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Beta-carotene content of postharvest orange-fleshed muskmelon fruit: Effect of cultivar, growing location and fruit size

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Abstract. The influence of two growing locations (soil types), six fruit sizes, and two years on the postharvest *Beta*-carotene content of muskmelon (*Cucumis melo* L. var. reticulatus Naud.) fruit was studied with two different cultivars. Fully abscised commercial size fruit: 9, 12, 15, 18, 23, and 30 (fruit/0.04 M^3 shipping box) had highly variable *Beta*-carotene contents (5.3 to 33.8 μg/g fresh weight) that varied by size class, soil type and cultivar. *Beta*-carotene content increased with fruit size up to a maximum, though fruit size continued to increase. Find sandy loam soil produced fruit with less *Beta*-carotene content than silty clay loam soil. The cultivar Primo contained higher *Beta*-carotene content levels than cultivar Cruiser. Mesocarp percent moisture content for both 'Cruiser' and 'Primo' at both locations by fruit size was not significantly correlated ($r = 0.40$) with *Beta*-carotene content. Indicating fruit cell dilution may not contribute to the differences in *Beta*-carotene content in different fruit size classes. *Beta*-carotene content of size class '18' fruit from six cultivars grown on the silty clay loam soil for two consecutive years, showed a year, and year by cultivar effect for some cultivars. Whereas, some cultivars did not differ in *Beta*-carotene content between the two years. This indicates a potential for controlling *Beta*-carotene content of muskmelon fruit at a constant, high level by careful selection of production cultivar.

Introduction

Beta-carotene is essential in human nutrition [1]. *Beta*-carotene's action can be indirect, as a precursor to vitamin-A which is important in human eye light reception, or *beta*-carotene can act directly in cancer prevention [2]. Thus, The US Cancer Institute has recommended that people increase their intake of high *beta*-carotene content foods [3]. Examples of low and high *beta*-carotene content fruits are: Apple (*Malus sylvestris* Mill.) 0.2 (μg/g fresh weight), apricot (*Prunis armeniaca* L.) 16.2, banana (*Musa* sp.) 2.2, grapes (*Vitis vinifera* L.) 0.6, mango (*Mangifera indica* L.) 28.8, muskmelon (*Cucumis melo* L. var. reticulatus

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Naud.) 20.4, nectarine (*Prunis persica* (L.) Batsch.) 9.9, oranges (*Citrus sinenis* (L.) Osb.) 1.2, and peach (*Prunis persica* (L.) Batsch.) 8.0 [4]. As a point of reference, carrots (*Daucus carota* L.) contain 66.0 μg/g fresh weight of *beta*-carotene [4]. Among the commonly eaten fruits, orange-fleshed muskmelon are one of the most rich in *beta*-carotene, but can *beta*-carotene content in this fruit be increased?

Beta-carotene is not translocated into fruits, rather it is rapidly synthesized in the fruit during ripening. Ripening is accompanied by a simultaneous loss of chlorophyll and an increase in *beta*-carotene content as chloroplasts change to chromoplasts [5]. Although carotenoids previously have been determined in developing muskmelons [6–9] little is known as to how factors such as: cultivar, fruit size, and production soil type affect *beta*-carotene content in harvested fruit. The purpose of this study was to determine how these factors may affect *beta*-carotene content in orange-fleshed muskmelons. Further, the possibility of increasing *beta*-carotene content by controlling choice of variety when growing muskmelons was investigated.

Materials and methods

Muskmelon seeds, for both experiments, were planted and fruit were commercially grown by the same farmer, on black plastic soil covers with drip irrigation during two consecutive years at two locations (2 km apart) on fine sandy loam and silty clay loam soil types [10], near Rio Grande City, Texas, USA. Fruit, free of defects were harvested at abscission (maturity) and separated into commercial size classes: 9, 12, 15, 18, 23 and 30, the number of fruit fitting commercial melon shipping boxes (0.04 M^3).

Experiment I. Cruiser and Primo cultivars were compared using five fruits per size class at each location each year.

Experiment II. Six cultivars were compared using ten, size class 18 fruit (av. weight 1.2 kg). The fruit representing the size regularly used in previous melon quality studies [5, 11]. The cultivars were grown both years but only on the silty clay loam soil.

