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Different Ripening Indices and Quality Attributes of Different Groups of *Cucumis melo*

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Abstract
Six Iranian accessions of *Cucumis melo*, including Inodorus, Cantalupensis, and Dudaim groups, were planted and then harvested at two harvesting stages including 21 and 28 days after anthesis for Dudaim group and 28 and 38 days after anthesis for Inodorus and Cantalupensis groups. At the time of harvest, we measured some quality parameters and appearance indices of fruits, such as the number of strips on surface, tendril condition, peduncle condition, presence or absence of the abscission zone formed around the peduncle, netting, presence of trichomes, and force needed to detach the fruit from the plant. Results showed that the best ripening indices for Inodorus, Cantalupensis, and Dudaim groups were not the same. Contrary to Samsouri and lately harvested Khatouni accessions, there were not any abscission zone in Dudaim fruits. In most of the treatments, tendril was yellow or dry in lately harvested fruits opposite to green in tendrils in early harvested fruits. Peduncles were green in all treatments and the force needed to detach the fruit from the plant in most treatments was the highest degree (score 3). Lately harvested fruits had more advanced levels of color, TSS, and firmness than early harvested ones. Generally, the best ripening indices for melon fruits corresponding to each accession were different.

Key words: Cantalupensis, day after anthesis, dudaim, inodorus, maturity.

Introduction

Melons, *Cucumis melo*, are a highly polymorphic species for fruit characteristics. The melons that are the most valued are the ones that turn sweet when ripe, including the muskmelons, cantaloupes, casabas, and Dudaim. Others, including the elongate adzhur, conomon, and snake melons, are consumed when immature, like cucumbers (Paris *et al*., 2012).

Maturity at harvest is one of the key factors influencing fruit quality, especially in melon, due to the existence of climacteric and non-climacteric groups of melon. Maturity at harvest has also shown to have a large impact on the sugar content (related to sweetness), volatile content (related to flavor and aroma), and texture of melon fruit (Beaulieu and Lancaster, 2007; Perkins-Veazie *et al*., 2012). Melon fruit ripening is a genetically determined event that involves a series of changes in color, texture, firmness, aroma, and flavor, making fruit scent and flavor appealing to consumers (Nunez-Palenius *et al*., 2007). Typically, muskmelon fruit maturity in the field is determined by the extent of the development of an abscission layer (also called ‘‘slip’’ in the trade) between the vine and the fruit. In addition, melons destined for long distance transport are typically harvested earlier, sometimes even before the clear development of an abscission zone (Vallone *et al*., 2013).

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Melon fruits are harvested using a combination of different harvest indices depending on their climacteric or non-climacteric behavior. Minimum harvest indices are the presence of a well-formed and defect-free fruit, firm, well-healed, and dry epidermis with lignified netting, and high density according to previous recall of the harvester (compactness), skin color, the senescence of the leaf close to the fruit, and stem scar development (Chaparro-Torres *et al.*, 2016). The most common harvest indices are yellowing of the ground spot, about 1/2 to 3/4 slip or skin netting development, yellowing close to the slip area, development of an annular ring in the peduncle that precedes fruit dehiscence, the start of cracking or history of cracking, volatile emission detected by the human nose, light yellow skin color, and whole fruit texture and peduncle suberization (Obando-Ulloa *et al*., 2008).

There have been many studies investigating different types of melons, focusing on ripening indices and the effect of harvest maturity on quality characteristics but very few about comparing them together. Nunez-Palenius *et al*. (2007) harvested Galia melons at 37, 42, and 50 days after pollination (DAP), corresponding to zero-, half-, and full-slip developmental stages, respectively, and reported that, as for most muskmelon fruit, the Galia fruit rind turns from green to yellow during ripening. Rind tissue is significantly more sensitive to impairment of ethylene synthesis and perception (Flores *et al*., 2001a, b). Mahmuda Khanom *et al*. (2003) harvested Prince Melons at 15, 20, 27, and 34 days after anthesis and reported that, at 34 days after anthesis, fruit had the best quality for consuming but unsuitable for shipping.

Recognition of ripening indices has a critical influence on fruit quality, storing, and marketability of harvested melon fruits. The purpose of this study was studying of ripening indices of different maturity stage of three groups of melon.

