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Physical Properties and Compositional Changes of two Cultivars of Cantaloupe Fruit During Various Maturity Stages

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ABSTRACT- Some physical properties and chemical compositions of two cultivars (Semsouri and Shahabadi) of cantaloupe studied during four different stages of maturity from fruit set to completely ripe. The physical properties investigated were the geometric mean diameter (GMD), specific gravity (SG), mean firmness (MF), rind, seed (%) and flesh (%). The chemical compositions were Brix, Titrable Acidity (TA), moisture content, pH, and ash. The results showed that the GMD, flesh (%), Brix, and pH values of both cultivars increased in the full-ripe stage of maturity whereas there was concurrent decrease in SG, rind (%), seed (%), moisture content, TA, and ash values obtained in the same period. There were also significant differences (using GLM-multivariate analysis) in all measured variables apart from ash, seed (%), rind (%), and flesh (%) between the two cultivars. Overall, the linear relationships were obtained between sugar content and GMD, SG, and MF respectively, correlation coefficients being higher than 0.87.

Keywords: Fruit quality, Muskmelon, Firmness, Ripeness, Brix analysis, Sugar content, Physical properties.

INTRODUCTION

Cantaloupe (*Cucumis melo* L.) is a climacteric fruit (Rowan et al, 1969) and its texture, flavor and sweetness effect its quality. Fruit quality requires a balance of sugar and acidity as well as its aroma. The fruit's sugar content and its firmness which is affected by changes in physical and mechanical properties and composition have received considerable attention (7 and 13). The firmness of cantaloupe flesh is one of the most important quality factors that influence consumer satisfaction. According to USDA's (U.S Department of Agriculture, 2007) Nutrient Database, the overall composition of cantaloupe (per 100g of fruit) was reported as follows: water 89.78 g, minerals 0.36g, proteins 0.88g, total lipid 0.28g carbohydrate 8.36g, total dietary fiber 0.8g, ash 0.71g. Commercial cultivars of cantaloupe fruit should be characterized by high fruit quality attributes as many consumers are not fully satisfied with the current standard of most horticultural products. Therefore, quality criteria play a major role in major cantaloupe breeding programs (12).

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Physical or chemical characteristics are important factors affecting the optimum maturity of fruit flesh. Previous studies have focused on the relationship between total soluble solids (TSS) and total sugars, titratable acids (TA) and total organic acids (3 and 10). However, cantaloupe quality cannot be assessed by only those parameters. Different factors have an impact on the taste quality including ripeness, cultivar, irrigation, and fertilization (9 and 15). Moreover, optimum quality is also dependent on harvesting at the suitable stage of fruit maturity which affects the shelf life of fruit after harvest (18). One sign of fruit immaturity could be its firmness. At optimum maturity, some cultivars of cantaloupe have flesh which is too soft (21).

Changes in sugar content occur during fruit growth based on the carbohydrates present in the fruit and alteration of fruit metabolism, and dilution happens when fruit volume increases. Carbohydrate supply is influenced by these factors, thus the sugar content is positively correlated to the size of the fruit (8).

Discovering the relationship between fruit texture and biochemical composition could result in improving the quality control and process design in the food manufactures. Many studies have already addressed either the changes in cantaloupe texture or changes in carbohydrate composition during fruit ripening, though few researches have correlated the two (20).

The aim of this research was to expand knowledge on compositional variability in cantaloupe and to study the relationship between sugar content and firmness and the specific gravity and size of cantaloupe fruit. Two cultivars with different textural characteristics were studied in order to investigate whether the differences in sugar content between two cantaloupe cultivars were due to differences in their texture over different stages of ripening.