Beta-carotene assay. From each fruit, three 1 cm^3 middle-mesocarp segments were cut from the fruit equator, devoided of rind and seed tissues and immediately frozen in liquid nitrogen. Tissue segments were stored under nitrogen at −80 °C until extraction. *Beta*-carotene was extracted under low light conditions (all lights off), using 1 g total tissue weight combined from the three 1 cm^3 segments. Extraction was performed with ice cold acetone/tetrahydrofuram (1: v/v); 10 mg butylated hydroxytoluene; and 1.2 mg $Mg_2\,CO_3$. The sample was placed on ice and macerated using a Polytron homogenizer (Brinkmann Instruments, Westbury, NY, USA) at medium speed for 1 min. Carotenoids were partitioned into petroleum ether, dried over $Na_2\,SO_4$ and

reduced in volume using a rotary evaporator at 32 °C. Carotenoids were resuspended to 10 ml in mobile phase, filtered through a 45 μm PTFE filter (Sigma Chemicals, St Louis, MO, USA) and stored at −80 °C until HPLC analyses. *Beta*-carotene was separated by high performance liquid chromatography using a C_{18} column with a mobil phase of 55% acetonitrile: 23% methylene chloride: 22% methanol (v/v/v) and detected at 454 nm [13]. Soluble solids concentration as masured in the juice obtained from 1 g fresh weight middle mesocarp tissue that was squeezed through a hand-held garlic press. Soluble solids were detected with a temperature corrected refractometer (Abbe Mark II, Reichert Sci. Instr., Buffalo, NY, USA). Moisture content was calculated from the percent weight loss of 1 g fresh weight middle mesocarp tissue after lyophilization.

Statistics. To relate fruit weight and *beta*-carotene content, the data of experiment I were analyzed using the general linear model regression technic [14]. *Beta*-carotene content was regressed on fruit weight for cultivar and soil type, and years were considered blocks. Maximum and minimum values, means and standard errors and number of fruit were calculated for each size class. Means were also calculated for each cultivar, location and size class combination. In experiment II, data comparing mean *beta*-carotene content from the six cultivars over 2 years were analyzed using analyses of variance at $p \leqslant 0.05$.

Results and discussion

Experiment I. Separating 'Cruiser' and 'Primo' fruit by size resulted in a relatively wide range of total fruit weights within each size class (Table 1). This overlapping of fruit weights from one size class to another as expected because muskmelons are commercially separated by diameter, not by weight. Even though a wide range of fruit weights exists within a size class, the mean fruit weight for a size class is statistically different ($\pm$ standard error), and therefore selecting fruits by size provides a useful grouping for determining variation in *beta*-carotene content in melons with varying weights.

In mature abscised fruit *beta*-carotene content of tissue from the inner-middle- and outer-mesocarp regions were not significantly different (data not shown). However, *beta*-carotene content in mature abscised fruit ranged from 5.3 to 33.8 μg/g fresh weight when assayed across all commercial size classes (Table 2). Mean *beta*-carotene content increased as fruit size increased, from size class 30 to 15, then a plateau in content occurred with size class 12. Beyond this fruit size *beta*-carotene content decreased. Significant quadratic regression coefficients for 'Cruiser' and 'Primo' from both locations (soil types) confirmed this *beta*-carotene content response with melon fruit weight (Table 2). A similar response has been shown to occur in carrot roots. Carrot root *beta*-carotene content increased as root size (diameter × length) increased up to 59 cm^3, then decreased, even though root size continued to increase [14].

