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Physical and Mechanical Changes in Ripening Melon Fruits

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Abstract: Changes in physical and mechanical properties of two melon (*Cucumis melo* L.) cultivars ('Zard-Eyvanekey' and 'Sousky-Sabz') were studied in five different stages of ripening. The fruits were harvested at immature, early ripening, moderately ripe, ripe and over ripe stages and taking into account some physical and mechanical properties (mass, size, surface area, sphericity, true density, fruit length/width ratio, seed cavity length/width ratio, moisture content and modulus of elasticity) in order to understand this behavior during the ripening process. The attributes mass, size, surface area, sphericity of both melon types increased with the advances in the harvesting ages, whilst a reverse was found with true density, fruit length/width ratio, seed cavity length/width ratio, moisture content and modulus of elasticity. The two cultivars generally changed in similar patterns, but not at the same rate. Analysis of variance showed significant differences between the different stages in each cultivar for every attribute. A two-way ANOVA test showed significant interactions in the behavior of all the attributes between cultivars during ripening.

Keywords: Melon, Physical and mechanical properties, Ripening

Kavun Meyve Olgunlaşmasında Fiziksel ve Mekanik Değişiklikler

Özet: İki kavun (*Cucumis melo* L.) çeşidinde (Zard-Eyvanekey ve Sousky-Sabz) fiziksel ve mekanik özelliklerdeki değişiklikler, olgunlaşmanın beş farklı aşamasında çalışılmıştır. Meyveler, ham, erken olgunlaşma, orta olgunlaşma, olgun ve aşırı olgun aşamalarda hasat edilmiş ve bazı fiziksel ve mekanik meyve özellikleri (irilik, ebat, yüzey alanı, küresellik, gerçek yoğunluk, meyve boy/en oranı, tohum boşluğu boy/en oranı, nem içeriği ve elastikiyet modülü), olgunlaşma sürecinde incelenmiştir. Her iki kavun çeşidinde meyve iriliği, ebat, yüzey alanı ve küresellik hasat aşamalarında artarken, meyve boy/en oranı, tohum boşluğu boy/en oranı, nem içeriği ve elastikiyet modülünün azaldığı belirlenmiştir. Her iki çeşit, genellikle benzer şekilde fakat farklı oranlarda değişmiştir. Varyans analizi, her özellik için çeşitlerin farklı aşamaları arasında önemli farklılıklar göstermiştir. İki yönlü ANOVA testi, olgunlaşma sırasında çeşitler arasındaki tüm özelliklerin davranışında önemli etkileşimler göstermiştir.

Anahtar kelimeler: Kavun, Fiziksel ve mekanik özellikler, Olgunlaşma

Introduction

Melon (*Cucumis melo* L.) is a commercially important crop in many countries. It is cultivated in all the temperate regions of the world due to its good adaptation to soil and climate. Fruits are consumed in the summer period and are popular because the pulp of the fruit is very refreshing and sweet, with a pleasant aroma. *Cucumis melo* includes a wide range of cultivars. Although crosses outside the species are sterile, intraspecific crosses are generally fertile, resulting in a confusing range of variation (Purseglove 1968). China and USA have the highest production of melon. Fruit ripening processes involve a number of coordinated biochemical and physiological pathways. Narain et al. (1992) analyzed variations in physical and chemical composition during maturation of umbu (*Spondias tuberosa*) fruits. The fruit was found to be round to ovoidal in shape, being, on average, 3.21 cm long and 2.86 cm in width. Half-ripe fruits contained the maximum (64.62%) pulp content (Narain et al. 1992). Rogiers and Knowles (1997) determined changes in physical and chemical two cultivars of saskatoon (*Amelanchier alnifolia*) fruit into nine maturity and ripeness stages based on differences in size and color. The fastest gains in fresh and dry weights occurred over the later stages of development (from stages 5 to 9), while increases in fruit diameter between stages 1 and 9 were linear (Rogiers and Knowles 1997). Amoros et al. (2003) studied physico-chemical and physiological changes during development and ripening of five loquat cultivars. They found that fruit growth have a sigmoid curve in all loquat cultivars. A good relationship between duration of fast growth phase and fruit size was found. In addition, a positive correlation was also established between seed number and fruit size, and between seed weight and both fruit and flesh weight (Amorós et al. 2003). Duru et al. (2005) determined changes in physical properties and chemical composition of Cactus pear (*Opuntia ficus-indica*) during maturation (Duru and Turker 2005). Golshan Tafti et al. (2005) evaluated changes in physical and chemical characteristics of Mozafati date fruit at different stages during development (Kimri, Khalal, Rotab and Tamr). The results indicated that the length, width and volume increased as the fruits developed and reached highest at the Kalal stage. Fruit weight increased rapidly at the Kimri stage and then started to decrease during ripening (Tafti and Fooladi 2005). Muskovics et al. (2006) evaluated changes in physical properties of three sweet cherry (*Prunus avium* L.) cultivars during fruit development. An increase in fruit volume, mass and dry matter content was observed and the three cultivars generally changed in similar patterns, but not at the same rate (Muskovics et al. 2006). Jha et al. (2006) investigated physical and mechanical properties of mango (*Mangifera indica* L.) during growth and storage for determination of maturity. They found that size of the fruits increased gradually during growth and the sphericity remained in the range of 0.67–0.70 (Jha et al. 2006). Keramat Jahromi et al. (2008) examined changes in physical properties of date fruit (cv. Shahani) during Khalah, Rotab and over ripened stages (Keramat Jahromi et al. 2008). Tosun et al. (2008) evaluated changes in some physical and chemical properties of blackberry (*Rubus* L.) at three levels of ripeness (Tosun et al. 2008). Onuegbu et al (2011) examined the physical properties of ube (African pear) during fruit development. They found that the development of the fruit differed significantly ($p < 0.05$) on all the physical properties (Onuegbu et al. 2011).

