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Testing the reliability of skin color as an indicator of quality for early season 'Brooks' (*Prunus avium* L.) cherry

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Abstract

During the 1997–1999 seasons, we investigated the relationship between 'Brooks' cherry skin color at harvest (full light red, 50% bright red, full bright red and full dark red) and consumer acceptance using fruit grown in different geographic locations in the San Joaquin Valley (SJV). Soluble solids concentration (SSC) increased, but titratable acidity (TA) levels did not decrease as cherries matured from the full light red to full dark red skin color. The perception of sweetness, sourness and cherry flavor intensity by a trained taste panel was highly correlated to skin color, SSC and SSC:TA at harvest. There were no differences in the level of correlation between SSC or SSC:TA and the perception of sweetness, sourness or cherry flavor by trained judges. In-store consumer tests indicated that 'Brooks' cherries with SSC $\geq$ 16.1% had the highest consumer acceptance (ca. 80–90%) and cherries with SSC $\leq$ 16.0%, the lowest (ca. 48%). Gender and ethnicity (Caucasian, Asian American, Hispanic, or African American) did not affect American consumer acceptance of 'Brooks' cherries.

Keywords: Sensory evaluation; In-store consumer acceptance; Demographics; Soluble solids concentration; Orchard survey

1. Introduction

Early May cherry shipments to Japan, Hong Kong and within the USA have become increasingly attractive to California cherry growers and shippers because of the high revenue returns. In the past, cherry production has been restricted to growing areas with mild summers; cherries grown in areas such as the San Joaquin Valley (SJV), with hot summers traditionally produce excessive double or spur fruits. However, in the last 10 years, new cherry cultivars such as 'Brooks', 'Tulare', 'Garnet', and 'King' that are not susceptible to double or spur fruits have been developed in the SJV. These cultivars are normally harvested the last week in April or the first week in May in California, and marketed to Asian countries and different areas within the USA. Of these cultivars, 'Brooks' is not a full dark red cherry in contrast to 'Tulare', 'King', 'Early Burlat' and 'Bing'. 'Brooks' was selected in the University of California cherry-breeding program among the progeny

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of a cross between two commercial sweet cherry cultivars Ranier (white flesh) and Early Burlat (Hansche et al., 1988). It is characterized as a very high quality, early maturing sweet cherry that possesses the outstanding ability to develop large fruit. In general, 'Brooks' ripens 5–7 days after 'Early Burlat' and about 7–12 days before 'Bing.' A better understanding of the relationships between cherry quality attributes and consumer acceptance is needed to assure that 'Brooks' cherries are harvested with the quality that meets consumer demands without loss of potential postharvest life.

Controlled trained panel sensory studies on the relationship between cherry quality attributes and sensory quality perception have been performed on other cherry cultivars such as 'Bing' (Dever et al., 1996; Drake and Fellman, 1987; Drake et al., 1989; Guyer et al., 1993; Schotzko, 1993; Kappel et al., 1996). However, no in-store consumer tests have been reported. Skin color is a practical and simple indicator with which to instruct harvesters on what to harvest. Therefore, it is important to establish a relationship between skin color and/or soluble solids concentration (SSC) on consumer acceptance to identify the skin color that cherries should be harvested to assure minimum taste consumer acceptance.

The objective of this study was to understand the relationship between consumer acceptance and SSC or skin color for early harvested 'Brooks' cherries. To meet this objective, three steps were followed. First, an industry-wide survey of 'Brooks' cherry quality attributes was conducted over 4 years for cherries picked at different skin colors. Second, a trained taste panel was used to determine if SSC is a key component of 'Brooks' cherry sensory quality. Third, based on data from the first two steps, an 'in-store' consumer acceptance test was conducted over 3 years.