Table 1. Total melon fruit weight (fruit wt) range and mean fruit weights by commercial fruit size class for combined Cruiser and Primo cultivars and growing locations

Size class	N	Range Fruit wt (kg)	Mean Fruit wt (kg)	Cruiser Fruit wt (kg)		Primo Fruit wt (kg)	
		Total of all fruits		Location		Location	
		min.-max.	mean ± SE	1	2	1	2
30	16	0.57 – 0.89	0.75 ± 0.02	0.78	0.74	0.76	0.75
23	38	0.62 – 1.07	0.86 ± 0.02	0.90	0.84	0.95	0.86
18	40	0.82 – 1.54	1.19 ± 0.03	1.11	1.19	1.34	1.16
15	40	1.13 – 2.02	1.70 ± 0.03	1.59	1.87	1.64	1.71
12	40	1.74 – 2.54	2.01 ± 0.03	1.99	1.96	2.16	1.94
9	40	2.20 – 2.97	2.30 ± 0.04	2.29	2.33	2.31	2.27

Mean fruit weight by size class for 'Cruiser' and 'Primo' grown at location 1 (find sandy loam) and location 2 (silty clay loam).
N = number of fruit assayed.
SE = standard error.

Table 2. *Beta*-carotene (μg/g fresh wt mesocarp tissue) range and mean content by commercial size class for combined Cruiser and Primo cultivars and growing locations

Size class	N	*Beta*-carotene	Mean *Beta*-carotene	Cruiser *Beta*-carotene		Primo *Beta*-carotene	
		Total of all fruits		Location		Location	
		min.-max.	mean ± SE[z]	1	2	1	2
30	16	5.3 – 18.1	12.2 ± 0.9	10.7	11.9	13.3	16.0
23	38	8.8 – 23.4	16.2 ± 0.6	13.1	17.2	15.2	18.8
18	40	11.1 – 25.5	16.6 ± 0.5	16.0	18.1	16.9	19.9
15	40	15.0 – 32.3	20.8 ± 0.7	17.7	21.8	21.5	22.3
12	40	11.6 – 33.8	21.3 ± 0.7	17.5	21.0	21.4	25.5
9	40	7.7 – 25.6	16'1 ± 0.6	15.1	18.2	18.0	18.1
				L***Q***	L***Q***	L***Q***	L***Q***

Mean *Beta*-carotene content by size class for Cruiser and Primo cultivars grown at location 1 (fine sandy loam) and location 2 (silty clay loam) and linear (L) and quadratic (Q) regressions between *Beta*-carotene content and fruit weight for each cultivar and location.
N = number of fruit assayed.
SE = standard error
***Significant at $p = 0.001$.
Multiple regressions for predicting *Beta*-carotene content were regressed on fruit wt and fruit wt^2 (F value = 21.3, df model = 5, df error = 205, Prob > F = 0.0001, $R^2 = 0.43$, Error mean sq. = 15.6).

Location 1
'Cruiser': *Beta*-carotene content = 3.12 + 15.5 (fruit wt) −4.11 (fruit wt)^2
'Primo': *Beta*-carotene content = 5.82 + 15.5 (fruit wt) −4.11 (fruit wt)^2

Location 2
'Cruiser': *Beta*-carotene content = 5.83 + 15.5 (fruit wt) −4.11 (fruit wt)^2
'Primo': *Beta*-carotene content = 8.25 + 15.5 (fruit wt) −4.11 (fruit wt)^2

Table 3. Percent mesocarp moisture content (%MC) range, and mean content by commercial size class for combined Cruiser and Primo cultivars and growing locations

Size class	N	% Moisture content	% Moisture content	Cruiser % MC		Primo % MC	
		Total of all fruits		Location		Location	
		min.-max.	mean ± SE	1	2	1	2
30	16	90.7 – 95.0	93.4 ± 0.3	93.2	94.3	92.4	94.2
23	20	89.9 – 96.2	93.0 ± 0.4	93.8	93.3	93.8	91.2
18	20	87.8 – 96.1	92.1 ± 0.4	93.0	92.0	92.5	90.6
15	20	88.5 – 93.7	91.3 ± 0.3	91.9	91.8	91.2	90.7
12	20	88.1 – 92.4	90.3 ± 0.3	91.2	90.5	90.6	88.7
9	20	88.7 – 94.2	91.2 ± 0.4	91.6	90.9	92.8	89.3
				L***Q*	L***Q*	L***Q*	L***Q*

Mean %MC by size class for Cruiser and Primo cultivars grown at location 1 (fine sandy loam) and location 2 (silty clay loam) and linear (L) and quadratic (Q) regressions by %MC and fruit weight for each cultivar and location.
N = number of fruit assayed.
SE = standard error.
*, *** Significant at $p = 0.05$ and 0.001 respectively.
Multiple regressions for predicting % MC were regressed on fruit wt and fruit wt^2 (F value = 32.9, df model = 3, df error = 112, Prob > F = 0.0001, $R^2 = 0.47$, Error mean sg. = 1.84).

