

# Histological Studies on the Black Discoloration of Peach Fruit Skin Exposed to Iron

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**Abstract.** The skin of 'Elegant Lady' peach [*Prunus persica* (L.) Batsch.] fruit turned black when exposed to 100 ppm ferrous sulfate solution. This color change appeared on the red and the yellow portions of the fruit. Microscopy of the skin showed blue-black pigment distribution in epidermal and hypodermal tissues. Some epidermal and hypodermal cells discolored immediately when exposed to ferrous solutions, but many cells turned black later. Some cells with anthocyanin pigments did not discolor. Chromic acid showed that tannic substances were distributed in the epidermal and hypodermal cells, and they likely are the main factor in black discoloration of peach fruit exposed to solutions containing Fe.

Peach skin discoloration or inking is a disorder confined to the surface of peach or nectarine fruit. This disorder is enhanced by vibration, excessive brushing, and a high Fe content in the hydrocooling water (Hopfinger, 1990). The anthocyanin pigment cyanidin-3-glucoside has been implicated, and its color is readily modified by the pH of the hydrocooling water, chemical reactions, or both (Denny et al., 1986). The initial symptoms are water-soaked areas on the red surface that eventually turn purplish-black (Hopfinger, 1990). Hopfinger and Frecon (1986) attributed the discoloration in peaches to the presence of Fe<sup>2+</sup> in the hydrocooling water and showed that increasing the water's pH to 6.5 decreased the Fe<sup>2+</sup> level and thereby alleviated the problem. Iron apparently combines with an anthocyanin pigment in the peach skin, but there is no direct evidence that an Fe-anthocyanin complex causes the discoloration. Peach skin contains catechin and chlorogenic acid, both of which turn black in the presence of Fe (Kubota et al., 1989; Reeve, 1959).

In this report, we present evidence that localization of the color change in peach fruit skin cells exposed to Fe<sup>2+</sup> involves tannic substances.

## Materials and Methods

'Elegant Lady' peach was harvested at the firm mature stage in a commercial orchard at Fresno, Calif. Fruit were not hydrocooled before analysis. Fresh sections were prepared by hand and dipped in 100 ppm ferrous sulfate or

1% chromic acid and observed under light microscopy.

## Results and Discussion

The skin of 'Elegant Lady' peach fruit is made up of small epidermal cells, generally

two to three cells deep, and a hypodermis of somewhat larger cells, three to four cells deep. Red-pigmented cells containing anthocyanin in their vacuoles are distributed throughout the epidermal and hypodermal cells (Fig. 1). In the highly colored area of the skin, anthocyanin is found in the deeper hypodermal cells.

'Elegant Lady' peach fruit treated with 100 ppm ferrous sulfate solution developed black spots or stripes within 3 min and subsequently turned completely black (Fig. 2). The degree of black coloration depended not only on the fruit type, but also on the area of the fruit. While black coloration was observed in the yellow area with no anthocyanin, the red areas turned much darker than the yellow areas. Vacuoles of ferrous-treated epidermal and hypodermal cells were blue-black (Fig. 3). Some red cells with anthocyanin appeared to be unaffected. In tissue treated with ferrous Fe, some vacuoles in the epidermal and hypodermal cells immediately became discolored (Fig. 4a), but after several hours, many of these cells had blue-black vacuoles (Fig. 4b). Blue-black coloration occurred at random, and no difference in distribution of blue-black vacuoles between epidermis and hypodermis was evident. Some red cells were unaffected by Fe. The black pigment was stable for several days.

Our observations suggest that anthocyanin is not the only substrate for the black discoloration in the presence of ferrous solution. Ferrous sulfate and ferric chloride are used for

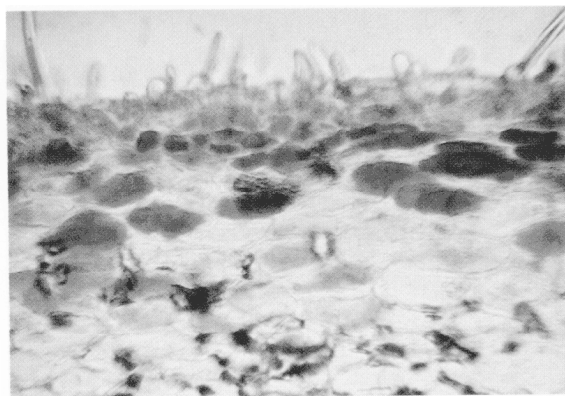


Fig. 1. Distribution of pigmented cells in hand-sectioned skin of 'Elegant Lady' peach (×180).