2. Materials and methods

2.1. Industry survey

During the 1995 through 1998 seasons, 'Brooks' cherries were harvested at four different maturity stages based on skin color: full light red (Hue = 26.15, $L = 41.35$, $C = 42.30$), 50% bright red (Hue = 21.96, $L = 36.24$, $C = 37.69$), full bright red (Hue = 16.90, $L = 32.54$, $C = 30.79$), and full dark red (Hue = 11.85, $L = 29.11$, $C = 23.77$) from five orchards in the SJV. Fruit at the four different skin colors were harvested from five healthy trees in each orchard. A completely randomized design with five replicates of 10 fruit per maturity stage was used to evaluate quality attributes. Quality attributes measured at harvest for each skin color included SSC, firmness (F), titratable acidity (TA), weight, pH and color. SSC, pH, and TA were measured on juice extracted with a food press and filtered through cheesecloth. SSC was measured with a temperature compensated refractometer previously calibrated with distilled water. TA was measured by adding 5 g of sample juice to 50 ml of distilled water and titrating with 0.1 N sodium hydroxide (NaOH) to an end point of pH 8.2. TA is expressed as percent of malic acid, which is the predominant acid in this species. Average color was evaluated according to the Commission Internationale de l'Eclairage (CIE), with a Minolta colorimeter (Minolta, CR-200, Japan). Cherry skin color is expressed as hue angle ($h°$), lightness (L) and chroma (saturation). The hue angle is expressed in degrees and is a measure of color that, for example, from 0 to 90° spans from red to orange to yellow. Lightness separates color into bright and dark. Chroma is a measure of color intensity with low values representing dull colors and high values representing vibrant colors. F was measured using a U.C. firmness tester with a 3 mm tip. Skin from opposite cheeks of each fruit was removed and F calculated as the average of two measurements per fruit expressed as Newtons.

Data were subjected to ANOVA and correlation analysis. Means were separated using LSD means separation at the 5 or 1% level using the SAS statistical software (SAS Institute, Cary, NC).

2.2. Sensory evaluation

2.2.1. Trained panel

During the 1996 season, a trained panel of 15 judges was selected for their taste acuity (O'Ma-

hony, 1986). Sensory perception of sweetness, sourness and cherry flavor intensity was evaluated on 'Brooks' cherries picked at different skin colors as previously described on fruit collected from two of the same orchards used for the fruit quality evaluations. Physical measurements of weight, SSC, pH, TA, and *F* were obtained from the corresponding fruit quality evaluations. Each judge tasted three replicates from each skin color per orchard. Samples consisted of two whole cherries at room temperature (20 °C) presented in random order in individual booths illuminated by fluorescent lighting. To minimize potential color differences judges were instructed to wear dark green glasses during the tasting. Judges scored cherries by circling a hatch mark placed at increments of 0.5 cm on a 10 cm horizontal line anchored 1 cm from both ends of the line by 'less' and 'more' for each sensory attribute (sweetness, sourness, and cherry flavor intensity).

Data were subjected to ANOVA and correlation analysis. Means were separated using LSD means separation at the 5 and 1% levels using the SAS statistical software (SAS Institute, Cary, NC).

2.3. In-store consumer test

Groups of 100, 400, and 150 consumers representing a diverse combination of ages, ethnic groups and genders were tested at two major supermarkets in Fresno County, California during the 1997, 1998 and 1999 seasons, respectively. Based on our industry-wide survey, each consumer was presented four 'Brooks' cherry samples to test the four targeted skin colors: full light red, 50% bright red, full bright red, and full dark red. Each consumer was asked if he/she ate fresh cherries; the interviewer would then note their gender and ethnic group. Then, the consumer was instructed to wear dark glasses (to mask the skin color) during the tasting. Each consumer was presented, in random order, the four cherry half samples without pits in coded 88.7 ml soufflé cups at room temperature (20 °C). Each consumer was instructed to sip bottled water between samples to cleanse his/her palate.

The interview process for all three seasons varied. In 1997, the consumer was asked if he/she 'liked' or 'disliked' the sample. In 1998, the consumer was asked if he/she 'liked' or 'disliked' the sample or was 'not sure'. In 1999, the consumer was asked if he/she 'liked', 'disliked' or 'neither liked nor disliked' the sample. Then the consumer was asked to indicate his/her degree of liking or disliking: slightly, moderately, very much or extremely. In all 3 years, SSC was measured on the second half of each cherry sample tasted as previously described.

In 1997 and 1998, consumer acceptance was measured as a percentage. Percentage of consumers liking the cherry sample was calculated as the number of consumers liking the sample divided by the total number of consumers within the sample. Percentage of consumers disliking the cherry sample was calculated as the number of consumers disliking the cherry sample divided by the total number of consumers within the sample. In 1998, the percentage of consumers indicating 'not sure' about the cherry sample liking or disliking was calculated as the number of consumers 'not sure' divided by the total number of consumers within the sample. In 1999, consumer acceptance was measured as both a degree of liking and a percentage. Percentage of consumers liking the cherry sample was calculated as the number of consumers liking the cherry sample (score > 5.0) divided by the total number of consumers within the sample (Lawless and Heymann, 1998). Percentage of consumers disliking the cherry sample (score $<$ 5.0) was calculated as the number of consumers disliking the cherry sample divided by the total number of consumers within the sample. Percentage of consumers that neither liked nor disliked the cherry sample (score $= 5.0$) was calculated as the number of consumers that neither liked nor disliked the cherry sample divided by the total number of consumers within the sample.