MATERIALS AND METHODS

Plant material

The experiment was carried out in the Agricultural and Natural Resources Research Center, Isfahan, Iran, during 2007. Two of the most commonly produced cultivars of cantaloupe (*Cucumis melo* L.) i.e. "Semsouri" and "Shahabadi" were selected for this study. Plants were grown in a farm at the end of April and picked at four stages of maturity over the period from fruit set to completely ripe. The four stages were at 12 (1), 24 (2), 36 (3) and 48(4) days after fruit set. Fruits were selected according to color, size and lack of blemishes in order to obtain homogeneous samples. Samples comprised of 4 fruits in order to limit individual sample variability.

Chemicals

The chemicals and reagents used in this study were obtained from Merck (Germany) and were of analytical grade.

Experimental methods

The physical properties of each sample were determined by the following methods: major diameter (a, mm), minor diameter (b, mm) and height (h, mm) of each fruit were measured by a caliper with 0.1 mm accuracy. Geometric Mean Diameter (GMD, mm) was calculated by means of the following equation 1 (11):

$$GMD = (abh)^{1/3} \tag{1}$$

Specific gravity (SG) was measured by liquid displacement method. Toluene (C_7H_8) was used, rather than water because water is absorbed by the fruits. Firmness was measured using a Magness-Taylor penetrometer with an 8.0 mm diameter probe tip Barreiroa et al.(3). It was calculated as the maximum force expressed as Newton, N) necessary to compress the cantaloupe 5 mm at constant speed of 20 mm/min. It should be noted that the samples were not peeled off. The impact of firmness force was measured at four reciprocal positions on all individual fruits Norton et al. (15): the stem end (F1), the blossom end (F2), a point rotated by 90^o angle from the stem-bottom axis (F3) and opposite side of F3 (F4). The average of firmness (MF) was determined as given below (equation 2):

$$MF= Sum (F1, F2, F3 and F4)/4 \qquad (2)$$

The percentage of rind, seed and flesh were calculated by measuring their weight divided by the total weight of each sample. The sugar content was quantitatively measured using a Brix meter (a CETI - Belalum digital-refractometer, Belgium) with a reference temperature of 20^oC. The actual Brix indices were corrected to fit the ambient temperature at 15^oC. The resolution and precision of the refractometer were 0.1% and ~0.2% respectively. The TA values were obtained according to the AOAC (2) method. The moisture content of the fruit flesh was measured by drying the samples to a constant weight in a 105 ^oC oven AOAC (1). The pH values of the extract from the fruit flesh were determined using a pH meter. The total ash content of samples was obtained by keeping them in a furan at 450^oC AOAC (2). Each experimental value was obtained from four replicates.

Data analysis

Data acquisition and statistical analysis were carried out with SPSS 15.0 software (2006). The analysis of variance (ANOVA) was performed independently for each cultivar and for all variables measured by physicochemical analysis and penetrometry. The GLM-univariate analysis (a Duncan's test) was used for 6 dependent factors consisting of GMD, SG, MF, rind (%), seed (%) and flesh (%) of two cantaloupe cultivars at four maturity stages.

Results and discussion

Table 1 shows that GMD values increased differently in both cultivars during ripening, particularly for Shahabadi cultivar (from 12.6 to 18.7). A downward trend was obtained for SG values of the two cultivars. The maximum SG values were similar for Semsouri (0.94 g/cm^3) and Shahabadi (0.93g/cm^3) cultivars. In addition, the minimum obtained SG value of Semsouri cultivar was 0.63 lower than that of Shahabadi cultivar (0.71). The MF values decreased from 32.9N to 14.5N for Semsouri cultivar and from 41.1N to 19.6N for Shahabadi cultivar, respectively. The flesh percentage for both cultivars respectively gradually increased to 75.8% for the Semsouri cultivar and to 75.4% for the Shahabadi cultivar- nearly similar values. On the other hand, the rind and seed percentage values for both cultivars decreased during maturity stages. For instance the rind percentage value (Shahabadi cultivar) was 18.3 (stage 1) and 8.1 (stage 4) and the seed percentage value (Shahabadi cultivar) was 17.5 (stage 1) and 9.1 (stage 4).

