INTERNATIONAL
Agrophysics
www.international-agrophysics.org

Int. Agrophys., 2013, 27, 107-109
doi: 10.2478/v10247-012-0074-y

Note

Physical properties of kumquat fruit

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Received September 8, 2011; accepted March 15, 2012

A b s t r a c t. Some physical properties of kumquat were investigated. Physical properties which were measured included fruit dimensions, mass, volume, projected area, density, geometric mean diameter, sphericity and surface area. Bulk density, porosity and also packaging coefficient were calculated. Mechanical properties such as the elasticity modulus, rupture force and energy required for initial rupture have been determined. The experiments were carried out at moisture content of 82.6% (w.b.). The results show that the kumquat fruit is one of the smallest fruit in the citrus family.

K e y w o r d s: kumquat, physical properties

INTRODUCTION

Kumquat (var. Nagami) is a citrus fruit and has an edible skin. It is the best known of the genus *Fortunella* which is closely related to citrus. This variety of kumquat has an oblong shape and bright orange colour. Its origin is Indochina but nowadays it is available in some other places such as the north of Iran.

Physical characteristics of agricultural products are the most important parameters in design of grading, transporting, processing and packaging systems. Among these physical characteristics, mass, volume and projected area are the most important in sizing systems. Other important parameters are width, length and thickness. Many studies have focused on the physical, mechanical and nutritional properties of fruits, such as persimmon (Altuntas*et al*., 2011) and oil palm (Akinoso and Raji, 2011). No detailed studies concerning the physical and mechanical properties of kumquat have been performed till now.

The aim of this research was to determine the physical and mechanical properties of kumquat fruits.

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MATERIALS AND METHODS

Fifty Kumquat fruits from the northern region of Iran were prepared and kept at 25°C in the laboratory. The three major dimensions *ie* length, width and thickness were measured by a digital caliper. The mass of each kumquat was measured by an electronic balance to an accuracy of 0.01 g. The fruit volume was determined by the water displacement method using a graduated cylinder. Specific gravity of each kumquat fruit was calculated by the mass of kumquat fruit in air divided by the mass of displaced water. Water content of fruits was determined using the standard hot air oven method keeping the fruit in the oven for 24 h at 105°C (Lorestani and Tabatabaeefar, 2006). The three important characteristics that were measured were the maximum, mean and minimum projected area (perpendicular to thickness, width and length, respectively). Parameters, such as the coefficient of sphericity, mean geometrical diameter, average projected area (known as the criterion area), surface area, arithmetic diameter, equivalent diameter and packing coefficient were determined (Mohsenin, 1986). The coefficient of packaging, bulk density, shell ratio, porosity and aspect ratio were computed (Owolarafe and Shotonde, 2004; Rafiee *et al*., 2007; Topuz *et al*., 2005). The shape index of kumquat fruit was evaluated according to Bahnasawy *et al*. (2004). The kumquat fruits were regarded as oval when the shape index was bigger than 1.5 and as spherical when the shape index was smaller than 1.5.

Quasi-static compression tests were performed with a Zowick/Roell Universal Testing Machine equipped with a 500 N compression load cell and integrator. The measurement accuracy was 0.001 N. The elasticity modulus, rupture force and energy required for initial rupture were determined. The individual kumquat fruit was loaded between two parallel plates of the machine and compressed at preset force condition until rupture occurred. The bioyield point was detected by a break in the force deformation curve. Once the bioyield was detected, the loading was stopped. The mechanical properties of the kumquat fruit were expressed in terms of the elasticity modulus, rupture force and energy required for initial rupture.

Spreadsheet software, Microsoft excel 2010, was used to analyze the data.

