DETERMINATION OF SOME ENGINEERING PROPERTIES OF KUMQUAT RELATED TO DESIGN PARAMETERS

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Abstract
The production of kumquat from the genus Fortunella of Rutaceae family is gradually increasing in South of Turkey. In this study, it is aimed to determine some mechanical properties of the kumquat for the design of the machines to be used harvesting and postharvest. The some mechanical properties of the kumquat grown in the Bati Akdeniz Agricultural Research institute were determined with the help of the texture analyzer device. Mechanical properties such as the elasticity modulus, puncture force, deformation, hardness, Poisson rate, stress and energy in puncture force have been determined. The tests were carried out in three harvest time (optimum harvest time, before and after 10 days from optimum harvest time).Published benchmark data that was generally statistically different will be useful to engineers to new equipment design for different kumquat varieties. These differences that founded can be attributed to environmental and growth conditions.

Key words*: design; mechanical properties; kumquat; puncture.*

INTRODUCTION

Kamquat is native to China but nowadays production is carried out in Japan, Taiwan and Philippines *(Ladaniya, 2008; Quijano & Pino, 2009)*. In recent years, production of kumquat in our country also tends to increase especially in the Mediterranean Region it is grown like other citrus fruits. *(Gölükcü, et al., 2017).*

Mechanical properties of agricultural products are the most important parameters in pre-harvest, harvest and post-harvest operation. To design and improve of relevant machines and facilities used in sowing, harvesting, sorting, conveying, storing, handling and transport, there is a need to know the various engineering parameters of kumquat

Many studies have been reported on the mechanical properties of fruits, such as peach (*Emadi et al., 2011*), oak fruits *(Jalilian, et al., 2011)*, pear *(Wang, 2004)*, persimmon *(Altuntas, et al., 2011)*, oil palm *(Akinoso & Raji, 2011)*, kiwifruit *(Larijani, et al., 2014)*. There is no much detailed studies concerning the mechanical properties of kumquat have been performed till now. Bohdziewicz & Czachor (2016) conducted studies on changes of mechanical properties of kumquat and cape gooseberry fruit during storage and Jalilian et al. (2013) determined physical and mechanical properties of kumquat variety grown in North of Iran.

The aim of this research was to determine the puncture properties of kumquat fruits in three harvest time for design processing machines.

MATERIALS AND METHODS

The Nagami Kumquat (*Fortunella.margarita*) variety that most grown in Turkey used for all the experiments in this study. Forty five kumquat samples that randomly selected were used in the experimental study for the purpose of measure their some mechanical properties in three harvest time They were grown in the Batı Akdeniz Agricultural Research Institute at Aksu, Antalya in the West Mediterranean region of Turkey and kept at room temperature of 20-21ºC in the laboratory. The tests were conducted within the Biological Test Devices Laboratory of Akdeniz University and BATEM, Antalya, Turkiye.

Mechanical Properties of Kumquat

A texture analyses device was used with a force measurement range of 0–100 N to determine the some mechanical properties of kumquat. Force-deformation data were recorded by its software during puncture test and saved as Excel file for all tests (Fig. 1). Also, force-time curves were recorded by software during tests (Fig. 1). The measurement accuracy was ±0.001 N in force and 0.001 mm in deformation. A curve-ended cylindrical probe 2 mm in diameter was used to compress the fruit at 0.5 mm/s loading velocity during all the tests (*ASAE, 1994*).

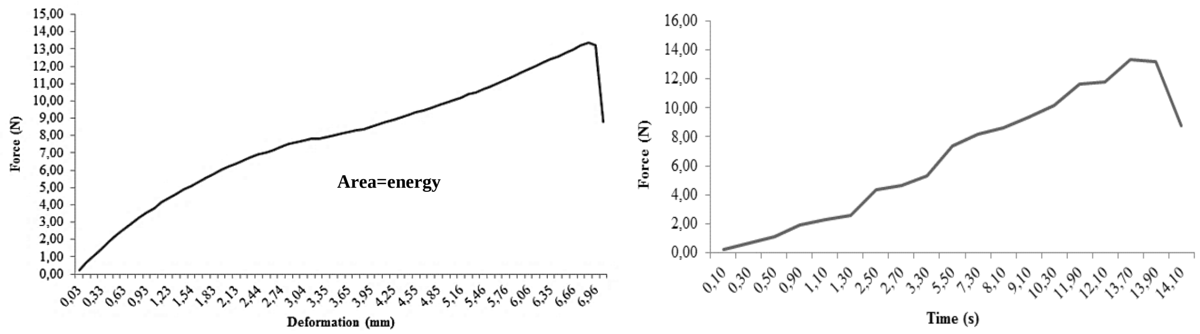

Fig. 1 Force-deformation and time curve from puncture test for Kumquat

Some mechanical properties such as force, energy and deformation at puncture were determined by using these force-deformation curves. The energy absorbed was determined directly from the diagram by measuring the area under the force-deformation curves (Fig. 1)

Poisson ratio, (ν) and Hardness, (H, Nmm^{-1}) were determined by using the following equation (*Finney, 1969; Mohsenin, 1980*).

$$\nu = (\Delta d | d_0) / (\Delta l | l_0) \qquad (1)$$

where, d_0 (orginal diameter of sample, mm), d (diameter of sample after compression, mm), Δd ($d-d_0$), l_0 (orginal length of sample, mm), l_0 (length of sample after compression, mm) and $\Delta l(l_0-l)$ are in mm.

$$H=\frac{F_{max}}{D} \qquad (2)$$

where, F_{max} (maximum puncture force in curve, N) and D (deformation in maximum puncture force, mm).