Table 2 shows an upward trend of Brix data for both cultivars. The maximum mean Brix value (7.1%) was obtained for Semsouri cultivar (in the fourth stage of maturity) which is nearly parallel to the USDA report (23). However, other melons such as muskmelon (Brix of 15.5% for Piel de Sapo cultivar and 14.6% for Rochet Cultivar) have higher Brix values as demonstrated by Villanueva et al (19). Moreover, (17) pointed out that commercial maturity melons such as honeydew cultivars had higher soluble solid content (Brix, 9.2%) than cantaloupe (8.0%).

Table 1. The GLM-univariate analysis was carried out for 6 physical properties of two canteloupe cultivars at different maturity stages using SPSS software.

Cultivr	Maturity stage	GMD (cm)	SG	MF (N)	Rind (%)	Seed (%)	Flesh (%)
Semsouri	1	10.2^{c}	0.94^{a}	32.9^{a}	14.8^{a}	21.2^{a}	60.5^{b}
	2	12.5^{b}	0.78^{b}	30.6^{a}	13.3^{ab}	18.0^{ab}	62.7^{ab}
	3	12.1^{b}	0.72^{bc}	20.3^{b}	12.0^{ab}	14.9^{ab}	65.9^{ab}
	4	15.1^{a}	0.63^{c}	14.5^{b}	10.7^{b}	11.5^{b}	75.8^{a}
Shahabadi	1	12.6^{c}	0.93^{a}	41.1^{a}	18.3^{a}	17.5^{a}	56.5^{b}
	2	13.8^{bc}	0.84^{b}	34.0^{a}	15.9^{a}	16.8^{a}	57.5^{b}
	3	15.1^{b}	0.76^{c}	22.8^{b}	11.7^{b}	13.9^{ab}	62.0^{b}
	4	18.7^{a}	0.71^{c}	19.6^{b}	8.1^{c}	9.1^{b}	75.4^{a}

Means in the same column represented by different letters are significantly (p<0.05) different based on Duncan's test.

Table 2. The GLM-univariate analysis, a Duncan'test, was carried out for 6 factors of two canteloupe cultivars at different maturity stages using SPSS software.

Cultivar	Maturity stage	Brix (%)	pH	TA	Brix/TA	Moisture (%)	Ash (%)
Semsouri	1	4.5^{b}	5.3^{d}	1.0^{a}	4.4^{b}	94.1^{a}	1.02^{a}
	2	5.1^{b}	5.5^{c}	0.99^{a}	5.2^{b}	93.5^{ab}	0.89^{a}
	3	5.7^{ab}	5.8^{b}	0.73^{b}	8.7^{b}	91.9^{bc}	0.86^{a}
	4	7.1^{a}	6.1^{a}	0.48^{c}	15.6^{a}	91.3^{c}	0.69^{a}
shahabadi	1	3.7^{c}	4.7^{c}	1.4^{a}	2.8^{c}	95.4^{a}	1.05^{a}
	2	4.5^{bc}	5.0^{c}	1.3^{a}	3.5^{bc}	94.8^{ab}	0.86^{ab}
	3	5.1^{ab}	5.5^{b}	1.0^{b}	5.0^{b}	93.6^{bc}	0.55^{bc}
	4	6.2^{a}	6.0^{a}	0.74^{c}	8.6^{a}	92.7^{c}	0.47^{c}

Means in the same column represented by different letters are significantly (p<0.05) different based on Duncan's test.

