Comparison of Cell Size and Kind of Sugars Accumulated in Grape Berries vs. Melon Fruits

Yasutaka KANO
Ishikawa Prefectural University, Noenchi, Ishikawa 921-8836, Japan

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The change in cell size with fruit development and the accumulation of sugars in fruits have been investigated independently in many kind of fruits. In this report the relationship between cell size and the kind of sugars accumulated was investigated using Delaware grape berries and melon fruits. The size of cells of grape berries at 65 DAA (days after anthesis) was 144 μm and the sucrose, glucose and fructose content was 13.5 g l⁻¹, 81 g l⁻¹ and 87 g l⁻¹, respectively. On the contrary, the size of cells of melon fruits at 50 DAA was 261 μm and the sucrose, glucose and fructose content was 54 g l⁻¹, 18 g l⁻¹ and 18 g l⁻¹, respectively. It is suggested that glucose and fructose accumulate preferentially in grape berries, which has a large number of smaller cells, but sucrose accumulates preferentially in melon fruit, which has a great number of larger cells.

Keywords: cell size, Cucumis melo L., sugar kind, Vitis vinifera L.

INTRODUCTION

The change in cell size with fruit development have been investigated in many kind of fruits (Addoms et al., 1930; Hirata et al., 1974; Nakagawa and Nanjo, 1965, 1966; Ragland, 1934; Sinnot, 1939; Smith, 1940, 1950; Toyama and Hayashi, 1957a, b; Tukey and Young, 1939). The accumulation of sugar in many kind of fruits has also been studied (Whiting, 1970). However, in these studies, cell size and sugars are investigated independently. Much less is known about the relationship between cell size and sugar accumulation. A close relationship between cell size and the kind of sugars accumulated in melon fruit has been reported (Kano, 2002, 2005, 2006). While sucrose accumulation is promoted in melon fruit in which cell enlargement is accelerated (Kano, 2002; Kano and Fukuoka, 2006; Kano, 2006), glucose and fructose accumulation is promoted in melon and Japanese pear fruits in which cell enlargement is suppressed (Kano, 2003, 2004a, b). From these results I surmised that cell size determines the kind of sugars accumulated in the fruit. Therefore, the relationship between cell size and the kind of sugars accumulated was investigated using grape berries and melon fruits.

MATERIALS AND METHODS

The flower clusters of grape cv. Delaware (Vitis vinifera L.) that opened on around 7 May 2002 were used in this experiment. Three berry clusters were collected 35 (11 June, mean cluster weight; 57.2 g), 50 (26 June, mean cluster weight; 81.2 g) and 65 (11 July, mean cluster weight;
91.9 g) DAA (days after anthesis). Six berries were collected from each cluster, the mean weight of the berries was calculated, and the 2 berries with weights nearest to the mean weight were selected from each cluster. Five berries with weights nearest to the mean weight were selected from each cluster. Earl’s Knight Natsukei No. 2 (Cucumis melo L.) melon seeds were planted on the seed bed on 12 April 2005. Nursery plants were spaced at 40 cm intervals in a plastic film greenhouse on 15 May. Flowers that opened on around 14 June were used in this experiment. Three fruits were collected 20 (24 July), 40 (13 August) and 50 DAA (23 August). All three fruits were used for cell and sugar analysis.

