Chlorophyll and Carotenoid Changes in Developing Muskmelons[1]

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Abstract. Growth, respiration, and ethylene production patterns of 'Crenshaw' and 'Persian' cultivars of muskmelon *(Cucumis melo* L.) were similar to patterns previously established for cantaloupe ('PMR 45'). From 3 weeks after anthesis the carotenoid content of the pulp of all 3 cultivars steadily increased from the low level characteristic of green tissue. Chlorophyll content decreased throughout the development of the fruits, but in the cantaloupe and 'Crenshaw' there was a final loss of chlorophyll during ripening.

In muskmelon flesh, the intensity of orange color is an important quality characteristic. The color, at least in the so-called "cantaloupes," is due primarily to carotenoid pigments; these are largely hydrocarbons (97%), of which β-carotene is the major component (1, 12). Most studies of pigment changes in fruits have been made with fruits of unknown cultivars, physiological age, or previous handling. We know of few studies relating the formation of carotenoids, which are important to the color of many fruits, to the physiological age of the fruit (2, 5, 9). The muskmelon is well adapted to such studies, since fruits of known physiological age can readily be obtained (7). Using orange-fleshed muskmelon cultivars, we have studied gross pigment changes and their relation to other parameters of fruit development and ripening.

Materials and Methods

Three muskmelon cultivars *(Cucumis melo)* were grown on the University farm at Davis: 'Powdery mildew Resistant Cantaloupe No. 45' ('PMR 45'), 'Crenshaw', and 'Persian'. Uniform fruit samples of known physiological age were obtained by tagging individual blossoms as described by McGlasson and Pratt (7). At regular intervals throughout fruit development, 5 specimens of the same age were harvested for analysis. Respiration and ethylene production were monitored for 24 hr after each harvest (6). An equatorial slice (5 to 6 cm thick) was then cut from each fruit, and the placental tissue and the outer 5 mm of skin and cortex were discarded. The slice was cut into small pieces (ca. 1 cm^3); 1 kg of the pieces was frozen immediately in liquid nitrogen and then stored at −20° C pending analysis. Flesh firmness for each melon was determined on 3 of the remaining pieces, using a penetrometer (Hunter Mechanical Force Gage, Model 1-30M, Amitek Inc., Hatfield, Pennsylvania) equipped with 0.5 cm^2 plunger. Soluble solids in the juice expressed from these pieces were measured with a refractometer.

Extraction and determination of pigments: Frozen tissue (50 g) was blended at low speed for 1 min in a Waring blendor with 10 ml methanol, 50 ml acetone, and a small amount of filter aid (Hyflo-Super Cell, Johns-Manville Corp., New York, N.Y.). After filtration, the pigments were transferred to petroleum ether, washed with water, and dried over anhydrous Na_2SO_4. The dried solution was evaporated under vacuum and made up to a known volume with anhydrous ethyl ether. Absorbance of the solution was measured at 644, 662, and 750 mμ in a Cary 14 recording spectrophotometer; chlorophyll content was calculated by the method of Ziegler and Egle (13).

The ether solution was blown to dryness with N, and the residue was saponified by the standard procedure (4). The unsaponifiable material was transferred to petroleum ether, washed with large amounts of water, and dried over Na_2SO_4. The dry solution was reduced in volume and then made up to known volume with petroleum ether. The value of the maximum absorbance of the saponified extracts was recorded, and the total carotenoid content was calculated using the $E^{1\%}_{1cm}$ value of β-carotene (3). Beta-carotene is the predominant pigment in ripening muskmelons (1), while β-carotene and its oxygenated derivatives are the main carotenoid pigments in green tissue.

Results and Discussion

Seven criteria of fruit development were evaluated at each time point for the developing melon fruits: fruit weight, respiration rate, ethylene production, flesh firmness, and the concentrations of carotenoids, chlorophyll, and soluble solids. In general, the patterns of change were similar for the 3 cultivars. For the sake of clarity, the pigment changes are compared with only some of the other criteria in each of the figures shown (Fig. 1, 2, and 3); each experimental point in the figures represents the mean of 5 individual melons.

Respiration, flesh firmness, ethylene production, soluble solids, and fruit weight of all 3 cultivars followed the pattern established in cantaloupe by McGlasson and Pratt (8). In all fruits, the chlorophyll content fell to an intermediate level by 5 weeks after anthesis, and this first stage in the loss of chlorophyll was probably due to dilution through growth. In 'PMR 45' and in 'Crenshaw' there was a subsequent rapid decline in chlorophyll which coincided with the respiration climacteric. In contrast to the pattern of chlorophyll change, the carotenoids, present in only small amounts in immature fruits, increased steadily from about 3 weeks after anthesis until full maturity.

