Determination of some engineering properties of snake melon (*cucumis melo var. flexuosus*) fruit

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Abstract: The physical and mechanical properties of agricultural products have an effective role in determining the quality of the products, reducing the potential damage caused by transportation and eventually designing the equipment used in the processing of the products. In this study, some physical and mechanical properties of snake melon were measured under standard conditions. Physical properties included length, width, thickness, mean diameter (geometric and arithmetic), sphericity, surface area, aspect ratio, mass, volume and density. The mechanical properties of the samples and their lengths were measured under the conditions of pressure (bruise), bending (break) and shearing of the snake melons in halves using a Zwick/Roell Instron testing machine based on the recommended standards. Length, width, thickness, volume, surface area and density are some of the physical properties that are important considerations while designing a special machine or analyzing the consequences of transferring materials. In the investigation of the mechanical properties, the maximum forces required for bruising, bending and shearing of the snake melon were 309.66, 44.4 and 36.5 N, respectively. The results of this study can contribute to the design and optimization of the equipment used for processing, transportation, separation and packaging of the snake melon.

Keywords: snake melon, physical properties, mechanical properties

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1 Introduction

Snake melon or *Cucumis melo var. flexuosus* is a type of vegetable which likes cucumber and belongs to the melon family. It is a kind of fruit which is used less than cucumber. Snake melon is cool and wet in nature and is mostly planted in the summer. This fruit is very useful for having a clear skin and treating kidney stones (Daraizadeh, 2014). The Biotechnology Research Institute of the Iranian Ministry of Agriculture has stated that more than 17 percent of the 106 million tons of the agricultural products in Iran turn into waste in different stages from production to supply and seven percent of them are destroyed in the stores due to inappropriate packaging and unsuitable storage methods (Rezai, 2008).

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One way to reduce losses in production is to investigate the physical and mechanical properties of agricultural products. The physical and mechanical properties of agricultural products have an effective role in determining the quality of the products, reducing the potential damage caused by transportation and eventually designing the equipment used in the processing of the products (Sitkei, 1987; Özgüven and Vursavuş, 2005; Singh and Reedy, 2006; Sharifi et al., 2007; Moghadam and Kheiralipour, 2015; Ghaffari et al., 2015; Janakbakhshi et al., 2016).

In a study conducted in Egypt, some physical and mechanical properties of onion were investigated. These properties included dimensions, mean diameter (geometric and arithmetic), surface area, volume, weight, apparent density, coefficient of static friction, roll angle, crushing strength and hole testing (Bahnasawy et al., 2004). Physical properties of four types of oranges were investigated in another study. Properties such as the main diameter, geometrical diameter, sphericity, mass, density and volume were measured. The results showed that there were significant physical and nutritional differences among the four types of oranges based on variety (Topuz et al., 2005). The volume and density of agricultural products are very important in different processes and in the assessment of product quality including the determination of fruit ripening (Sitkei, 1987). A study measured the mechanical properties of oranges such as tensile strength, incisional energy, yield point and shear energy. The amount of force at yield point at horizontal and vertical loadings were reported to be 138.8 and 153.3 N, respectively (Singh and Reddy, 2006). Prasad and Gupta (1975) studied the shear force and effect of the corn stalk. The results of their study showed that in direct shearing, increase in the shearing speed reduced strength and the shearing force. Ince et al. (2005) carried out a study on the flexural and shear properties of sunflower. They found out that increased moisture would reduce shear modulus of elasticity and bending stress and increase shear energy.

Numerous studies have been carried out on the physical and mechanical properties of different products such as cherry (Demir and Kalyoncu, 2003), apricot (Hacıseferogullari et al., 2007; Hassan-Beygi, 2009), strawberry (Ozcan and Haciseferogullari, 2007), tomato (Taheri-Garavand et al., 2011), pear (Kabas et al., 2006), apple (Kheiralipour et al., 2008), orange (Topuz et al., 2005), mango (Jha et al., 2006), potatoes (Wright and Splinter, 1968) and scolymus (Jahanbakhshi et al., 2016) so far.

The aim of this study is to determine some engineering properties of the snake melon fruit. The results of this study can be useful in mechanized harvesting and post-harvest operations of the snake melon fruit to reduce losses.

2 Materials and methods

2.1 Determination of physical properties

The experiments of this study were conducted in July-August (2016) in precision instruments laboratory at Ilam University in Iran. The samples were selected randomly from the farm and were in a similar condition regarding their rates of ripening. They were then manually cleaned and were transferred to the laboratory. To determine the moisture content, the warm air standard method was applied using the Memmert UNE 500 oven. In order to do so, 20 g samples were kept inside the oven for 24 hours at 75°C±2°C in three replications (USDA, 1970; Doymaz, 2007; Akar and Aydin, 2005; Moghadam and Kheiralipour, 2015). For weighing the samples before and after of being in the oven, a digital scale (model GF600, USA) with accuracy of 0.01 g was used. According to Equation (1), moisture content of snake melon was calculated.

$$MC = \frac{M_W - M_d}{M_W} \times 100 \tag{1}$$

where, *w*: Initial mass of fruit, g; *Md*: Mass of dried fruit, g; *MC*: Moisture content of fruit, wet base, %.