Parveen et al. (2012) investigated the effect of harvest maturity stage on quality of muskmelon (cv. Ravi) harvested at immatured, half matured and full matured stages were stored at 10°C. They found that colour; firmness and TSS had a good co-relation with the maturity stage at harvesting time and influenced the storage quality. Muskmelon harvested at half maturity (at half-slip) was better in storage quality regarding TSS, pH, acidity and colour (Parveen et al. 2012).

Kahnamuy et al. (2013) evaluated the physical and chemical properties of two persimmon cultivars in three harvesting time. They found that the persimmon's dimension and its geometric mean diameter and arithmetic mean diameter, mass, volume and density increased by ripening. Franco et al. (2013) found the shell weight and thickness of Gulupa Fruits (*Passifl oraedulis* SIMS) decrease during ripening and postharvest (Franco et al. 2013). In another study on meldar fruit Altuntaş et al. (2013) found that the geometric mean diameter, sphericity, surface area, density, total soluble solid content and total acidity decreased, while, bulk density increased at ripening period (Altuntas and Bayram 2013). Little detailed information is available on the nonhomogeneous and anisotropic physical and mechanical properties of Iranian melons. The objective of this research study was to determine the range of variation on physical and mechanical properties of two different melon cultivars Zard-Eyvanekey and Sousky-Sabz during ripening.

Materials and Methods

This research was conducted on Zard-Eyvanekey and Sousky-Sabz cultivar (export cultivars) obtained from a plantation in Garmsar township (35° 13' 20" N, 52° 20' 26" E).

The Sousky-Sabz type is characterized by its green external colour and fragrant greenish flesh. The Zard-Eyvanekey has a yellow external colour and white-creamy flesh. Both cultivars have fibrous and shallow root system, netted surfaces, crunchy texture and somewhat sculptured skin. The melon fruits can be either climacteric or nonclimacteric, but these cultivars are climacteric type. They are native to different parts of Iran and primary center of origin is hot valley of Iran and adjacent areas such as Garmsar.

They were carefully hand-picked during the summer and autumn in the early morning from the area of Davarabad, Garmsar, Iran. Fruits were selected according to color, size and lack of blemishes in order to obtain homogeneous samples (Figure 1). Before each test series, the melon was transferred to department laboratory at 18 to 22°C temperature for 24 hours.

Figure 1. Studied cultivars, up: Zard-Eyvanekey down: Sousky-Sabz.

They were selected at five different stages of ripening (Table 1). All the physical and mechanical parameters each series of tests were studied for 65 fruits from each cultivar.