RESULTS AND DISCUSSION

A summary of the descriptive statistics of various physical dimensions are shown in Table 1. The average value of length, width and thickness for the kumquat fruits were 39.5, 25.7 and 25.1 mm, respectively. The mean sphericity was found to be 74.5%, with a standard deviation of 3.5. The sphericity observed varied from 65.9 to 83.0% and was found to be lower than the value reported for tangerine (Sahraroo *et al*., 2008). True density ranged from 1.0 to 1.3 g cm^{-3}, with mean of 1.2 g cm^{-3}. This shows that the true density of the kumquat fruit was higher than the density of water, so this fruit settles in water and can not be transported by it. The shape index was obtained as 1.6. The shape index was higher than 1.5, therefore, according to Bahnasawy *et al*. (2004), the kumquat fruits are considered as oval. The volume of the kumquats varied from 5 to 20 ml, with an average value of 12.3 ml and similarly, the mass of kumquat varied from 4.9 to 24.8 g, with an average value of 14.3 g. Those were found to be lower than the values reported for tangerine (Sahraroo *et al*., 2008). The post-harvest gravimetrical properties of the kumquat fruit such as length, width, thickness, geometrical mean diameter, sphericity and surface area were lower than in the tangerine. This shows that the kumquat fruit is one of the smallest fruit in the citrus family. The average surface area and criterion area were found to be 2 743.0 and 736.0 mm^2.

Table 1. Properties of kumquat fruit at moisture content of 82.6% w.b.

Parameter	Mean (SD)	CV (%)
	Measured parameters	
Length (mm)	39.5 (± 3.8)	9.5
Width (mm)	25.7 (± 2.8)	11.0
Thickness (mm)	25.1 (± 2.8)	11.1
Max projected area (mm^2)	859.3 (± 177.4)	20.5
Mean projected area (mm^2)	809.4 (± 153.2)	18.9
Min projected area (mm^2)	539.2 (± 147.6)	27.4
Mass (g)	14.3 (± 3.9)	27.5
Volume (ml)	12.3 (± 3.0)	26.8
	Calculated parameters	
True density (g cm^{-3})	1.2 (± 0.1)	6.7
Geometric mean diameter (mm)	29.4 (± 3.0)	10.0
Sphericity (%)	74.5 (± 3.5)	4.7
Surface area (mm^2)	2 743.0 (± 528.0)	19.2
Equivalent diameter (mm)	29.4 (± 2.95)	10.0
Arithmetic diameter (mm)	30.1 (± 2.95)	9.8
Criteria area (mm^2)	736.0 (± 154.4)	21.0
Aspect ratio (%)	65.1 (± 4.6)	7.1
Shell ratio (%)	55.5 (± 5.7)	10.3
Shape index	1.6 (± 0.1)	7.2
	Mechanical properties	
Elasticity modulus (MPa)	52.1 (± 42.0)	30.0
Rupture force (N)	24.1 (± 4.4)	18.2
Energy used for rupture (N mm)	83.4 (19.1)	22.8

At the same moisture level, bulk density, porosity, the coefficient of packaging and true density were also evaluated as 0.4 g cm^{-3}, 63.8%, 0.4 and 1.2 g cm^{-3}, respectively. The kumquat has low bulk density, therefore, it would require more packing space to fill with kumquats. The porosity of kumquat is higher than that of the orange (Sharifi *et al*., 2007). This was due to the large variation in three dimensions of the kumquat and consequently sphericity. This implied that a lower quantity of kumquats could be stored in a specified volume as compared to orange.

The average rupture force of the kumquat was 24.1 N, while the rupture force for barberry was 47.2 N (Fathollahzadeh *et al*., 2008) and pine nut 468 N (Faruk *et al*., 2005). The average elasticity modulus of the kumquat was 52.1 MPa. Average energy required for initial rupture of the kumquat was 83.4 N mm^{-1}. It can be noticed that the standard deviations of data relevant for calculating the mechanical properties are high. This indicated that the variation in these properties among the samples was high even though the stage of maturity of the samples was the same.

CONCLUSIONS

1. The average mass and volume were 14.3 g and 12.3 ml, respectively.

2. The dimensions were in the range from 27.9 to 48.7 mm in length, 17.8 to 30.9 mm in width, and 17.0 to 30.9 mm in thickness.

3. The mean projected area perpendicular to length, width and thickness obtained were 539.2, 809.4 and 859.3 mm^2, respectively.

4. The geometric mean diameter and surface area were calculated as 29.4 mm, 2743.0 mm^2, respectively, while sphericity was measured to be 74.5%.

5. The average rupture force, elasticity modulus and energy required for initial rupture of the kumquat were 24.1 N, 52.1 MPa and 83.4 N mm^{-1}, respectively.

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