The pH in both cultivars followed an upward trend during fruit development (values reached to 6.1 in the Semsouri cultivar and 6.0 in the Shahabadi cultivar at maturity). The variations were significant (Duncan's test) for Semsouri samples, although two variation levels (a&b) were obtained for Shahabadi samples. The trend of TA values was opposite the trend of pH values. The ripening index (Brix/TA) followed upward trends in both cultivars. However, values were higher in Semsouri cultivar than Shahabadi cultivar. In addition, the moisture content values decreased gradually and the variations were significant ($P < 0.01$) for the two cultivars. Furthermore, the ash contents of Semsouri cultivar decreased slightly (no significant differences) despite the fact that ash values of the Shahabadi cultivar decreased significantly ($P<0.05$). The differences in mentioned values of physicochemical properties could be affected by climate conditions and maturity at harvest (3 and 15). The sugar content (Brix value) is a good indicator of consumer appraisal in relation to fruit quality. The appropriate Brix level is generally dependent on region. For instance, the British do not consume too ripe melons (22). The results of Duncan's test for Brix data showed significant variations in both cultivars during maturity stages. The Brix values increased from 4.5 to 7.1% (2.6 fold differences) for Semsouri cultivar and, the Brix values of Shahabadi cultivar varied from 3.7 to 6.2% (2.5 fold differences). Fig. 1 shows the Brix values of two cultivars of canteloupe at different maturity levels (1, 2, 3 & 4).

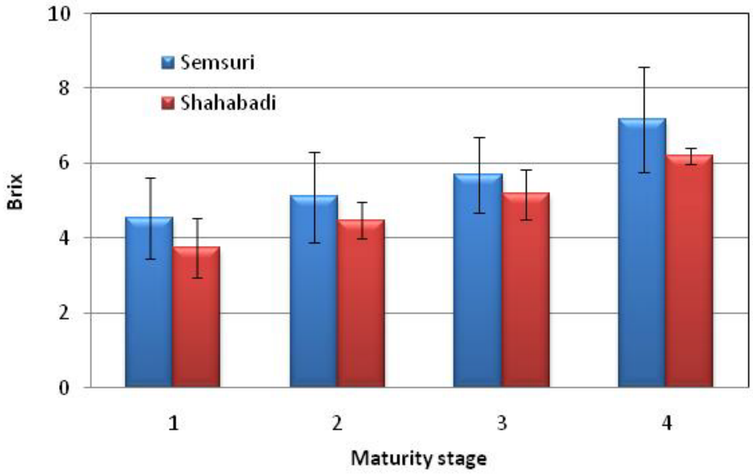

Figure 1. The brix values of two cultivars of fruit cantaloupe are shown at different maturity levels. The standard deviations are included as error bars.

The GLM-multivariate analysis considers the interrelation between dependent variables and analyzes the variables simultaneously Esbensen et al (6). The effect of cultivar and maturity stages and their interaction with physical and chemical properties were studied. The results (Table 3) showed that there were significant differences across cultivars for GMD, pH values ($P<0.001$), moisture ($P<0.01$) and, SG, MF and Brix ($P<0.05$), nevertheless other variables were insignificant. There were significant differences (at $P<0.01$ or $P<0.001$) between the maturity stage for all variables, while for the interaction between maturity stage and cultivar, there was no significant difference found among any of the variables except for rind percentage ($P<0.05$).

Table 3. The GLM-multivariate analysis was used by SPSS software. The dependent variables were GMD, SG, MF, Rind (%), Seed (%), Flesh (%), Brix, pH, TA, °Brix/TA, moisture and ash. The cultivar and maturity stage were as fixed factors.

Variable	cultivar	Maturity stage	Maturity stage& cultivar
GMD	**40.3*** **	**31.8*** **	**1.4ns**
SG	**5.3***	**40.1*** **	**0.96ns**
MF	**5.5***	**20.2*** **	**0.3ns**
Rind (%)	**1.2ns**	**17.4*** **	**3.4***
Seed (%)	**1.7ns**	**6.1*** **	**0.1ns**
Flesh (%)	**1.7ns**	**9.1*** **	**0.1ns**
Brix	**4.4***	**10.3*** **	**0.09ns**
pH	**36.0*** **	**36.4*** **	**1.95ns**
TA	**57.6*** **	**44.2*** **	**0.19ns**
Brix/TA	**14.3*** **	**17.1*** **	**1.8ns**
Moisture	**12.3** **	**9.9*** **	**0.08ns**
Ash	**3.1ns**	**6.9** **	**1.1ns**