These cultivars should be well supplied with N, P and K and, in particular, with the minor elements to maintain a well-balanced soil fertility to encourage vigorous growth. Fertilizer was delivered as a pre-plant base comprising 80 kg N/ha, 50 kg P/ha and 80 kg K/ha. They are mainly grown on sand and sandy-loam soils on river bed. But other type of soil is also favorable for its cultivation. The optimum soil PH is 6.0 to 7.0. The land is prepared thoroughly by repeated ploughing. Irrigation was subjectively delivered to meet the crop requirements. Irrigate the crop once in 4-5 days during summer depending upon the soil and weather condition. The melon seeds were sown at 3-4 cm depth, 50 cm spacing in row with 200 cm between rows in farm.

Table 1. Date of harvesting and tests series

Stage	Operation	Date	Description
1	First series of test	Mid-August	Immature
2	Second series of test	Late-August	Early ripening
3	Third series of test	Mid-September	Moderately ripe
4	Forth series of test	Late-September	Ripe
5	Fifth series of test	Mid-October	Over Ripe

The moisture content (MC) of melon was measured by cutting approximately 50 g flesh of each test series. The pieces of melon were weighed and placed in an aluminum box and positioned inside oven for 72 h at 65°C. The moisture content was determined by knowing the weight of melon sample from before and after and the weight of empty box by applying standard wet basis moisture content equation (AOAC; 1984). The mass (M) of the melon was measured with a precision balance and volume was determined by the water displacement technique. The true density (ρ) is the ratio of mass of melon to its volume. Each fruit was then cut lengthwise from the stem-scar towards the blossom end and measured for its external size and the size of the seed cavity in two perpendicular directions by digital vernier calipers, shown in Figure 2. Cavity is the seed bearing compartments of the placenta.

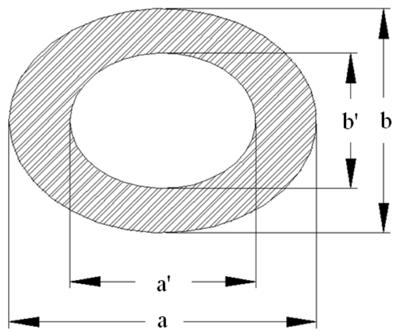

Figure 2. Dimension notations of melon.

The size, sphericity, S_P and surface area, S values were calculated by considering Eq. (1) and Eq. (2), respectively (Mohsenin 1970).

$$Size = (abc)^{1/3} \tag{1}$$

$$S_P = \frac{(abc)^{1/3}}{a} \tag{2}$$

$$S = \pi.(abc)^{2/3} \tag{3}$$

The fruit length/width ratio, $q = (a/b)$ defined as the length from stem end to blossom end of the fruit divided by the width at the broadest point, Whereas seed cavity length/width ratio, $q' = (a'/b')$ is the ratio of two perpendicular directions (Shuang-wu and Jun-pu 2006). Three cylindrical cores were cut near the equator from one half of each melon, were the flesh tends to have the largest thickness, using a cylindrical borer through the flesh along the radial direction. Each 14 mm diameter cylindrical core was then cut into 14 mm long samples. The modulus of elasticity (E) of melon was evaluated using 20 samples by Universal Testing Machine (Santam, SMT-5). The machine was equipped with a load cell of 150 N at a compressive rate of 25.4 mm/min. Analysis of variance (ANOVA) was applied to the data. Means corresponding to the different stages of evolution were compared using Duncan's multiple range tests ($p<0.05$). Two-way ANOVA (cultivar and time) was applied in order to know the incidence of these factors.

Results and Discussion

During ripening, a fruit passes through a series of changes in colour, texture and flavor indicating that compositional changes are taking place. The following figures and tables present the values of the representative parameters over the course of development for the two melon cultivars considered.

The mass of samples increased during the growing season rapidly as the mass of Zard-Eyvanekey from 0.591 to 3.913 kg (about 6.6 times) and the mass of Sousky-Sabz from 0.569 to 3.904 kg (about 6.8 times) increase (Figure 3). However, the increasing rates were different during the harvesting stages in both cultivars: faster rate in the initial stages and lower in the final stages. The average of mass in the fourth harvest (ripened), Zard-Eyvanekey and Sousky-Sabz estimated 3.663 and 3.424 kg respectively. The Zard-Eyvanekey mass was more than the Sousky-Sabz mass in full ripening, although the rate of increase in the mass was more in Sousky-Sabz cultivar.