All the physical properties were tested on 50 types of snake melon. Dimensions of the snake melons (length (*L*), width (*W*) and thickness (*T*)) were measured using a DC-515, Taiwan digital caliper with the precision of 0.01 mm. Then, the geometric mean diameter, arithmetic mean diameter and sphericity were calculated through Equations (2), (3) and (4).

$$D_g = \sqrt[3]{LWT} \tag{2}$$

$$D_a = \frac{L + W + T}{3} \tag{3}$$

$$\phi = \frac{D_g}{L} \tag{4}$$

where, D_g is the geometric mean diameter, mm; D_a is the arithmetic mean diameter, mm; and *Ø* is the sphericity of the snake melons. The surface area (*S*) and the aspect ratio (R_a) of the snake melons were obtained through Equations (5) and (6).

$$S = \pi D_g^2 \tag{5}$$

$$R_a = \frac{W}{L} \tag{6}$$

The snake melons' mass was measured using a GF600, USA digital scale with the precision of 0.01 g. To determine the volume of the snake melons, the platform method was used (Mohsenin, 1986). Thus, the samples were dipped in a beaker that was placed on a scale using a legged clamp. The second reading of the scale showed the weight of the fruit dipped into the water minus the weight of the container and the water which equaled the weight of the displaced water. This weight is inserted into the following and the volume of the snake melons is calculated through Equation (7).

$$V = \frac{W_W}{\rho_W} \tag{7}$$

The density of the snake melons is obtained by Equation (8).

$$\rho_t = \frac{M}{V} \tag{8}$$

where, W_w is the density of the displaced water; ρ_w is the density of the water; ρ_t is the true density; M is the mass and V is the volume of the snake melons.

2.2 Determining the mechanical properties

In order to determine the mechanical properties of the snake melon, three tests of pressure (bruise), break (bending) and shear were performed. To do so, Zwick/Roell Instron machine (Z 0.5 model) was used. To test bruising, a round pressure prap and bending, a three-point prap were used under vertical loading based on the ASTMD 790-03 standard and for the shear test, a straight edge blade with the thickness of 1.4 mm and the blade angle of 30 degrees was used based on the DIN 53294 standard at room temperature and the testing speed of 20 millimeters per minute (Figure 1), (Jahanbakhshi et al., 2016; Akhoundzadeh, 2016). The Instron machine was simultaneously connected to a computer and data mining was carried out. Each of the experiments was replicated three times.

A B C

Figure 1 A) Bruise test, B) Break test and C) Shear test

3 Results and discussion

3.1 Physical properties

The snake melons' moisture content (w.b) was calculated to be 76.2%. The measured physical properties of the snake melon fruit are shown in Table 1. The mean length, width, thickness, geometric mean diameter, arithmetic mean diameter, surface area, mass and volume of the snake melons were 290.01, 35.85, 35.83, 71.56, 120.56 mm, 16234.44 mm^2, 178.39 g and 182.18 cm^3. Agricultural products waste is partly due to improper packaging and insufficient transportation equipment. Packaging must take into account the requirements of transportation and marketing in terms of the weight, size and shape of the agricultural products. This entails knowing the physical properties of the agricultural products. Since the length of the snake melon has a great difference to its width and thickness, it can be concluded that snake melon has a low sphericity (25%) and this property must be taken into consideration in designing transfer, handling and grading systems. The true density of the snake melon was 0.97 g cm^{-3} and this property can be used in designing the cleaning and separation processes. Jahanbakhshi et al. (2016), Mohsenin (1986) and Omobuwajo et al. (2000) has discussed and stressed upon the importance of these properties in determining the size of the machines particularly that of the separation, transfer and sorting equipment.

Table 1 Physical properties of snake melon fruit

Parameter	Mean	Max	Min	SD	CV %
Length, mm	290.01	391.08	199.56	59.14	20.39
Width, mm	35.85	40.12	28.95	3.85	10.73
Thickness, mm	35.83	40.11	28.94	3.84	10.71
Geometric mean diameter, mm	71.56	81.81	55.09	7.19	10.04
Arithmetic mean diameter, mm	120.56	150.34	85.81	19.86	16.47
Sphericity, %	0.25	0.31	0.18	0.03	12
Surface area, mm^2	16234.44	21017.75	9529.64	3139.10	19.33
Aspect ratio	0.12	0.17	0.07	0.02	16.66
Mass, g	178.39	203.13	138.56	15.87	8.89
Volume, cm^3	182.18	209.67	140.23	16.71	9.17
True density, g cm^{-3}	0.97	0.98	0.96	0.007	0.72