The modulus of elasticity *E (*Nmm^{-2}*)* of the test fruits was calculated using Boussinesq techniques as follows (*Mohsenin, 1980*)

$$E=F(1-\nu^2)/2aD \qquad (3)$$

where E is the modulus of elasticity in compression, F(N) is the force in puncture, ν is the Poisson ratio, D(mm) is the deformation, a(mm) is the diameter of the cylindrical probe (2 mm)

Stresses (σ, Nmm^{-2}) were obtained from the following equation (*Sitkei, 1986*)

$$\sigma=F/A \qquad (4)$$

where, F (N) is force and A (mm^2) is an initial cross section of the sample.

RESULTS AND DISCUSSION

The means and significant levels of puncture force, deformation stress, puncture energy, hardness, Poisson ratio and modulus elasticity for the initial rupture of the kumquat fruits as a function of harvest time are presented in Tab. 1.

Tab 1.Some engineering properties of Kumquat according to harvest date

	Before 10 days from optimum harvest time	Optimum Harvest time	After 10 days from optimum harvest time	Sig. Level
Puncture Force (N)	9.827b	15.813a	16.714a	**
Deformation (mm)	5.913b	6.724ab	7.12a	*
Stress(N/mm^2)	3.120b	5.036a	5.323a	**
Energy(Nmm)	30.840b	54.446a	59.864a	**
Hardness (N/mm)	1.642b	2.409a	2.385a	**
Poisson ratio	0.280	0.281	0.283	n.s
Modulus of elasticity(N/mm^2)	45.711b	47.383ab	50.065a	*

All data represent the mean of three replications with 15 determinations; a;b letters indicate the statistical difference in rows; *; ** significant levels at 5%, 1% respectively; ns: not significant.

As seen in Tab. 1, some mechanical properties of the kumquat in three harvest time were found to be statistically significant at the different probability levels (5% or 1%), with the exception that the Poisson ratio was found to be insignificant.
The puncture force, stress, energy and hardness of the kumquat were found to be statistically significant at the 1% probability level and Deformation and modulus of elasticity value were determined to be statistically significant at the 5% probability level, also, Poisson ratio was found to be insignificant.
The puncture force of the kumquat (9.827 N) before 10 days from optimum harvest time was significantly greater than other harvest times. There is no difference statistically between optimum harvest time and 10 days after optimum harvest time. The results show that the puncture force increased by increasing harvest time from 9.827 N to 16.714 N. *Jaliliantabar, et al. (2014)* found that the average rupture force of the kumquat was 24.1 N.
In all cases the highest deformation for kumquat fruits (7.120 mm) was obtained at 10 days after optimum harvest time while the lowest for fruits (5.913 mm) was at 10 days before optimum harvest time. The results show that the deformation increased by increasing harvest time from 5.913 mm to 167.120 mm.
According to the test data in Tab. 1, the average values of stress of kumquat 10 days before optimum harvest time, optimum harvest time and 10 days after optimum harvest time were 3.120 Nmm^{-2}, 5.036 $Nmm^{-2}$and 5.323 Nmm^{-2}, respectively. *Bohdziewicz and Czachor, (2016)* carried out on kumquat fruit and found similar result.
According to harvest time, the highest energy value of the kumquat was 59, 864 (Nmm) 10 days after optimum harvest time while the lowest for fruits (30.840 Nmm) was at 10 days before optimum harvest time. The energy value of the kumquat before 10 days from optimum harvest time was significantly greater than other harvest times.
The results show that the hardness was grading increased by increasing from 1.642 to 2.409 Nmm^{-1} by harvest time then decreased from 2.409 to 2.385 Nmm^{-1}. As shown in Table 1, there is no difference statistically between optimum harvest time and 10 days after optimum harvest time for hardness. Also, the results show that the modulus of elasticity increased by harvest time from 45.711 Nmm^{-2} to 50.065 Nmm^{-2}.

CONCLUSIONS

Effects of harvest time on some engineering properties of kumquat (*Citrus fortunella*) related to design parameters wood were investigated. The results of study indicate that harvest date significantly affect the mechanical properties of kumquat such as the puncture force, stress, energy and hardness of the kumquat were found to be statistically significant at the 1% probability level and Deformation and modulus of elasticity value were determined to be statistically significant at the 5% probability level, also, Poisson ratio was found to be insignificant.

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