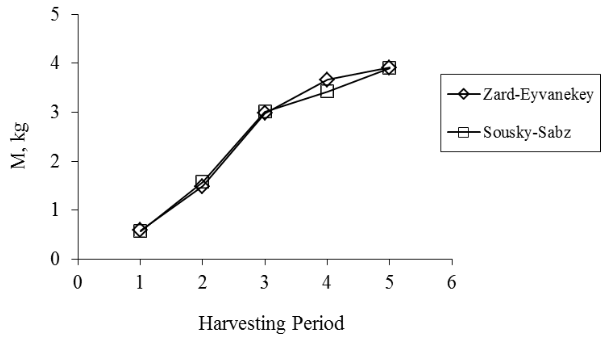

Figure 3. Mass of melon cultivars trend over five test series.

The size of the melons increased over the period of ripening (Figure 4). Initial stages of growth the change was so noticeable and then was gradually. The size of Zard-Eyvanekey from 106.55 to 206.92 mm and size of Sousky-Sabz from 105.55 to 204.32 increased. The size Zard-Eyvanekey cultivar (201.02mm) was a little more than Sousky-Sabz cultivar (197.26) in full ripening.

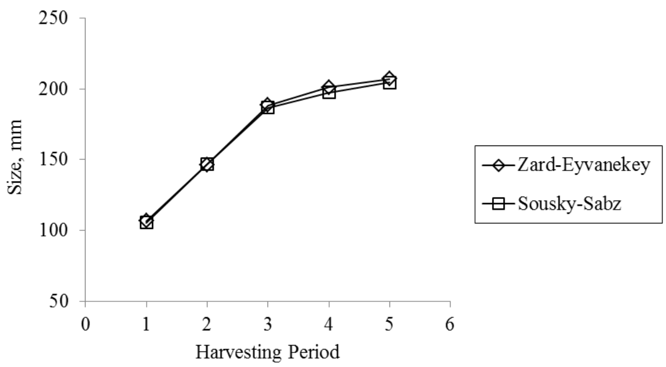

Figure 4. Size of melon cultivars trend over five test series.

The surface area of the two cultivars increased over the period of development and ripening (Figure 5). This parameter increased from 359.97 to 1347.45 cm^2 for Zard-Eyvanekey and from 355.01 to 1314.09 cm^2 for Sousky-Sabz cultivar from 1^{st} to 5^{th} stage of ripening. The average of surface area in the ripened stage, Zard-Eyvanekey and Sousky-Sabz estimated 1272.12 and 1224.84 cm^2 respectively.

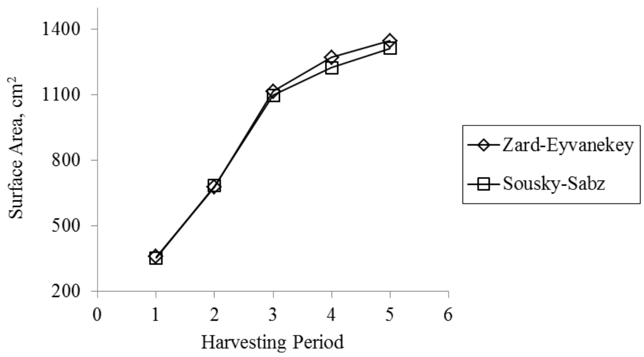

Figure 5. Surface area of melon cultivars trend over five test series.

The sphericity of the two cultivars increased over the period of development and ripening (Figure 6). Sphericity, Zard-Eyvanekey, was 72.5% in first test series and 79.1% in fifth test series, whereas these values were 72.7% and 79.2% for Sousky-Sabz. The sphericity, Zard-Eyvanekey was 78.4%, whereas this value was 78.5% for Sousky-Sabz at ripe stage.

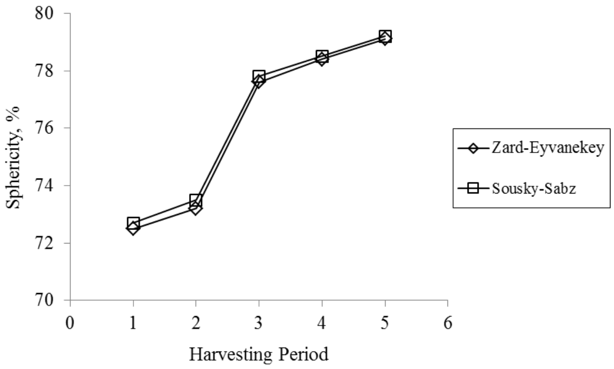

Figure 6. Sphericity of melon cultivars trend over five test series.

