Superficial Scald Intensity of 'Rome Beauty' Apples after Storage is Correlated with Chromaticity Values at Harvest

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Additional index words. *Malus domestics*, superficial scald, chromaticity values

Summary. Chromaticity values (L*, a*, b*) of 'Rome Beauty' apples (Malus domestics) were measured at weekly intervals during maturation periods in 1988 and 1989. Chromaticity was measured using a Minolta Chroma Meter CR–200b calorimeter on four quadrants of the fruit at locations midway between the stem and calyx ends. The apples continued to develop red color through the maturation period. After storage, the peel areas where chromaticity was measured were evaluated for scald intensity. The L* value at harvest was correlated positively with scald intensity, while the a* value was correlated negatively. An equation has been developed to describe the relationship between chromaticity values at harvest and scald intensity after storage.

Superficial scald (scald), a storage physiological disorder of apples and pears *(Pyrus communis* L.), is characterized by the appearance of irregular brown areas on the peel of the fruit. All of the damaged tissue can be removed by shallow peeling, but scald is an excluding grade defect for the fresh market.

Literature on scald physiology and control has been reviewed by Ingle and D'Souza (1989). Scald is believed to be caused by conjugated triene hydroperoxides, which are oxidation products of the sesquiterpene α– farnesene (Huelin and Coggiola, 1970). Since their introduction in the 1950s, diphenylamine and ethoxyquin (6 ethoxy-1-2dihydro-2-2, 4-trimethyl quinoline) applied as postharvest, prestorage dips or drenches have become the major tools for scald reduction (Smock, 1955, 1957). Because potential for scald development cannot be assessed accurately prior to storage, the highest label rate of diphenylamine or ethoxyquin commonly is applied at the commercial packing house or by storage operators. The future availability of the inhibitors is uncertain; hence, it is imperative to reduce dependence on their usage.

Scald incidence and severity are related to a number of environmental and cultural conditions that occur during the growing season. Color of the fruit at harvest is thought to be related to scald intensity in storage. Some apple cultivars, notably those with heavily pigmented peel, are more resistant to the disorder (Meigh, 1970). Among susceptible cultivars, such as 'Rome Beauty', the scalded areas occur more on the green rather than the pigmented areas. Objective evaluations of apple color at harvest vs. scald intensity after storage have not been reported. The objectives of this study were to monitor changes in chromaticity values (color) during the maturation period of 'Rome Beauty' apples and to determine their relationship to intensity of scald development after storage.

Materials and methods

'Rome Beauty' apples were obtained from the West Virginia Univ. Experiment Farm, Kearneysville. The experimental block consisted of 36 trees (6 × 6) with a 6 × 6-m spacing. The trees on MM.111 rootstock were planted in 1982 on a Hagerstown silt loam soil. Commercially recommended cultural practices and pesticide spray programs were followed. Apples were harvested first 154 or 160 days after bloom (DAFB) in 1988 and 1989, respectively, and at weekly intervals thereafter. The optimum harvest period for 'Rome Beauty' apples is between 165 and 175 DAFB (Hailer et al., 1941). "Fruit were harvested from 10 trees uniform in vigor and crop load. Two trees constituted a replication. At each harvest, one 20-kg box of fruit was obtained from all regions of the tree. The fruit were measured within 24 h for maturity and chromaticity.

At each harvest, fruit firmness was measured on opposite pared sides of 10 fruit from each of five replications using an Effegi penetrometer (11-mm-diameter tip) mounted on a drill press. The relative starch content was determined on these same fruit according to Priest and Lougheed (1981).