For all 3 years, data was subjected to analysis of variance (ANOVA) prior to the Least Significant Differences (LSD) mean separation using the SAS program.

3. Results and discussion

3.1. Industry survey

In general, fruit weight, SSC, and SSC:TA increased as cherry skin color changed from full light red to full dark red (Table 1). The largest increase in fruit weight occurred between the light red and 50% bright red skin color. SSC increases were relatively evenly distributed between the different skin colors, increasing by about 1.0% SSC with each successive maturity stage. TA did not change as 'Brooks' cherries changed color from full light red to full bright red. However, TA decreased form 0.89 to 0.77% when cherries changed color from full bright red to full dark red. Thus, SSC:TA increased greatly when cherry skin color changed from bright red to dark red. This lack of TA decrease during final cherry maturation was previously observed in 'Brooks', 'Tulare' and 'King' cherries growing in the SJV (Crisosto et al., 1993, 1997). Fruit pH remained relatively unchanged during cherry maturation and among orchards. Fruit quality attributes of weight, SSC, TA, and SSC:TA also varied significantly among orchards (Table 1). The large range in the SSC:TA (18–28) among orchards was mainly due to differences in TA. Year also influenced fruit quality attributes. Of the 4 years, cherries grown in 1995 were among the largest (8.0 g), had the highest SSC:TA (29.1), had the lowest TA (0.59%), and one of the lowest SSC (16.6%). During the 1996 season, SSC and TA were the highest (19.4 and 1.20%, respectively), and SSC:TA and fruit weight were the lowest (16.6 and 7.5 g, respectively).

During the 4-year evaluation period, there were interactions between skin color, orchard and year for most of the quality attributes evaluated. This indicates that at a given skin color, fruit quality

Table 1
Effect of skin color, orchard and year on 'Brooks' cherry quality attributes measured at harvest (1995–1998)

Sources of variability	Fruit weight (g)	SSC (%)	TA (%)	SSC:TA	pH
Skin color (*SC*)	**	**	**	**	*
Full light red	7.1d	15.3d	0.81c	20.3d	3.9a
50% Bright red	8.0c	16.8c	0.85b	21.5c	3.9ab
Full bright red	8.2b	18.7b	0.89a	22.6b	3.9ab
Full dark red	8.5a	20.4a	0.77d	27.6a	3.8b
Orchard (*Or*)	**	**	**	**	**
No. 1	7.1e	17.6b	0.85b	22.5c	3.8
No. 2	8.1b	17.0cd	0.79c	22.2c	3.9
No. 3	8.9a	17.9a	1.00a	17.9d	3.8
No. 4	7.6c	16.9d	0.63d	28.4a	4.0
No. 5	7.4d	17.2c	0.79c	23.2b	3.9
Year (*Y*)	**	**	**	**	NS
1995	8.0a	16.6c	0.59d	29.1a	3.9
1996	7.5c	19.4a	1.20a	16.6d	3.9
1997	7.7b	17.4b	0.97b	18.1c	3.9
1998	8.2a	16.5c	0.72c	23.2b	3.8
Interactions					
SC*Or	*	**	*	**	NS
SC*Y	**	*	**	**	*
Or*Y	**	**	**	**	**
SC*Or*Y	**	**	*	**	NS

Values within each column and source of variability followed by different letters are significantly different according to the LSD means separation. NS, no significant differences; * and ** significant differences at the 0.05 and 0.01 levels, respectively. No letters within a column indicates no significant differences between treatments.