Materials and Methods

Planting and Harvesting

Six Iranian accessions of *Cucumis melo*, including Khatouni, Samsouri, Garmak, Zangi-abad, Kermanshah, and Kangavar (Fig. 1), were planted in randomized completely block design. These accessions belonged to the vars. Inodorus (Khatouni), Cantalupensis (Samsouri and Garmak), and Dudaim (Zangi-abad, Kermanshah, and Kangavar) (Soltani *et al*., 2010; Raghami *et al*., 2013). Female flowers were tagged on the day of anthesis and then fruits were harvested at two harvesting stages including 21 and 28 days after anthesis for Dudaim group and 28 and 38 days after anthesis for Inodorus and Cantalupensis groups. At the time of harvest, we investigated some appearance indices of fruits such as the number of strips on surface, tendril condition (green=1 score, yellow=2 score, or dry=3 score), peduncle condition (green=1, yellow=2, or dry=3), presence or absence of the abscission zone formed around the peduncle (without abscission=0, 1/3 abscission=1, 2/3 abscission=2, full abscission=3), netting (soft=1, moderate=2, rough=3), presence of trichomes (without trichome=0, poor=1, moderate=2, severe=3), force needed to detach the fruit from the plant (easily=1, moderate=2, hardly=3), and also fruit size and weight.

Quality Analysis

Surface color values were measured using a Minolta Chroma Meter (Model CR-400, Japan) at three random points of the flesh fruits. Fruit flesh firmness was measured at two points on the equatorial zone of the fruit using a hand-held firmness penetrometer (Model FT 327, Italy) fitted with an 8-mm diameter plunger tip. Titratable acidity expressed as percentage of citric acid was measured through titrating 5 ml of fruit juice by 0.01 N NaOH to pH 8.1. Total soluble solids (TSS) content of fruit juice was determined by a hand-held refractometer (ATAGO (0-32 Brix)).

Statistical Analysis

The treatments were arranged in a factorial design 6×2×3 on the basis of a randomized complete block design (RCBD): 6 accessions of melon (Khatouni, Samsouri, Garmak, Zangi-abad, Kermanshah, and Kangavar) ×2 maturity stages (early and lately harvested fruits) ×3 blocks and 4 observations (totally 144 fruits). The analysis of variance was performed using the Statistical Analysis System 9.1 computer package (SAS Institute, Inc., Cary, NC). Significant differences among the treatments were detected using the least significant difference (LSD) test at the 5% level of significance.

Results and Discussion

Fruit Weight and Morphological Traits

The longest width was for lately Garmak and Samsouri accessions (about 159-162 cm) and the shortest width was for Kermanshah accession (about 54-63cm). Khatouni accession had the longest length (about 274-364 cm) and Kermanshah accession had the shortest length (69-79 cm) between all treatments. Lately harvested Garmak, Samsouri, and Khatouni accessions were heavier (about 1868-2385 g) and greatly affected by harvest time (about 1051 g). Flesh weight of Kermanshah and Zangi-abad accessions were the lowest amount (about 99-199 g). About seed weight, opposite to Khatouni accession which had clear difference between early and lately harvested fruits, in other treatments there was not great difference between the two stages of maturity (Table 1).

Abscission Zone

Only Samsouri and lately harvested Khatouni accessions showed abscission zones. Average of scores were 2, 0.67, and 0.67 in lately harvested Samsouri, early harvested Samsouri, and lately harvested Khatouni accessions, respectively. In melons, the presence or absence of the abscission zone formed around the peduncle, commonly called ‘‘slip’’ is a good indicator of maturity and harvest time. Fruits are classified as ‘‘full slip’’ when a fully developed abscission zone (as evidenced by the development of a crack around the peduncle) is visible at harvest time. Physiologically mature melons have full size without any visible slip (‘‘pre-slip’’ fruit) (Vallone *et al*., 2013). Fruit harvested before development of the abscission zone will not develop adequate quality including flavor attributes. However, fruit harvested at or after development of the abscission have a shorter storage life, and flavor or textural loss may occur before completion of the marketing process (Beaulieu *et al*., 2004; Beaulieu, 2006).

Netting and Presence of Trichomes

The higher amount of netting was observed in lately harvested Kangavar accession (1.08 score). In Samsouri accession (both of early and lately harvested fruits) and lately harvested Khatouni accession, amounts of netting were 1 (soft). The ethylene production of melon has been suggested to correlate with the rind type. The netted melon group (such as reticulatus) produce considerable quantities of climacteric ethylene at or close to harvest than non-netted melon group (such as inodorus). The surface meshworks (‘net’) found in melon epidermis consist of an elaborate system of lenticels derived from the subepidermal periderm. The netted rind is reported to be associated with higher ethylene production and could be as a result of enhanced gas exchange of the melon mesocarp afforded by the lenticels (Ezura and Owino, 2008). In all treatments, only Zangi-Abad and Kermanshah accessions had trichomes (about 3 score).