Chromaticity of fruit was measured with a Minolta Chroma Meter CR–200b calorimeter (Minolta, Ramsey, N.J.) on five replicates of 20 fruit each. Measurements were made on four quadrants by placing the 8-mm-diameter measuring area of the meter at the midpoint between the stem and calyx ends of fruits, which had been wiped clean. These spots were marked for subsequent scald intensity evaluations. Description and calibration procedures of the color meter were reported previously (Singha and Townsend, 1989; Singha et al., 1991). Color or chromaticity values were recorded in Commission Internationale de 'Eclairage L*, a*, and b* color space coordinates (Hunter, 1975). In this system, L* represents the value (lightness) of colors; it is low for dark colors and high for light colors; a* is negative for green and positive for red; whereas b* is negative for blue and positive for yellow. After measurements were made, the fruits were placed in storage at 0C and 85% to 90% RH.

After 4 and 6 months in storage, fruits were graded for scald intensity on areas where chromaticity measurements had been made. Scald intensity was graded on a scale of 1 to 4, where 1 represented no scald and 4 represented severe or intense scald. Scald incidence was also evaluated as percent of fruit unmarketable (> 10% of fruit surface scalded). Correlation coefficients between chromaticity values and scald intensity were determined (SAS Institute, Cary, N.C.). SAS was also used for regression analysis on maturity and chromaticity evaluations.

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Approved for publication by the Director, West Virginia Agr. and For. Expt. Sta., as Scientific Article no. 2422. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement *solely to indicate this fact.*

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Results and discussion

Fruit harvested ≈ 167 DAFB and thereafter were considerably less firm than those harvested a week earlier (Table 1). Fruit harvested later than 167 DAFB also contained little or no starch. The L* and b* values decreased, indicating darker and yellower color, and the a* values increased, indicating redder color with time of harvest in both 1988 and 1989. The L*, a*, and b* values at harvest were correlated with scald intensity values after 4 and 6 months of storage in 1988 and 1989 (Tables 2 and 3). Generally, correlations were higher in apples picked 161 DAFB and prior in 1988 (Table 2) and 167 DAFB and prior in 1989 (Table 3).

Scald intensity was lower in 'Rome Beauty' apples with high and uniform red coloration (low L* or high a* values) or with portions of the fruit with high red coloration than in portions of fruit or whole fruits with lower red coloration. Data for the 2 years were pooled and a regression equation was calculated to describe the relationship between scald intensity and chromaticity values:

$$Y = 0.95 + 0.02L^* - 0.03a^* + 0.03b^*$$

$$r = 0.30 \ (P \leq 0.05)$$

where Y = scald intensity (1 = no scald and 4 = severe or intense scald) and L*, a*, and b* are chromaticity values.

Correlation coefficients are higher for fruit harvested early as compared to late in the maturation period (Tables 2 and 3). This is because that, with later harvests, scald symptoms were not as prevalent, even on areas of fruits with low red coloration. Hence, the r^2 and r values being significant at $P = 0.05$, are not strikingly high. Scald incidence was lower on fruits from later harvests in 1988 and 1989 (Tables 2 and 3), with the exception of fruits harvested 175 DAFB in 1988 and evaluated 120 days after storage (Table 2). The decrease in scald susceptibility with an increase in fruit maturation is well-documented (Ingle and D'Souza, 1989).

The observation that well-colored (red) fruit are less-susceptible to scald dates back many years. Sando (1937) postulated that certain changes taking place during color development of the fruit while on the tree result in a skin condition that is highly resistant to scald in storage. Meigh (1970) described apples with heavily pigmented peel as being more resistant to scald development. Factors that promote anthocyanin synthesis in apples, such as low temperature during the latter part of the growing season (Creasy, 1969), also reduce scald in storage (Merritt et al., 1961).