Table 2
Quality attributes according to the interaction between orchard and skin color for 'Brooks' cherries during the 1997 season

		Weight (g)	Firmness[a] (*N*)	SSC (%)	TA (%)	SSC:TA
Orchard × skin color						
No. 1	Full light red	5.6c[b]	2.02a	16.8d	1.22c	13.7c
	50% Bright red	6.4b	1.81ab	18.8c	1.27b	14.8b
	Full bright red	7.2a	1.63b	21.3b	1.30ab	16.4a
	Full dark red	7.2a	1.75b	22.2a	1.35a	16.4a
No. 2	Full light red	8.1c	2.13c	18.8d	1.00c	18.8c
	50% Bright red	9.2a	2.59b	22.2c	1.08ab	20.6b
	Full bright red	8.6b	2.67b	23.2b	1.05bc	22.1a
	Full dark red	8.6bc	2.99a	25.3a	1.12a	22.6a
No. 3	Full light red	7.6c	2.64a	18.1c	1.35	13.4c
	50% Bright red	8.1b	2.17b	18.8c	1.34	14.0c
	Full bright red	8.3ab	1.94c	19.9b	1.34	14.9b
	Full dark red	8.5a	1.95c	21.6a	1.33	16.2a
No. 4	Full light red	6.8b	2.68	18.7d	1.15b	16.3c
	50% Bright red	7.5a	2.85	20.1c	1.19ab	16.9c
	Full bright red	7.8a	2.61	21.8b	1.19ab	18.3b
	Full dark red	7.1b	2.85	24.2a	1.23a	19.7a
No. 5	Full light red	6.5c	2.76	16.8d	1.05b	16.0c
	50% Bright red	7.2b	2.70	17.9c	1.08b	16.6c
	Full bright red	7.5ab	2.49	20.0b	1.14a	17.5b
	Full dark red	8.0a	2.61	23.2a	1.14a	20.4a

[a] Flesh *F* measured with a 3 mm tip.

[b] Values within each column and source of variability (orchard × skin color) followed by different letters are significantly different according to the LSD means separation. NS, no significant differences; * and ** significant differences at the 0.05 and 0.01 levels, respectively. No letters within a column indicates no significant differences between treatments.

attributes will be different depending on the orchard and year. Thus, a given skin color cannot assure a minimum SSC and/or SSC:TA. For example, in 1997, SSC measured in cherries with 50% bright red skin color from orchard No. 2 was higher than the SSC in cherries with the full bright red skin color from orchards No. 1, 3, 4 and 5 (Table 2). Full bright red cherries from orchard No. 2 had a SSC equal to or higher than the SSC for full dark red cherries from orchards No. 1, 3, and 5. A similar situation occurred for the other quality attributes tested such as SSC:TA, fruit weight, and *F*.

3.2. Sensory evaluation.

3.2.1. Trained panel

Trained judges were able to detect differences in sweetness, sourness and cherry flavor intensity between different skin colors of 'Brooks' cherries (Table 3). Cherries at each successive skin color, from full light to full dark red, were progressively sweeter and had more cherry flavor intensity. Cherries harvested at the full light red color had the highest perception of sourness and cherries harvested at the full dark red color, the lowest. Trained judges did not detect differences in sourness between the 50% bright red and the full bright red skin colors. All of the physical and chemical quality attributes were correlated to sensory sweetness, sourness and cherry flavor intensity of 'Brooks' cherries. Of these attributes, skin color, SSC, and SSC:TA had the highest positive correlation with sweetness and cherry flavor intensity and the highest negative correlation with sourness (Table 4). There were no differences in perception of fruit quality sensory attributes based on either SSC or SSC:TA; in all of these

Table 3
Relationship between skin color and perception of sensory quality attributes evaluation for 'Brooks' cherry

	Sweetness	Sourness	Cherry flavor intensity
Full light red	3.8a[a]	5.4a	3.7a
50% Bright red	4.7b	4.7b	4.6b
Full bright red	5.5c	4.3b	5.5c
Full dark red	6.6d	3.5c	6.4d
P-value	0.0001	0.0001	0.0001
LSD 0.05	0.6	0.6	0.5

[a] Scores ranged from 0.5 to 9.5 in 0.5 increments on a 10-cm horizontal line anchored 1 cm from both ends by 'less' (1) and 'more' (9). Values within each column followed by the same letters are not significantly different according to the LSD means separation at $P<0.05$.

cases, the correlation coefficients (r) were highly significant between 0.824 and 0.932. As TA measurements involve careful laboratory analysis, we recommend only the use of SSC measurements.

3.2.2. Consumer test

In all 3 years, as the SSC increased the percent consumer acceptance increased. Combining 1997–1999 data, consumer acceptance was related to cherry SSC and there was no interaction between year and SSC on consumer acceptance (Table 5). Based on consumer acceptance, fruit SSC was segregated into three groups. 'Brooks' cherries with SSC $\geq$ 20.1% had the highest consumer acceptance (ca. 93%) and cherries with SSC $\leq$ 16.0%, the lowest (ca. 48%). Cherries within the 16.1–20% SSC range were accepted by approximately 83% of consumers.