Location 1
'Cruiser': %MC = 96.7 – 4.6 (fruit wt) + 0.99 (fruit wt)^2
'Primo': %MC = 96.7 – 4.60 (fruit wt) + 0.99 (fruit wt)^2

Location 2
'Cruiser': %MC = 96.7 – 4.60 (fruit wt) + 0.99 (fruit wt)^2
'Primo': %MC = 94.7 – 4.60 (fruit wt) + 0.99 (fruit wt)^2

Comparison of 'Cruiser' and 'Primo' fruit grown at two locations (fine sandy loam and silty clay loam soils), demonstrated both a cultivar and location effect (Table 2). Fruit from the cultivar Cruiser had less *beta*-carotene content than fruit form the cultivar Primo, when compared by size class at the same location (Table 2). However, for both cultivars fruit grown on fine sandy loam (location 1) had generally less *beta*-carotene content than fruit grown on silty clay loam (location 2) when each location was treated separately.

Percent mesocarp moisture content (%MC) of 'Cruiser' and 'Primo' fruit was calculated to determine if cell dilution could explain the differences in *beta*-carotene content in different melon size classes (Table 3). Percent MC minimum and maximum range within a size class combined for cultivars and locations (Table 3) is not as variable as fruit weight (Table 1) or *beta*-carotene content minimum and maximum ranges (Table 2). Percent MC decreased as fruit size increased from 30 to 15, the lowest %MC occurred with size class 12, then increased in size class 9. Percent MC regressed with fruit weight demonstrated a significant quadratic regression ($R^2 = 0.50$) indicating that %MC is a main effect in determining fruit weight and by association may influence

Table 4. ANOVA comparison of size '18' melons for mean *Beta*-carotene content from 6 commercial cultivars grown on silty clay loam soil in year 1 and 2

Cultivar	N	Mean *beta*-carotene content	
		Year 1	Year 2
		μg/g fresh weight	
Mission	10	20.6 a	20.9 a
Explorer	10	19.4 a	19.9 a
Cristobal	10	15.8 c	20.7 a
Primo	10	17.4 b	19.9 a
Cruiser	10	16.2 bc	17.1 c
Tasty Sweet	10	15.2 c	18.6 b
LSD		1.2	1.2

N = number of fruit assayed each year.
Means within columns with differences larger than the LSD value are significantly different at the $p \leqslant 0.05$.

mesocarp *beta*-carotene content. However, when *beta*-carotene content is correlated with %MC the correlation coefficient is r = 0.40, and not significant, suggesting %MC does not greatly affect mesocarp *beta*-carotene content.

Experiment II. Six commercial muskmelon cultivars, grown on silty clay loam soil each of two years, were compared for possible variations in *beta*-carotene content in size 18 melons (Table 4). Analyses of variance demonstrated a significant year effect and a year × cultivar interaction (ANOVA not shown). Means comparison of *beta*-carotene content for these six cultivars showed that 'Mission' and 'Explorer' fruit were not influenced by the different production years, as *beta*-carotene content from these two cultivars did not differ between the two years. For both years, 'Mission' and 'Explorer' fruit were highest in *beta*-carotene content compared to the other cultivar fruit. 'Cristobal', however, demonstrated great variability in *beta*-carotene content having low *beta*-carotene content in year 1 and high in year 2. These cultivar mean comparisons of *beta*-carotene content from fruit grown at the same location and sampled from the same fruit size class demonstrate, that by controlling cultivar when growing muskmelons, especially when growing Mission and Explorer cultivars, increased and constant *beta*-carotene contents are achievable.

Our data demonstrates that cultivar, fruit size, growing location and year may interact to influence *beta*-carotene content of orange-fleshd muskmelon fruit. Future analyses of orange-fleshed melon cultivars should consider these factors, especially fruit size class, when measuring and comparing *beta*-carotene content in muskmelon fruit.

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