Because of increased volume more than of mass, then the true density of the two cultivars decreased over the period of development and ripening (Figure 7). This reduction is a consequence of the ripening process, which leads the seed cavity to occupy a larger space.

The true density of two cultivars had shown a decreasing trend. True density, Zard-Eyvanekey, was 901.84 kgm^{-3} in first stage and 842.33 kgm^{-3} in fifth stage (reduction 6.6%), whereas these values were 908.11 kgm^{-3} and 860.03 kgm^{-3} (reduction 5.3%) for Sousky-Sabz. The true density Sousky-Sabz cultivar (864.41 kgm^{-3}) was a little more than Zard-Eyvanekey cultivar (855.45 kgm^{-3}) in full ripening.

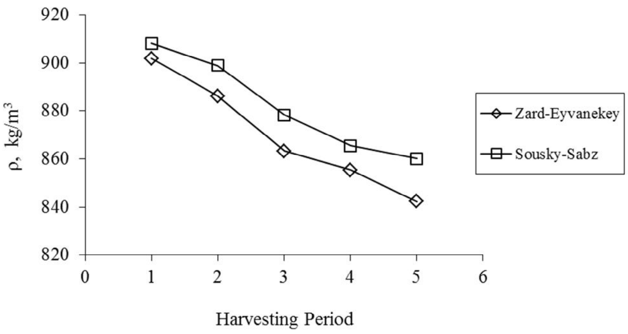

Figure 7. True density of melon cultivars trend over five test series.

The fruit length/width ratio of the two cultivars decreased over the period of development and ripening, in other words in early of growth the shapes had high elongation and then gradually had low elongation (Figure 8). Fruit length/width ratio, Zard-Eyvanekey, was 1.63 in first test series and 1.44 in fifth test series, whereas these values were 1.63 and 1.43 for Sousky-Sabz. This decline is the most evident when fruits change from stage 2 to stage 3 in which almost there are reductions of about 8% for both fruit cultivars. The fruit length/width ratio of melon was 1.44 at ripe stage for both cultivars.

The seed cavity length/width ratio exhibited a tendency to decline during ripening (Figure 9). Seed cavity length/width ratio, Zard-Eyvanekey, was 2.27 in first test series and 2.08 in fifth test series, whereas these values were 2.46 and 2.07 for Sousky-Sabz. The seed cavity length/width ratio, Zard-Eyvanekey was 2.07, whereas this value was 2.10 for Sousky-Sabz at ripe stage.

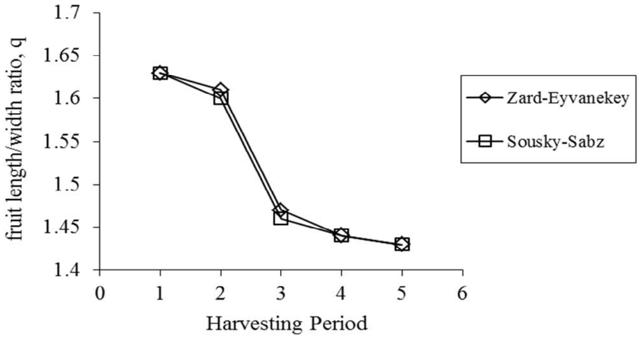

Figure 8. The fruit length/width ratio of melon cultivars trend over five test series.

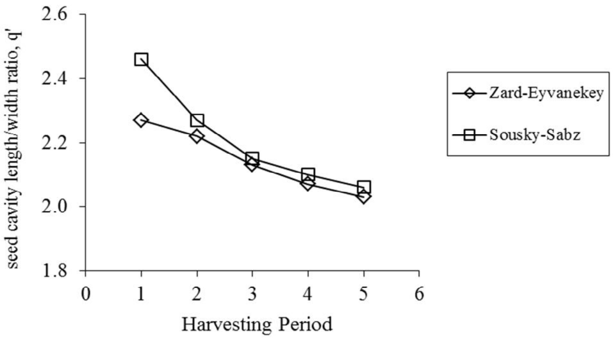

Figure 9. The seed cavity length/width ratio of melon cultivars trend over five test series.

Figure 10 shows a decrease in moisture content as ripening Progresses. The moisture content decreased from 95.67 to 90.07% for Zard-Eyvanekey and from 95.86 to 89.54% for Sousky-Sabz cultivar during of ripening. The moisture content, Zard-Eyvanekey was 92.16%, whereas this value was 91.26% for Sousky-Sabz at ripe stage.