The carotenoid content of muskmelons begins to increase at least 10 days prior to the onset of the respiration climacteric. Visually, the development of orange pigmentation was a gradual process in the melons studied, commencing in the center of the fruit as a faint yellow coloration of the jelly surrounding the seeds and progressing outward through the pericarp, until the flesh was uniformly orange at full maturity. Therefore, the gradual rise in carotenoid content observed in developing fruits does not reflect a uniform increase throughout the cells of the pericarp, but primarily an increase in the amount of tissue containing high levels of carotenoids.

At the climacteric maximum, the carotenoid content of the 'Persian', 'PMR 45', and 'Crenshaw' cultivars was

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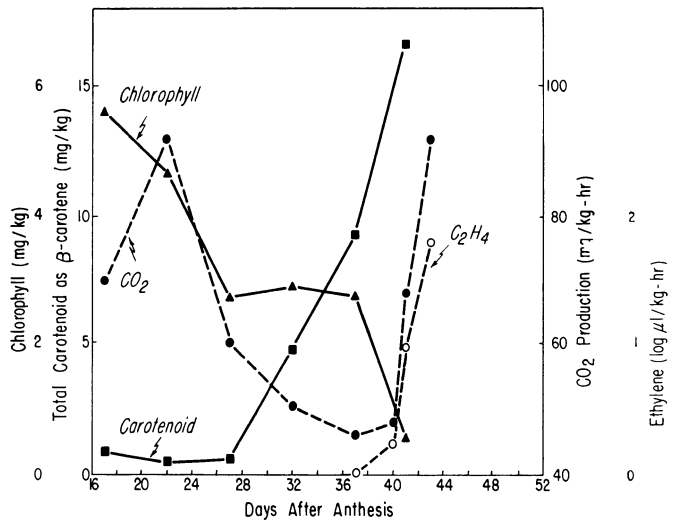

Fig. 1. Changes in cantaloupe ('PMR 45') during development and ripening.

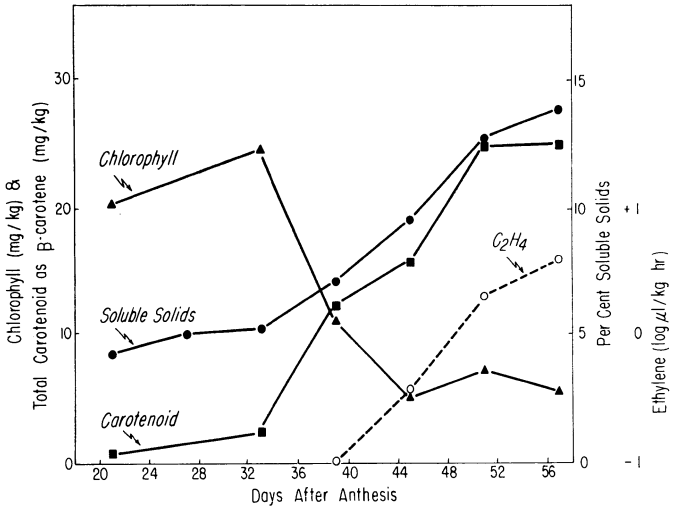

Fig. 2. Changes in 'Persian' melons during development and ripening.

25, 16.5, and 8 mg per kg of fresh tissue, respectively, and the visual pigmentation of the flesh at maturity reflects these differences in concentration. The visible spectra of the saponified extracts from all 3 cultivars were similar, an indication that only minor differences exist in their pigment composition.

Although these 3 closely related cultivars are morphologically diverse, our study indicated a general similarity of behavior, although the 'Persian' melons did have a variable respiration pattern as previously reported (11). One intriguing aspect of the variations in muskmelons is the existence of green-fleshed cultivars such as 'Casaba' and 'Honey Dew'. It would be interesting to examine the metabolic pathways to carotenes in these melons for metabolic blocks similar to those found in tomatoes (10).

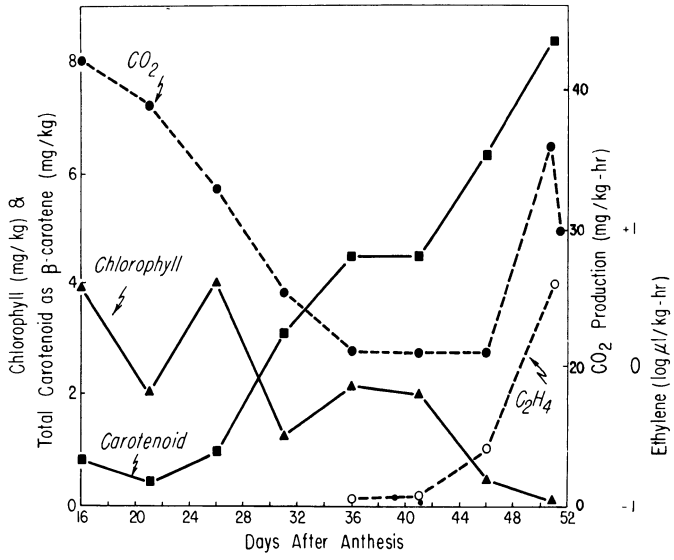

Fig. 3. Changes in 'Crenshaw' melons during development and ripening.

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