The statistical values of F were shown at significant levels consisting of ns not significant,
$* \ p < 0.05$, $** \ p < 0.01$ and $*** \ p < 0.001$

The Brix data was plotted against GMD, SG and MF data sets so as to observe linearity of each relationship and more concisely the association between chemical data and physical data as shown in Fig. 2. All numbers are the average of the four determinations. Fig. 2a represents the relationship between GMD and Brix mean values (R^2, 0.90 for Semsouri cultivar and 0.96 for Shahabadi cultivar). The R^2 of SG-Brix correlations were 0.87 (Semsouri cultivar) and 0.95 (Shahabadi cultivar) respectively, as seen in Fig. 2b. The correlation between MF and Brix mean data is shown in Fig. 2c with R^2 of 0.91 (Semsouri cultivar) and 0.92 (Shahabadi cultivar). All the R^2 values exceeded 0.87, a value that indicates a good correlation within three pairs of data sets.

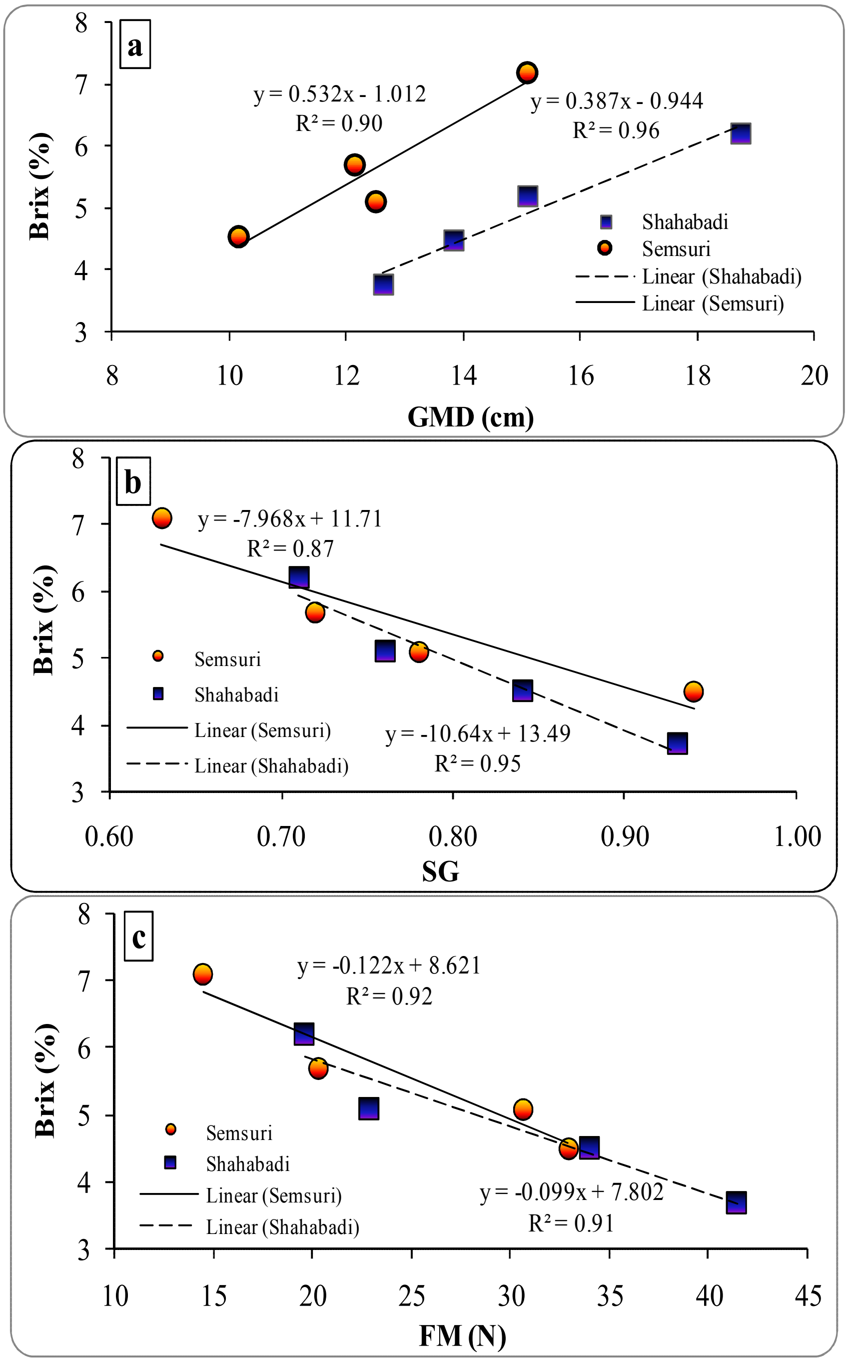

Figure 2. A comparison of Brix values as a function of GMD (a), SG (b) and MF (c) for Semsouri and Shahabadi cultivar respectively. Each value is an average of four measurements.

Conclusions

It is generally believed that size, weight and firmness of melon fruits would be good indicators of fruit maturity in the marketplace for many consumers. Therefore, it is of interest to estimate the development of fruit ripeness by correlating physical properties to biochemical examinations. In this respect, the relationship between GMD, SG and MF, and Brix values were studied. The results illustrated changes in GMD, SG and MF related to the sugar content of fruit. However; there is a limitation in declining fruit firmness due to the overriping criterion and the fruit's shelf life. Due to the climacteric pattern of cantaloupe ripening, the optimum stage of harvesting needs some more considerations. It is concluded that the Shahabadi cultivar had higher GMD values compared to Semsouri cultivar despite its lower sugar content over four stages of maturity.

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REFERENCES