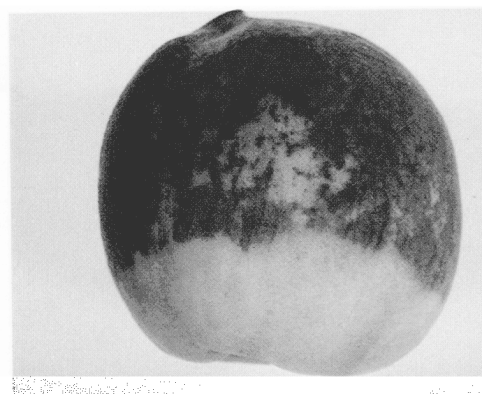


Fig. 2. Black coloration of 'Elegant Lady' peach fruit after exposure to ferrous

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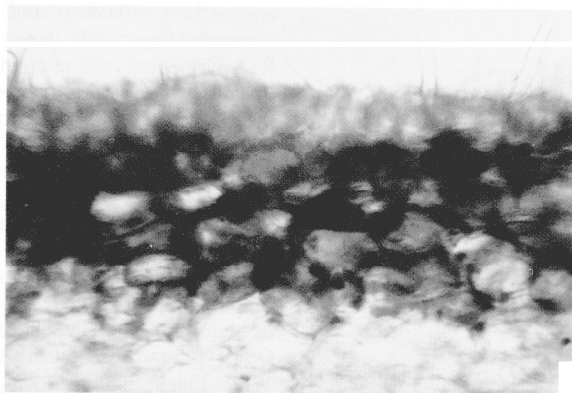


Fig. 3. Distribution of black cells in hand-sectioned skin of 'Elegant Lady' peach exposed to ferrous sulfate solution (100 ppm) ( $\times 180$ ).

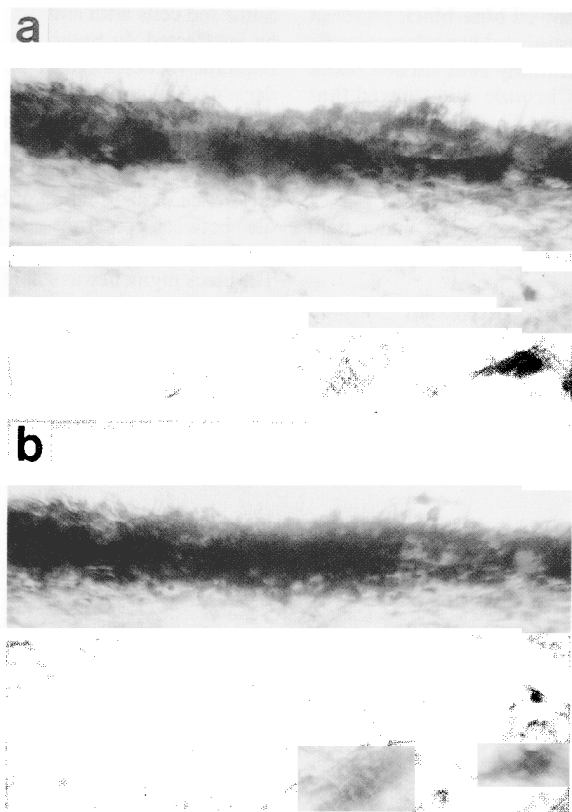


Fig. 4. Influence of time on skin discoloration of 'Elegant Lady' peach exposed to ferrous sulfate solution (100 ppm) (a) immediately after preparation and (b) after several hours ( $\times 75$ ).

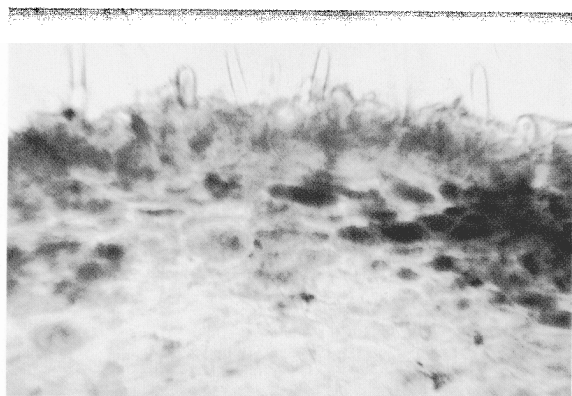


Fig. 5. Confirmation of catechin, as indicated by browning of peach skin exposed to 1% chromic acid ( $\times 180$ ).

detecting tannic substances in plant tissue (Reeve, 1959). Catechin and chlorogenic acid are present in the peach fruit (Kubota et al., 1989; Reeve, 1959), and catechin in epidermal and hypodermal cells was confirmed with chromic acid as indicated by the brown in Fig. 5 (Yasuda, 1970). Therefore, blue-black coloration in the epidermal and hypodermal cells following exposure to  $\text{Fe}^{2+}$  could involve tannins. That yellow portions of fruit also turned black is further evidence that anthocyanin is not the sole substrate for the color reaction. Because cyanidin-3-glucoside-iron complexes depend on  $\text{pH} > 5.5$  (Jurd and Asen, 1966), and pH values in peach and nectarine tissues are  $< 5.5$ , it is unlikely that such complexes were formed in our study.

Although the symptoms of inking were similar to those reported by Hopfinger (1990) and Denny et al. (1986), tannic substances more likely are the main factor for black coloration in peach exposed to Fe. We, therefore, question the role of Fe in this disorder in the Fresno area because a) the water for hydrocooling was essentially free of Fe and b) inking occurs in orchards with no history of spray applications of Fe. Brown discoloration may be related to injury that causes polyphenolic browning, especially with tannins (Chastagner and Ogawa, 1976; Wang and Mellenthin, 1973).

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