For grapes, a berry was cut at the maximum transverse diameter, and one sample from the maximum transverse diameter toward the calyx end was used for cell analysis and one from the maximum transverse diameter toward the peduncle end for sugar analysis. The size of all the cells on the maximum transverse diameter of an individual berry was measured. The number of cells in each division of 50 microns from 1 micron to 600 microns were counted by dividing total number of cells in each 50 microns by five. One half berry was wrapped in cheesecloth and squeezed using pincers to extract the juice. For melon, two disks approximately 10-mm thick were excised from each of the three fruits from each treatment; one from the maximum transverse diameter toward the calyx end for cell analysis and one from the maximum transverse diameter toward the peduncle end for sugar analysis. A sample measuring approximately $10 \times 10$ mm was removed from the disk with 5 mm straddling the maximum diameter line across each disk (Fig. 1). Rectangular parallelepips (hereafter RP), each measuring 7 mm, were serially sampled across the diameter of the disk. Except for the RP containing seeds and the RPs from both ends containing the epidermis, all the RPs along the 7 mm-long strip through the diameter of the fruit body were used. The number of RPs obtained from the fruit was 6, 8 and 10 at 20, 40 and 50 DAA, respectively. All of the RPs obtained from fruit from each treatment were dehydrated using various concentrations of alcohol (70%, 80%, 90% and 100%) before being embedded in paraffin. Seven 10 μm-thick sections were prepared from these paraffin blocks, and the clearest section from each RP of each treatment was examined under a microscope. As shown in Fig. 2, the maximum diameter

![Fig. 1](image-url)

An illustration of the collection of rectangular parallelepiped parts for the determination of the size and the number of cells and sugar content in melon fruits. This is an example of melon fruit at 40 DAA.
of individual cells on the maximum transverse diameter in the RPs, was measured. The number of cells in each division of 50 microns from 1 micron to 600 microns were counted by dividing total number of cells in each 50 microns by three. Cell size was calculated by dividing total cell diameter of all RPs of three fruits by the number of cells of all RPs of three fruits.

RPs from the disk taken from the maximum transverse diameter toward the peduncle end were used for sugar analysis. With the exception of the 7 mm-RPs containing the seeds and both epidermal layers, all of the RPs were wrapped in cheesecloth and squeezed using pincers to extract the juice. The juice was diluted tenfold with distilled water. The solution was centrifuged at \(8,000 \times g\) for 15 min before being filtered through a 0.45 \(\mu\)m filter. Twenty \(\mu l\) of the filtrate was then injected into a HPLC (LC-10ADvp, Shimadzu Inc., Japan) fitted with a refractive index detector (RID-10A, Shimadzu Inc.) and equipped with Shim-pack SCR-101C (Shimadzu Inc.), at 0.8 ml min \(^{-1}\) at 80°C. Sucrose, glucose and fructose standards at 20,000 mg l \(^{-1}\) were injected into the HPLC before injection of the filtrates. The mean sucrose, glucose and fructose content in the fruit was calculated by dividing the total sucrose, glucose and fructose content of all RPs of three fruits by the number of PR of three fruits.

RESULTS

The weight of grape berries was small, being 1.3 g at 65 DAA, but the weight of melon fruit increased 1901 g 50 DAA (Fig. 3).

![Fig. 2](image1.png)  
**Fig. 2** An illustration of the measurement of the size and the number of cells of melon fruits 40 days after anthesis. White dots indicate the actual cells measured.

![Fig. 3](image2.png)  
**Fig. 3** Comparison of the growth between grape berry and melon fruit. Vertical bars are SD (grape; \(n=20\), melon; \(n=3\)).
The cell diameters of grape berries collected at 35 and 50 DAA were distributed at up to 350 μm centering on 125 μm, and at 65 DAA at up to 350 μm centering on 150 μm (Fig. 4). The cell diameters of melon fruits at 20 and 40 DAA were distributed at up to 400 μm centering on 200 μm, and at 50 DAA, at up to 450 μm centering on 250 μm.

The fraction in which the largest number of cells of grape berries was included was 51 ~ 100 μm, 51 ~ 100 μm and 101 ~ 150 μm at 35, 50 and 65 DAA, respectively (Fig. 5). The fraction in which the largest number of cells of melon fruit at 20, 40 and 50 DAA was included was 151 ~ 200 μm, 201 ~ 250 μm and 201 ~ 250 μm, respectively. The percentage of cells smaller than 200 μm in grape berries was above 75% at all growing stages. The percentage of cells greater than

**Fig. 4** Comparison of the size and the number of cells in the fruit between grape berry and melon. The numbers under the figures are fruit numbers.