1. AOAC. 1984. Official methods of analysis. 14th ed. Arlington: Association of Official Analytical Chemists.

2. AOAC. 1990. Official methods of analysis.15th ed. Arlington: Association of Official Analytical Chemists.

3. Barreiroa M., G. da, F. C. Lidonb, and M. Pintoa. 2001. Physicochemical characterisation of the postharvest senescence of the winter melon. Fruits. 56: 51–58.

4. Beaulieu J. C., and J. M. Lea. 2007. Quality changes in cantaloupe during growth, maturation, and in stored minimally processed cubes prepared from fruit harvested at various maturities. Journal of American Society Horticultural Science. (In Press).

5. Chachin, K., and T. Iwata. 1988. Physiological and compositional changes in Prince melon fruit during development and ripening. Bulletin of the University of Osaka Prefecture. Series B, Agriculture and biology. 40: 27–35.

6. Esbensen K. H. 2001. Multivariate Analysis in Practice. fifth ed. CAMO Press AS ISBN 82-993330-2-4.

7. Flores, F., M. Ben Amor. B. Jones. J. C. Pech. M. Bouzayen. A., Latché., and F. Romojaro. 2001. The use of ethylene-suppressed lines to assess differential sensitivity to ethylene of the various ripening pathways in Cantaloupe melons. Physiology Plant**.** 113:128–133.

8. Genard M, and M. Souty. 1996. Modeling the peach sugar contents in relation to fruit growth. Journal of the American Society for Horticultural Science. 121: 1122–1131.

9. Kays S. J., 1991. Postharvest physiology of perishable plant products. AVI, New York.

10. Lester, G., and J. R. Dunlap. 1985. Physiological changes during the development and ripening of Perlita muskmelon fruits. Scientia Horticulturae. 26: 323–331.

11. Mohsenin N. N., 1986. Physical Properties of Plant and Animal Materials. Gordon and Breach Science Publishers pp. 20–89.

12. Moreau-Rio, M., and C. Roty. 1998. L'abricot: Perceptions et attentes des consommateurs français. Ctifl-Infos. 141: 16–21.

13. Mutton, L. L., B. R. Cullis, and A. B. Blakeney. 1981. The objective definition of eating quality in rockmelon (Cucumis melo L.). Journal of Science and Food Agriculture. 32: 385–391.