Table 4
Correlation coefficients (r) between physical and chemical attributes and sensory quality attributes for 'Brooks' cherry

	Sweetness	Sourness	Cherry flavor intensity
Skin color	0.958***	−0.904***	0.983***
Weight	0.512**	−0.123**	0.559**
SSC	0.842***	−0.824***	0.904***
SSC:TA	0.842***	−0.932***	0.890***
TA	0.344**	−0.072**	0.404**
pH	0.185**	0.276**	0.188**
F	−0.584**	0.835***	−0.614**
L	−0.910***	0.838***	−0.956***
Hue	−0.902***	0.906***	−0.951***
Chroma	−0.976***	0.857***	−0.995***

, * Significant at 1 and 0.1% levels, respectively.

Table 5
Relationship between SSC and consumer acceptance for 'Brooks' cherries measured during three consecutive 'in-store' consumer tests

Treatments	Acceptance (%)
SSC (%)	
≤16.0	47.9a[a]
16.1–20.0	83.4b
≥20.1	93.4b
$LSD_{0.05}$	21.3
Year	
1997	72.1
1998	75.8
1999	77.3
SSC × year	NS

[a] Values within each column and source of variability followed by different letters are significantly different according to the LSD means separation at $P<0.05$. No letters within a column indicates no significant differences between treatments.

Consumer acceptance was related to cherry skin color as has been reported in other commodities (Bruhn et al., 1991). In this case, there was interaction between skin color and year on consumer acceptance (Table 6). In all 3 years, cherries harvested at the full light red skin color had the lowest consumer acceptance (ca. 33%). Consumer acceptance for cherries harvested at the 50% bright red color reached approximately 76%, except for the 1998 season that only attained 53% consumer acceptance. For cherries harvested at the full bright red and full dark red skin colors, consumer acceptance was approximately 82 and 91%, respectively. In general, full dark red cherries had higher consumer acceptance than full bright red cherries. The interaction between skin color and year on consumer acceptance can be explained by the variability due to year/orchard on the relationship between SSC and skin color. The reason why consumer acceptance of the 1998 cherries harvested at the 50% bright red color was lower than for the same skin color in 1997 and

1999 may be explained in part because the cherries had only 14.1% SSC (1998) compared with 18.4 and 15.5% in 1997 and 1999, respectively. Other sensory quality attributes such as cherry flavor may also have been a factor. In the 3 years of these in-store consumer tests, 'Brooks' cherries harvested at the full bright red skin color assured acceptance by approximately 80% of the consumers. In general, fruit weight and SSC increased as skin color darkened but postharvest life decreased (Crisosto et al., 1993, 1997).

Based on our 4-year data, only cherries with a minimum SSC > 16.0% should be harvested to assure consumer satisfaction. In most of the cases, 'Brooks' cherry, which is not a full dark red cherry like 'Bing', reaches a minimum of 16% SSC before it develops a full bright or dark red skin color. We recommend growers measure SSC in 'Brooks' cherries at different skin colors. According to their specific orchard and growing season relationship, growers can instruct harvesters as to which skin color they should be picking. However, as the consumer decision in many markets is currently based on full dark red color, promotional and educational programs to demonstrate that high consumer acceptance of 'Brooks' cherries is independent of full dark red color development should be pursued. Using this proposed harvesting protocol and educational programs will allow 'Brooks' orchards with this high SSC potential to be harvested before they develop a full dark red skin color.

Table 6
Interaction between skin color and year on 'Brooks' cherry consumer acceptance measured during a 3-year period

Skin color × year	Acceptance (%)	SSC (%)
Full light red		
1997	37.1a[a]	13.5
1998	31.9a	12.4
1999	29.8a	12.8
50% *Bright red*		
1997	74.7a	18.4
1998	52.8b	14.1
1999	77.6a	15.5
Full bright red		
1997	83.8a	19.3
1998	81.0a	16.5
1999	80.7a	17.5
Full dark red		
1997	89.9a	21.1
1998	88.7a	18.3
1999	94.5a	21.6

[a] Values within each column and source of variability (skin color × year) followed by different letters are significantly different according to the LSD means separation at $P < 0.05$. No letters within a column indicates no significant differences between treatments.

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