3.2 Mechanical properties

The mechanical properties of the snake melon in the pressure (bruise) test are given in Table 2. The mean values of the properties measured in the pressure test (Elasticity module, the maximum force required to bruise the snake melon, deformation when actions of maximum force, the work done to reach the maximum force required for bruise the snake melon under vertical load) were 0.027 MPa, 309.66 N, 11.96 mm and 1348.16 N·mm, respectively. These properties are considered as the basic information in designing the machinery and equipment used during the harvesting and post-harvesting operations. Fruit tissue hardness is one of the parameters that can be affected by static and dynamic loads and fruit quality might decrease as a result of change in hardness. Modulus of elasticity is one of the parameters that can be used to measure fruit tissue hardness. The higher the modulus of elasticity is, the harder the fruit tissue will be. In a similar study, Jahanbakhshi and Ghamari (2015) examined the mechanical properties of plum fruit. In a bruise test, they reported the modulus of elasticity equal to 0.0118 MPa. Compared to the present study, it can be stated that snake melon has a higher modulus of elasticity and thus a harder tissue. Agricultural products often show different behaviors regarding their strength in front of pressure forces. In order to minimize mechanical damage, the pressure forces caused during the transfer of the products must be reduced to the minimum rate possible (lower than 309.66 N).

Table 2 Mechanical properties of snake melon fruit in the pressure test

Parameter	Mean	Max	Min	SD	CV %
Elasticity modulus, MPa	0.027	0.029	0.026	0.0015	5.55
F_{max}, N	309.66	313	298	3.51	1.13
DL at F_{max}, mm	11.96	16.20	10.40	1.42	11.87
W to F_{max}, N·mm	1348.16	1357.10	1340.98	3.06	0.22

The mechanical properties of the snake melon in the break (bending) test are shown in Table 3. The mean values of the measured properties in the bending test (elasticity module, the maximum force required to bend the snake melon, deformation when actions of maximum force, the work done to reach the maximum force required to bend the snake melon under vertical load) were 21.33 MPa, 42.40 N, 23.70 mm and 531.76 N·mm, respectively. The results indicate that in order to prevent snake melons from breaking in the packaging, transportation and processing, the application of forces above the value of 42.40 N must be avoided. In another study, Jahanbakhshi et al. (2016) examined the mechanical properties of Scolymus through a bending test and obtained the elasticity modulus of 3.41 MPa. Compared to the present study, the high modulus of elasticity (21.33 MPa) in snake melon, shows that this fruit is very resistant to pressure tensions.

Table 3 Mechanical properties of snake melon fruit in the bending test

Parameter	Mean	Max	Min	SD	CV %
Elasticity modulus, MPa	21.33	23	20	1.52	7.12
F_{max}, N	42.40	45.10	38.60	0.75	1.76
DL at F_{max}, mm	23.70	25.30	20.70	0.60	2.53
W to F_{max}, N·mm	531.76	547.02	519.60	2.16	0.40

The mechanical properties of the snake melon in the shear test are shown in Table 4. The mean value of the required force for shearing the snake melon was 33.66 N and this shows the low strength of the snake melon against shearing. The mean value of deformation when shearing was 8.37 mm which was a very low and showed the strength of the snake melon against deformation caused by the forces exercised during the shear process. Moreover, the shear modulus mean and shear strength were 0.0126 and 0.037 N·m^{-2}, respectively. The data obtained about the mechanical properties through the shear test can be applied in the snake melon processing factories. Yet in another study, Jahanbakhshi et al. (2016) applied a shear test to examine the mechanical properties of acanthus plant and reported the average shear modulus of 0.002 N.mm^{-2}. Comparing the result of that study with the present one, we can see that the snake melon has a high shear modulus (0.0126 N·mm^{-2}). It can be concluded that this product was hard and had a high resistance against shear strain.

Table 4 Mechanical properties of snake melon fruit in the shear test

Parameter	Mean	Max	Min	SD	CV %
Shear modulus, N·mm^{-2}	0.0126	0.0133	0.0119	0.0002	1.58
F_B, N	33.66	39.21	29.87	0.66	1.96
T_B, N·mm^{-2}	0.037	0.042	0.033	0.0002	0.54
v_B, mm	8.37	10.35	7.76	0.57	6.81

4 Conclusion

1. Length, width, thickness, mass, volume and geometric mean diameter have direct relationships with the size of the snake melon while volumetric mass (density) has an inverse relationships.

2. Snake melon has a low sphericity (0.25%) and a relatively high density (0.97 g cm^{-3}). These features must be taken into account when designing transfer, displacement and grading systems.

3. In examining mechanical properties, the maximum force required in bruising, bending and shear tests of the snake melon were 309.66, 42.40 and 33.66 N, respectively.

4. The results obtained about the physical properties can be used in designing the equipment for packaging and grading snake melon. In addition to the importance of studying mechanical properties in minimizing mechanical damage, these properties are considered as the basic data in designing the machinery and equipment used during the harvesting and in the post-harvesting operations.

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