14. Norton, J. D., R. D. Cosper, D. A., Smith, and K. S. Rymal, 1985. A high quality "Jumbo" cantaloupe. Circular. 278: 9-11.

15. Robertson, R.W., and Decker- D.S. Walters. 1999. Cucurbits. CAB International, New York.

16. Rowan, K. S., W. B. Mcglasson, and H. K., Pratt, 1969. Changes in Adenosine Pyrophosphates in Cantaloupe Fruit Ripening Normally and after Treatment with Ethylene. Journal of Experimental Botany. 20: 145-155

17. Saftner R., J.A. Abbott, G., Lester, and B. Vinyard. 2006. Sensory and analytical comparison of orange-fleshed honeydew to cantaloupe and green-fleshed honeydew for fresh-cut chunks. Postharvest Biology and Technology. 42: 150–160.

18. Seymour, G. B., and W. B. McGlasson. 1993. Melons. ***In:*** G. B. Seymour, J. E. Taylor and G. A. Tucker, (***eds.***), Biochemistry of fruit ripening. London, Chapman and Hall.

19. Villanueva, M. J., M. D. Tenorio, M. A. Esteban, and M. C. Mendoza. 2004. Compositional changes during ripening of two cultivars of muskmelon fruits. Food Chemistry. 87: 179–185.

20. Wang, Y., S. G Wyllie, and D. N. Leach. 1996. Chemical changes during the development and ripening of the fruit of Cucumis melon (cv. Makdimon). Journal of Agricultural and Food Chemistry. 44: 210–216.

21. Yamaguchi, M., D. L. Hughes, K. Yabumoto, and W. G. Jennings. 1977. Quality of cantaloupe muskmelons: variability and attributes. Scientia Horticulturae. 6: 59–70.

22. Zapata, M. P. Cabrera. S. Bañón., and P. Roth. 1989. El melón., Mundi Prensa, Madrid.

23. USDA (U.S. Department of Agriculture), USDA National Nutrient Database, 2007. URL: http://www.nal.usda.gov/fnic/foodcomp/ , Accessed 12/02/2007

مطالعه ويژگيهاي فيزيكي و تغييرات تركيب شيميايي دو رقم ميوه طالبي درطي مراحل مختلف رسيدگي

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چكيده - بعضي ويژگيهاي فيزيكي و شيميايي دو رقم طالبي (سمسوري و شاه آبادي) درطي ٤ مرحله مختلف رسيدگي از دوره گل دهي تا رسيدگي كامل موردمطالعه قرارگرفت. ويژگيهاي فيزيكي موردبررسي شامل قطرمتوسط هندسي، وزن مخصوص، سفتي متوسط، درصدپوسته ، درصد بذر و درصدگوشت ميوه بودند. تركيبات شيميايي شامل بريكس، اسيديته قابل تيتراسيون، رطوبت ، pH و خاكستر بودند. نتايج نشان داد كه مقاديرقطرمتوسط هندسي، درصد گوشت ميوه ، بريكس و pH براي دو توده تا مرحله رسيدگي كامل افزايش داشت درحالي كه مقادير وزن مخصوص ، درصد پوست ميوه ، درصد بذر، رطوبت ، اسيديته قابل تيتراسيون و خاكستر درهمان دوره سير نزولي داشت. همچنين اختلاف هاي معني داري (بااستفاده از آناليز مدل خطي عمومي- چندمتغيره) درهمه متغيرهاي اندازه گيري شده بجز خاكستر، درصد بذر و درصد گوشت ميوه بين دو توده وجودداشت. بين مقدار قند و سه ويژگي قطرمتوسط هندسي ، وزن مخصوص و سفتي متوسط، ارتباطات خطي با ضريب همبستگي بيشتر از ۰/۸۷به دست آمد.

واژه های کلیدی: کیفیت میوه، طالبی، سفتی، رسیدگی، آنالیز بریک

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