**Fig. 5** Comparison of the number of cells and cell size within the transverse diameter of the fruit between grape berry and melon. Vertical bars are SD (grape; n=5, melon; n=3). The numbers of 50, 100 and 150 under the figures show the size of cells which are between 0 to 50 microns, between 51 to 100 microns and between 101 to 150 microns. DAA; days after anthesis. Numerical values in the figures are the percentage of cells smaller and larger than 200 microns in grape berry and melon fruit, respectively.
CELL SIZE AND KIND OF SUGARS

200 μm in melon fruit at 50 DAA was 82%. The mean size of cells of all the grape berries at 35, 50 and 65 DAA was 121, 139 and 144 μm, respectively, but the size of cells of all the melon fruits at 20, 40 and 50 DAA was 220, 221 and 261 μm, respectively (Fig. 6).

The mean glucose and fructose content of grape berry was 20 g l⁻¹ and 4 g l⁻¹, 35 g l⁻¹ and 33 g l⁻¹, and 81 g l⁻¹ and 87 g l⁻¹ at 35, 50 and 65 DAA, respectively (Fig. 7). The sucrose content was less than 15 g l⁻¹ at all three time points. On the contrary, in melon fruit the sucrose content was 29 g l⁻¹ at 40 DAA and 54 g l⁻¹ at 50 DAA. The glucose and fructose content was less than 20 g l⁻¹ at all three time points.

DISCUSSION

The percentage of cells smaller than 200 μm in grape berries at 65 DAA was 77, and the mean cell size was 144 μm. The size of parenchymatous cells of Delaware’s berries at maturity is approximately 200 μm (Nakawa and Nanjo, 1965; Yukiaga, 1964). The percentage of cells larger

![Fig. 6](image-url)  
Comparison of cell size in the fruit between grape berry and melon. Vertical bars are SD. The numerical values above SD vertical bars are actual number of cells tested. DAA; days after anthesis. Values with different letters are significantly different at $P<0.05$ using LSD test. DAA; days after anthesis.

![Fig. 7](image-url)  
Comparison of sugar content in the fruit between grape berry and melon. Vertical bars are SD. Numerical values above SD vertical bars in the top are actual number of samples tested. Values with different letters are significantly different at $P<0.05$ using LSD test. DAA; days after anthesis.
than 200 μm in melon fruit at 50 DAA was 82, and the mean cell size was 261 μm, which was approximately twice the size of grape berry cells. The cell size of matured fruits of melon cv. Earl’s Favorite is around 320 μm (Masuda, 1970). A large number of cells from 200 μm to 550 μm exists in the matured fruit of melon, cv. Earl’s Knight Natsukei No. 2 (Kano, 2002, 2005) and the mean cell size of the matured melon fruit was approximately 300 μm (Kano, 2006; Kano and Fukuoka, 2006). These results suggest that the cell size of the great portion of total cells in grape berry is smaller than 200 μm, but in melon fruit the cell size of a great portion of total cells is larger than 200 μm.

The glucose and fructose content in Delaware’s berry was 81 g l⁻¹, which was 13 times the sucrose content. The glucose and fructose content is high, but sucrose content is low or at trace level in Delaware’s berry (Inaba, 1975; Matsui, 1976; Matsui et al., 1980). Furthermore, the glucose and fructose content is high in the berry of Vitis vinifera L (Hale, 1968; Kliwer, 1966; Whiting, 1970). In contrast, the sucrose content in melon fruit was 87 g l⁻¹, which was 5 times as much as the glucose and fructose content. The content of sucrose, glucose and fructose in melon fruit cv. Earl’s Favorite is approximately 8%, 2% and 1%, respectively (Mizuno et al., 1971; Yoshida et al., 1990; Miyazaki and Ookubo, 1989). The greater part of ¹⁴C applied to leaves translocates into sucrose in the fruit of melon cv. Natsukei No. 16 (Motomura et al., 1989). These results show that glucose and fructose content is high in Delaware’s berry, but sucrose content is high in melon fruit.

Putting together these results it can be concluded that glucose and fructose accumulate preferentially in grape berries, which has a large number of smaller cells, but sucrose accumulates preferentially in melon fruit, which has a great number of larger cells.

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REFERENCES


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