Table 1. Comparison of the means related to evaluated ripening indices and measured quality parameters

Accession	Maturity stage	Strip (number)	Tendril (score)	Abscission zone (score)	Netting (score)	Trichome (score)	Force Needed (score)	Width (cm)	Length (cm)	Flesh weight (g)	Seed weight (g)	Hue of flesh	Chroma of flesh	Firmness+skin (kg cm^{-2})	Firmness- skin (kg cm^{-2})	TSS (Brix)	pH	TA (%)
Khatouni	DAA28	9.67d	1.00c	0.00c	0.00b	0.00c	3.00a	115.37cd	274.56b	1231.95c	256.85a	67.49def	14.28e	8.33d	4.95g	3.05e	5.99f	0.07cde
	DAA38	10.00cd	1.00c	0.67b	1.00a	0.00c	3.00a	125.59bc	363.36a	2384.20a	167.60c	65.72ef	23.25bc	10.11c	5.25g	5.70cd	6.26e	0.11bcd
Samsouri	DAA28	10.00cd	0.00d	0.67b	1.00a	0.00c	3.00a	137.58b	135.21d	983.90c	203.75b	64.40f	30.06a	12.63ab	9.78bc	4.00de	5.86fg	0.11bcd
	DAA38	9.67d	0.00d	2.00a	1.00a	0.00c	2.33b	159.70a	189.57c	2024.15ab	202.45b	69.09def	25.03bc	10.30c	5.97fg	5.10d	6.91b	0.10bcde
Garmak	DAA28	0.00e	1.33abc	0.00c	0.00b	0.00c	3.00a	124.81bc	133.44d	920.20c	143.60cd	66.14ef	20.47cd	12.90a	11.53a	5.40cd	5.82fg	0.10bcde
	DAA38	0.00e	2.00a	0.00c	0.00b	0.00c	3.00a	161.48a	175.58c	1868.25b	150.40cd	78.20bc	24.79bc	13.00a	10.75abc	10.95a	6.71cd	0.13bc
Zangi-Abad	DAA21	10.29bc	1.00bc	0.00c	0.00b	2.92a	3.00a	63.97fg	82.03ef	154.26e	66.35g	71.37de	16.86de	13.17a	11.25ab	6.97bc	6.88bc	0.16b
	DAA28	10.42abc	1.88ab	0.00c	0.00b	2.83b	3.00a	70.56f	87.13ef	198.93e	84.64fg	83.76ab	17.66de	11.33bc	8.12de	8.23b	7.64a	0.06de
Kermanshah	DAA21	10.83a	1.00c	0.00c	0.00b	3.00a	3.00a	62.49fg	78.79f	147.01e	79.78fg	68.85def	16.26de	13.50a	12.03a	5.50cd	7.00b	0.10bcde
	DAA28	10.50ab	1.63abc	0.00c	0.00b	2.96a	3.00a	54.85g	69.36f	99.99e	54.48g	85.17a	23.36bc	11.30bc	7.32ef	10.23a	7.81a	0.04e
Kangavar	DAA21	0.00e	1.29abc	0.00c	0.00b	0.00c	3.00a	85.81e	99.93e	324.20de	111.15ef	66.81def	12.75e	12.92a	9.25cd	5.30cd	6.56d	0.05de
	DAA28	0.00e	1.92a	0.00c	1.08a	0.00c	3.00a	109.09d	138.81d	747.16cd	129.72de	73.36cd	26.40ab	12.92a	10.82ab	7.10bc	5.75g	0.40a

†Values with different letter, within columns, are significantly different from each other by LSD Test at $P \leq 0.05$.

Force Needed to Detach

In all treatments, the force needed to detach the fruit from the plant was the highest degree (3 score) with the exception of lately harvested Samsouri fruits (2.33). Bertelsen *et al.* (1994) also reported that, unlike cantaloupes, mature honeydews do not form an abscission layer between the melon and the stem that permits easy separation of the fruit from the vine. Cantaloupes are harvested manually at the full-slip stage of maturity for best taste and texture. At full slip, the stem pulls away from the fruit, leaving a scar at the stem end (Orzolek *et al*., 2006). Motes *et al*. (2007) reported that properly matured cantaloupes for shipping (i.e., market maturity) should be half-slip, firm, well netted, and not deeply colored (at half-slip, the abscission layer between the stem and fruit is half formed and will allow the remaining half to separate with minimal force).

Number of Strips

In Khatouni and Samsouri accessions, the mean of strips were 9.83 for per fruits and in Zangi-Abad and Kermanshah accessions, the mean of strips were 10.35 and 10.67, respectively. There were not any strips on surface of Garmak and Kangavar accessions. The higher number of strips were observed in Kermanshah accession. In comparison of early and lately harvested fruits, in Khatouni and Zangi-Abad accessions, lately harvested fruits had higher number of strips than early harvested fruits, and in Samsouri and Kermanshah accessions, early harvested fruits had higher number of strips than lately ones.

