed that the resistance of orange fruit in response to applied force first decreased and then increased with increasing the time. Also rupture force was affected by load direction so that this value is significantly lower in the longitude direction than the transverse direction. It is recommended that situations in transportation and storage be such that large forces are exerted on the orange in the transverse direction.

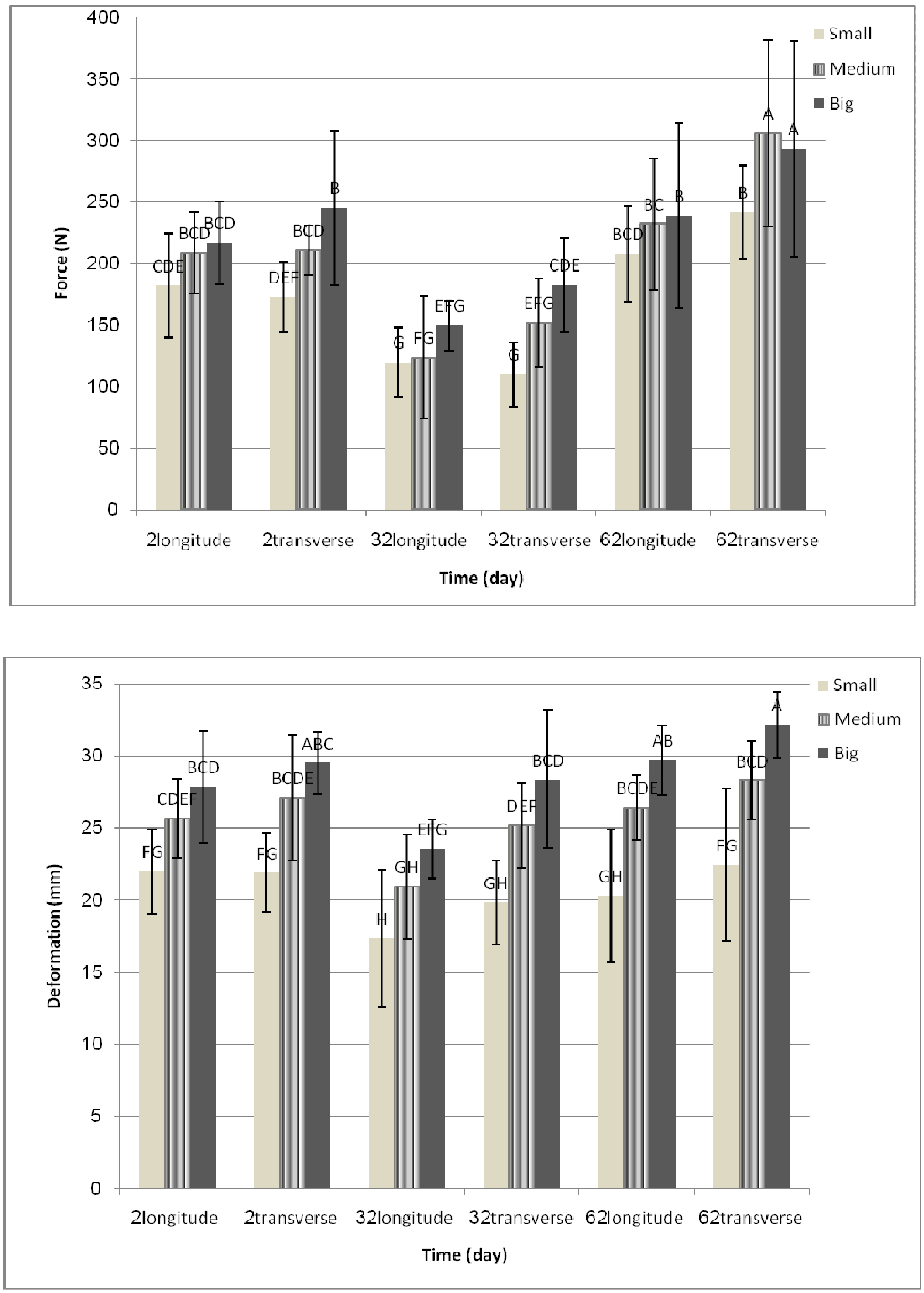

Fig3. The failure force and deformation in 3 storage time at 2 load directions

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