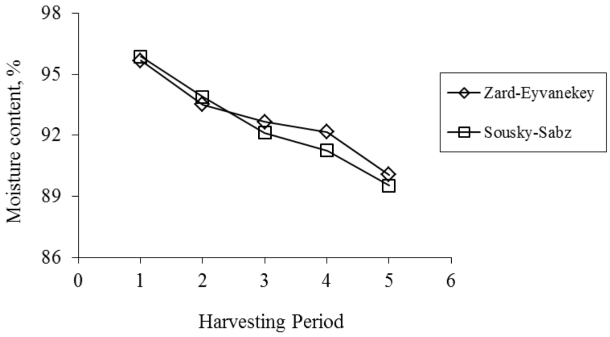

Figure 10. The moisture content of melon cultivars trend over five test series.

Figure 11 shows that elastic modulus values decreased in both cultivars in the throughout ripening. The modulus of elasticity Zard-Eyvanekey for the first test series was 0.466 MPa and then in fifth test series become 0.149 MPa that had an effect of 68% on modulus of elasticity. For Sousky-Sabz the modulus of elasticity in first test series was 0.417 MPa and then in fifth test series become 0.154 MPa that had an effect of 63% on modulus of elasticity. The rate of elastic modulus loss was also higher in Zard-Eyvanakey than Sousky-Sabz cultivar. Initial elastic modulus values of Zard-Eyvanakey were higher than those of Sousky-Sabz. This may be related to differences in physiological stage of ripeness, but also to the higher amount of cell wall polysaccharides in Zard-Eyvanakey than Sousky-Sabz pulp. Both cultivars have fruits with high elastic modulus at the first harvest date what shows compact and high density fruit.

The average of elastic modulus in the fourth harvest (ripened), Zard-Eyvanekey and Sousky-Sabz was estimated 0.199 and 0.176 MPa.

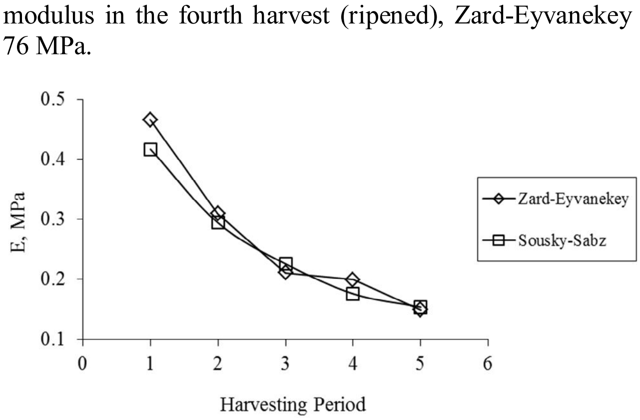

Figure 11. Modulus of elasticity of melon cultivars trend over five test series.

A high percentage of perishable fruits are lost by damage during transport and storage. Some of these losses can be prevented through better understanding of the postharvest physiology of these fruits and by exploiting knowledge of the ripening process in melon cultivars. Since both melon cultivars used in this study were grown under the same conditions and at the same location, the variations can be attributed to the genetic differences and not environmental influences. Analysis of variance was applied for understanding significant differences between data.

Table 2 shows changes in mass (M), size, surface area (S), spericity (S_p), true density (ρ), fruit length/width ratio (q), seed cavity length/width ratio (q'), moisture content (MC) and modulus of elasticity (E) during the ripening of melon fruits. As it can be seen in table, melon mass, size, surface area and sphericity increases during ripening period and difference of these parameters in five harvesting times significant in 5% probability level, except sphericity which is only significant in 5% probability level between 2st to 3th stage of ripening, while a decrease in true density, fruit length/width ratio, seed cavity length/width ratio, moisture content and modulus of elasticity from immature fruits to over ripe fruits.