Tendril and Peduncle Condition

In Samsouri accession, there was not any tendril in front of peduncle. Opposite to Khatouni accession that early and lately harvested fruits had same tendril condition (1=green tendril), in other accessions, lately harvested fruits had more advanced condition (yellow or dry tendril than green tendril) than early harvested ones as in early harvested fruits tendril was green and in lately harvested fruits was yellow or dry. In all treatments, peduncle was green.

Color of Flesh

Comparing all treatments showed that in all accessions, lately harvested fruits had more amounts of Hue than early harvested ones with the exception of Khatouni accession as there was not any significant difference between its early and lately harvested fruits. Lately harvested fruits also had more amounts of Chroma than early harvested ones with the exception of Samsouri accession with more Chroma amounts of its early harvested fruits. In melons, color values are related to β-carotene (yellow to range pigment) and chlorophyll (green pigment) depending on the group since the flesh color of Cantaloupe, Inodorus, and Dudaim group melons are mainly "orange," "green-white," and "white," respectively (Portnoy *et al.*, 2008). Chroma and hue angle values in more mature fruits with low acidity were higher than less mature fruits since acid hydrolysis and/or increase in activity of enzymes may have resulted in the degradation of both β-carotene and chlorophyll pigments (Güler *et al.,* 2013).

In Kermanshah and Zangi-Abad accessions, the stripes changed color upon approaching maturity, the dark green became intense orange or maroon or brown and the light green became intense yellow (Fig. 2). We measured color on flesh of fruits instead of skin color because the skin color data are useless for comparison purposes particularly when non-homogeneous color is found (i.e. in Dudaim accessions) or in case of incidence of sunscald or other colors that do not change much over time. One of the important marketable (consumer acceptance) quality attributes is melon flesh color that is a measure of whiteness index (black = −100 and white = +100), chroma (color intensity), and hue angle (color purity; Güler *et al.*, 2013).

Fig. 1. Six used accessions including Inodorus (Khatouni),Cantalupensis (Samsouri and Garmak) and Dudaim (Zangi-Abad, Kermanshah and Kangavar)

Fig. 2. Early (harvested at 21 days after anthesis) and lately (harvested at 28 days after anthesis) harvested Zangi-Abad fruits

Flesh Firmness

In Kermanshah, Zangi-Abad, and Samsouri accessions, early harvested fruits were significantly firmer than lately harvested ones. In other three accessions, the maturity stage was not significant for firmness. Samsouri accession was softer than the rest of the accessions.

TSS

In all six accessions, lately harvested fruits had higher levels of TSS than early harvested ones. Highest and lowest level of TSS were detected in lately harvested Garmak fruits and early harvested Khatouni fruits, respectively. Sugar content is the principal measure of maturity and an important aspect of honeydew quality. The

average soluble solids of mature honeydew ranges from 10–14° Brix, with at least 10° Brix for good dessert quality (Bertelsen *et al*., 1994).

pH and TA

Usually lately harvested fruits had higher levels of pH than early harvested ones. Lately harvested Kangavar fruits significantly had the highest level of TA than other treatments.

Lower rate of acidity in more mature fruits (lately harvested fruits) can be related to higher respiration and ripening rate where organic acids could be used as a substrate in respiration process or to their conversion to sugars (Shahidul Islam *et al.*, 1996). Titratable acidity of the fruit varies between planting dates and cultivars. Seasonal and genotypic effects on organic acid levels in ripe fruit have previously been reported (Beaulieu *et al*., 2003; Vallone *et al*., 2013).

Conclusion

The preferred harvesting stage for three Dudaim accessions was 28 days after anthesis and for Inodorus and Cantalupensis groups was 38 days after anthesis. In fact, lately harvested fruits (harvested at 28 or 38 days after anthesis) had more advanced amounts of TSS, firmness, color values (Hue and Chroma), weight (flesh or seed), width, and length than early harvested fruits. So, about proper ripening indices for per accession, those indices are reliable that show significant difference between early and lately fruits. The best appearance ripening indices for Dudaim group were tendril condition (yellow or dry tendril) and the color change of stripes (dark green to intense orange or maroon or brown and the light green to intense yellow). The recommended internal ripening indices for Dudaim group were color of fruit`s flesh and TSS.

The best appearance ripening index for Khatouni and Samsouri accessions were presence of the abscission zone formed around the peduncle and fruit weight and fruit size (width and length) and for Garmak accession was presence of yellow or dry tendril in front of peduncle and fruit weight and fruit size (width and length). The best internal ripening index for Khatouni and Samsouri accessions was TSS and for Garmak accession was color of fruit`s flesh, TSS, and TA.

In the present study, different groups and maturity stages of melon were compared simultaneously. We investigated both appearance and internal parameters in order to have a comprehensive evaluation about melon's ripening indices. Generally, the results of this study showed that proper ripening indices for different accessions of melon can be different.

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