The relationship between red color on 'Rome Beauty' apples and

Table 2. *Correlations* (R) *of L*, a', and b * values at harvest with scald intensity of 'Rome Beauty' apples after storage (1988–1989).*

Days after full bloom	L*	a*	b*	Scald incidence[z] (%)
	After 120 days in storage			
154	0.34*	–0.56*	0.56*	72
161	0.37*	–0.41*	0.37*	72
168	0.26*	–0.32*	0.13[NS]	48
175	0.16[NS]	–0.12[NS]	0.06[NS]	69
Combined	0.32*	–0.35*	0.28*	
	After 190 days in storage			
154	0.66*	–0.64*	0.56*	75
161	0.59*	–0.65*	0.56*	62
168	0.32*	–0.33*	0.26*	50
Combined	0.52*	–0.54*	0.46*	

[z]*Fruit with > 10% of surface scalded (unmarketable).*
*,NS *Significant at* P ≤ 0.05 *or nonsignificant, respectively.*

Table 3. *Correlations* (R) *of L*, a*, and b* values at harvest with scald intensity of 'Rome Beauty' apples after storage (1989–1990).*

Days after Full bloom	L*	a*	b*	Scald incidence[z] (%)
	After 120 days in storage			
160	0.34*	–0.42*	0.32*	85
167	0.45*	–0.52*	0.47*	44
174	0.22*	–0.23*	–0.02[NS]	8
181	0.21*	–0.24*	0.18*	5
Combined	0.42*	–0.49*	0.40*	---
	After 190 days in storage			
160	0.17*	–0.20*	0.24*	85
167	0.43*	–0.49*	0.46*	47
174	0.46*	–0.48*	0.43*	24
181	0.33*	–0.37*	0.25*	8
Combined	0.31*	–0.34*	0.33*	---

[z]*Fruit with > 10% of surface scalded (unmarketable).*
*,ns *Significant at* P ≤ 0.05 *or nonsignificant, respectively.*

Table 1. *Maturity characteristics and L*, a*, and b* values of 'Rome Beauty' apples at different harvest dates (1988 and 1989).*

Year	Days after full bloom	Firmness (N)	Starch index	L*	a*	b*
1988	154	64.6	3.9	49.41	18.77	17.00
	161	63.1	5.5	45.42	23.87	15.50
	168	51.1	8.2	42.61	25.38	13.57
	175	41.5	9.0	40.35	27.19	12.27
Significance		L[z]	L	L	L	L
1989	160	63.1	5.0	45.64	21.20	14.37
	167	53.0	6.2	42.41	24.18	12.62
	174	51.8	8.6	41.04	24.97	11.79
	181	53.9	8.5	38.50	27.52	11.17
Significance		L	L	L	L	L

[z]*L = Linear at* P = *0.05.*

scald intensity in storage maybe direct or indirect. There maybe an enhanced synthesis of antioxidants with enhanced synthesis of red pigmentation and, hence, less scald. Alternately, red pigmentation may help mask scald symptoms. The practical value of this relationship should be used. Orchard management systems should aim at producing fruit of uniformly high red color. Also, fruit should be harvested as late as possible (without compromising firmness) to take advantage of the high coloring potential of 'Rome Beauty' apples during maturation. Finally, fruit should be sorted at harvest according to uniformity and intensity of red color. Nonuniformly colored apples harvested early in the maturation period may have to be treated with the highest-labeled concentration of scald inhibitor chemicals due to higher scald potential, or be sold as soon as possible. Uniformly and well-colored apples could be treated with lower concentrations. Apples with uniformly dark red coloration may not require any inhibitor treatment. Because growing conditions vary considerably among apple-producing regions, the relationship between chromaticity values of 'Rome Beauty' apples and scald intensity will have to be evaluated under local conditions. Storage operators could conduct small-scale tests to determine whether low concentrations of scald inhibitor chemicals are adequate to suppress scald on dark red 'Rome Beauty' apples. Several color sorters are now commercially available to facilitate sorting.

Chemical usage for fruit storage will have to be reduced significantly in the future due to consumer concerns about residues or due to regulatory restrictions. From this study, it appears that the scald intensity of 'Rome Beauty' apples after storage is related to chromaticity values measured at harvest. This information can be of practical value as an aid in reducing usage of scald-inhibiting chemicals for fruits with low scald potential. It would be desirable to determine whether a relationship between chromaticity values and scald intensity exists in other susceptible cultivars. The relationship may be a valuable storage management tool.

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