The fruit mass rapidly increased from the 1st to 5th stage of ripening (581.64 g to 3909.12 g). This indicates the period of the fruit cell development with accumulation of cell (nutrient) constituents. The higher weight of over ripe fruits compared with other stages of ripening of fruits could be attributed to the metabolic changes during ripening. These results agree with those reported by previous researcher, (Onuegbu and Ihediohanma 2008)

Table 2. Changes in mass (M), size, surface area (S), spericity (S_p), true density (ρ), fruit length/width ratio (q), seed cavity length/width ratio (q'), moisture content (MC) and modulus of elasticity (E) during the ripening of melon fruits

Stage	M (g)	Size (cm)	S (cm^2)	S_p (%)	ρ (g/cm^3)	q	q'	MC (%)	E (MPa)
1	581.64^e	106.09^e	357.72^e	72.6^b	0.905^a	1.63^a	2.34^a	95.77^a	0.558^a
2	1535.85^d	146.46^d	682.25^d	73.2^b	0.893^a	1.61^a	2.24^a	93.78^b	0.301^b
3	2996.92^c	187.56^c	1108.32^c	77.7^a	0.870^b	1.47^b	2.11^b	92.41^b	0.219^{bc}
4	3535.77^b	199.01^b	1246.79^b	78.4^a	0.861^{bc}	1.44^b	2.07^b	92.71^{bc}	0.186^c
5	3909.12^a	205.70^a	1331.79^a	79.1^a	0.851^c	1.43^b	2.06^b	89.81^c	0.151^c

Means in the same column followed by different letters are significantly different according to Duncan's test ($p<0.05$).

The table shows that the size increased progressively in both cultivars over the period of development and ripening as expected. The increase in size may be due to physiological growth. The knowledge related to size would be valuable in designing the grading process. The surface area increased progressively from immature fruits to over ripe fruits. The surface area could be beneficial in proper prediction drying rates and hence drying time in the dryer. Onuegbu et al. (2011) found fruit length and width of ube (African pear) increased significantly ($p< 0.05$) during fruit development (Onuegbu et al. 2011). The sphericity (%) increased slightly, i.e. varying from elongate to round shape in both cultivars. The high sphericity is indicative of the tendency of the shape towards a sphere. The true density decreased slightly during ripening. This agreed with the observations reported by Onuegbu et al. (2011) (Onuegbu et al. 2011). The mass and true density may be useful in the separation and transportation of the fruit by hydrodynamic means. The same table shows that fruit length/width ratio and seed cavity length/width ratio decreased slightly the greatest variation occurred during between second and third stages. The fruit shape (sphericity and fruit length/width ratio) gave us an idea about the pedigree of the most of cultivars. Al-Maiman and Ahmad (2002) found the fruit length/width ratio of pomegranate (Taifi Cultivar) decrease during fruit maturation. Documented information don't achieve about the seed cavity length/width ratio of melons. The moisture content decreased during of ripening (95.77 to 89.81%) (Al-Maiman and Ahmad 2002). Villanueva et al. (2004) evaluated chemical composition changes during ripening of the fruit of both muskmelons (*Cucumis melo* L.) cultivars in five different stages of maturity (Villanueva et al. 2004). Weight increased up to the full-ripe stage of both melon types, while a decrease in moisture occurred in the same period. The change in modulus of elasticity is associated with the stage of ripening. The modulus of elasticity decreased from 0.558 MPa to 0.151 MPa during ripening. It may be due to change in structure of the pectin polymers during ripening in the cell wall. Abbot and Lu (1996) had shown that ripeness will reduce the mechanical parameters over time (Abbott and Lu 1996). Mechanical properties are critical aspects of a melon's quality and knowledge of these properties helps in the development of methods for sorting melons according to firmness.

The results of two-way ANOVA showed that there were significant differences between the two melon cultivars for time for all the parameters. There were no significant differences for the interaction of cultivars and time (Table 3). Lack of statistical significance for differences found for some parameters between both cultivars could be due to the same agronomic and climatic conditions.

Table 3. Two way ANOVA cultivar (V) and time (T): F statistic values

Variable	V	T	VT
Mass (g)	0.18^{ns}	506.8^{***}	0.98^{ns}
Size (cm)	1.15^{ns}	658.19^{***}	0.19^{ns}
Surface Area (cm^2)	1.48^{ns}	598.08^{***}	0.34^{ns}
Sphericity (%)	0.01^{ns}	20.50^{***}	0.02^{ns}
True Density (g/cm^3)	7.78^{ns}	20.41^{***}	0.26^{ns}
q	0^{ns}	22.91^{***}	0.02^{ns}
q'	3.88^{ns}	6.12^{***}	0.63^{ns}
Moisture Content	0.04^{ns}	8.03^{***}	0.44^{ns}

^{ns} $p > 0.05$. * $p < 0.05$. ** $p < 0.01$. *** $p < 0.001$.

Conclusion

The results of this study showed that the fruit ripening had an effect on the physical and mechanical properties of the melon fruits. There was an increase in the values of mass, size, surface area and sphericity and a decrease in true density, fruit length/width ratio, seed cavity length/width ratio, moisture content and modulus of elasticity in both melon cultivars during ripening. The some properties had greatest variation during between second and third stages of ripening. Analysis of variance showed significant differences between the different stages in each cultivar for every attribute. A two-way ANOVA test showed significant interactions in the behavior of all the attributes between cultivars during ripening.

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References

Abbott J, Lu R (1996). Anisotropic mechanical properties of apples. Transactions of the ASAE 39, 1451-1459.

Al-Maiman, SA, Ahmad D (2002). Changes in physical and chemical properties during pomegranate (Punica granatum L.) fruit maturation. Food Chemistry 76, 437-441.

Altuntas E, Bayram ENGM (2013). The physical, chemical and mechanical properties of medlar (Mespilus germanica L.) during physiological maturity and ripening period 2. Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi 30, 33-40.

Amorós A, Zapata P, Pretel M, Botella M, Serrano M (2003). Physico-chemical and physiological changes during fruit development and ripening of five loquat (Eriobotrya japonica Lindl.) cultivars. Food Science and Technology International 9, 43-51.

Duru B, Turker N (2005). Changes in physical properties and chemical composition of cactus pear (Opuntia ficus-indica) during maturation. J PACD 7, 22-33.

Franco G, Cartagena V, Correa L, Lobo A (2013). Physical characterization of gulupa fruits (Passiflora edulis Sims) during ripening and postharvest. Agronomía 21, 48-62.

Jha S, Kingsly A, Chopra S (2006). Physical and mechanical properties of mango during growth and storage for determination of maturity. Journal of Food engineering 72, 73-76.

Keramat Jahromi M, Jafari A, Rafiee Sh MR, Mohtasebi S (2008). Changes in physical properties of date fruit (cv. Shahani) during three edible stages of ripening. American-Eurasian Journal of Agricultural and Environmental Science 3, 132-136.

Mohsenin NN (1970). Physical properties of plant and animial materials. Vol. 1. Structure, physical characterisitics and mechanical properties. Physical properties of plant and animal materials. Vol. 1. Structure, physical characteristics and mechanical properties. 1.

Muskovics G, Felföldi J, Kovács E, Perlaki R, Kállay T (2006). Changes in physical properties during fruit ripening of Hungarian sweet cherry (Prunus avium L.) cultivars. Postharvest biology and technology 40, 56-63.

Narain N, Bora PS, Holschuh HJ, Vasconcelos MAdS (1992). Variation in physical and chemical composition during maturation of umbu (Spondias tuberosa) fruits. Food Chemistry 44, 255-259.

Onuegbu N, Ihediohanma N (2008). Some proximate analysis of african pear (Dacryodes edulis). Journal of Applied Sciences and Environmental Management 12.

Onuegbu N., Nwosuagwu U, Kabuo N, Nwosu J, Ihediohanma N (2011). The Physical Properties of Ube (Dacryodes edulis) at Different Stages of Fruit Development. Nature & Science 9.

Parveen S, Ali, MA, Asghar M, Khan AR, Salam A 2012. Physico-chemical changes in muskmelon (Cucumis melo L.) as affected by harvest maturity stage. Journal of Agricultural Research 50, 249-260.

Purseglove JW (1968). Tropical crops. Dicotyledons 1 and 2. Tropical crops. Dicotyledons 1 and 2.

Rogiers SY, Knowles NR (1997). Physical and chemical changes during growth, maturation, and ripening of saskatoon (Amelanchier alnifolia) fruit. Canadian journal of botany 75, 1215-1225.

Shuang-wu M, Jun-pu L (2006). Descriptors and data standard for melon (Cucumis melo L.). Beijing: China Agricultural Press.

Tafti AG, Fooladi M (2005). Changes in physical and chemical characteristics of Mozafati date fruit during development. J. Biol. Sci 5, 319-322.

Tosun I, Ustun NS, Tekguler B (2008). Physical and chemical changes during ripening of blackberry fruits. Scientia agricola 65, 87-90.

Villanueva, M., Tenorio, M., Esteban, M., Mendoza, M., (2004). Compositional changes during ripening of two cultivars of muskmelon fruits. Food chemistry 87, 179-185.