Sensory Evaluation of Sweet Cherry Cultivars

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Abstract. Cherry cultivars (*Prunus avium* L.) from the breeding program located at Agriculture and Agri-Food Canada, Research Centre, Summerland, B.C., were profiled for their sensory characteristics. Judges scored six visual attributes, five flavor/texture attributes, and the degree of liking on 10-cm anchored line scales. There were significant differences ($P \leq 0.001$) in external firmness, size, and color intensity as well as differences in flesh firmness, juiciness, sweetness, sourness, and intensity of cherry flavor among the cultivars. Principal component analysis (PCA) showed the relationships among the internal sensory attributes, including a calculated sum of perceived sweetness and sourness, and the analytical values (pH, soluble solids concentration, sugar : acid ratio). Factor scores located individual cultivars on the PCA plot and provided a graphic illustration of their sensory characteristics.

The Summerland cherry breeding program was established in 1928 and produced its first named cherry cultivar ('Van') in 1944. Twenty cultivars have been introduced, of which four ('Van', 'Stella', 'Lapins', and 'Summit') are widely grown internationally and five ('Sam', 'Sunburst', 'Sweetheart', 'Newstar', and 'Sylvia') are minor international cultivars. Some new releases are being planted by the North American and European cherry industries.

The breeding program evaluates 5000 seedlings yearly with ≈ 20 propagated for second-stage cultivar. Seedlings are selected based on growth habit, self-fertility, and resistance to rain-induced splitting as well as fruit quality factors, such as size, color, firmness, sugar-acid balance, and cherry flavor.

Cherries have a relatively short fresh-market season and do not store as well as many other fruit; therefore, extension of the season through the development of either late or early maturing cultivars is an important aspect of fruit breeding (Fogle, 1975). Maturation dates for Summerland cultivars range from 25 June to 10 Aug., with the midseason cultivar Van harvested 7 to 10 July.

Consumer studies have shown that size, texture, and color are cultivar attributes important to the North American market (Schotzko, 1986; Sloulin, 1990), while a survey of Japanese consumers found that flavor, freshness, and then color were considered important. Cherry size had only minor significance in the purchase decision of Japanese consumers (Miller et al., 1986). Cliff et al. (1996) showed that size, color uniformity,

sweetness, and flavor were the principal attributes contributing to cherry liking, again based on a panel of North American consumers.

Traditionally, a hedonic scale (often nine points) has been applied to whole-fruit evaluations of attributes, such as appearance, flavor, texture, or overall acceptance (Grauslund, 1987; Stebbins et al., 1992). However, with the development of overseas markets, a hedonic sensory evaluation based on regional preferences will not give plant breeders sufficient information to make cultivar cultivars.

Our research was undertaken to establish a sensory profile for some of the more promising numbered cultivars (as determined by horticulture records and subjective sensory evaluations) in the Summerland breeding program. Established cultivars, such as 'Bing', 'Lambert', and 'Lapins', were included in the study to provide commercial standards.

Materials and Methods

Cherry sampling. Twenty-one numbered selections (hereinafter referred to as cultivars) and seven named sweet cherry cultivars (Table 1) from the breeding program at Agriculture and Agri-Food Canada, Research Centre, Summerland, were evaluated over 6 weeks. Commercially established cultivars were included in several sessions (Table 1) as standards for comparison. The cherries were harvested on one of six dates, (23 and 28 June; 6,

Table 1. Summary of analytical values and field traits for early, midseason, and late-harvest cherry cultivars.

Cultivar	Avg over years (including 1994)				Avg for 1994			
	Years (no.)	Maturity date	Mean wt (g) ^y	SSC ^z (%)	Mean wt (g) ^y	SSC ^z (%)	pH	TA ^z (mg·liter ⁻¹)
Early harvest								
13S-24-28	13	3 July	10.7	18.0	10.8	17.2	4.05	5.2
Bing—1st harvest	---	---	---	---	8.8	18.0	3.80	8.1
13N-04-51	1	24 June	10.4	17.0	10.3	17.2	4.05	6.53
2C-61-22	11	6 July	10.7	17.4	9.8	17.9	4.17	5.15
13S-05-22	11	30 June	9.5	17.4	10.3	17.1	4.00	5.66
13S-08-33	7	5 July	11.1	19.0	---	15.5	3.84	7.66
Bing—2nd harvest	---	---	---	---	9.4	16.9	3.88	8.92
13S-17-20	12	9 July	10.4	20.7	10.5	19.9	3.89	9.85
11W-16-50	6	8 July	11.6	17.0	11.3	15.1	3.95	6.12
Newstar	10	7 July	10.0	17.9	8.9	17.1	3.90	7.91
13S-21-20	10	5 July	9.7	17.3	9.0	16.2	4.27	7.63
Midseason harvest								
13S-10-40	13	12 July	11.6	20.4	13.1	18.9	4.11	8.36
Bing—3rd harvest	4	10 July	9.3	16.7	10.4	19.5	3.82	8.29
Summit	13	11 July	12.6	18.2	13.2	18.2	3.94	5.85
13N-07-19	1	9 July	12.5	17.6	13.0	19.3	4.00	5.02
13S-36-18	9	13 July	11.5	19.3	10.9	18.7	3.90	6.64
13S-06-59	8	11 July	12.7	18.5	13.1	19.5	3.89	9.62
Lapins—1st harvest	---	---	---	---	---	16.1	4.00	6.99
13S-18-15	10	12 July	11.7	16.2	12.1	18.6	4.27	4.80
13S-11-34	12	12 July	10.8	17.6	10.9	18.1	3.76	12.26
Bing—4th harvest	---	---	---	---	---	23.0	3.86	10.90
Sylvia—1st harvest	13	15 July	10.6	16.8	12.1	18.6	4.11	5.87
Late harvest								
Bing—5th harvest	---	---	---	---	9.6	26.0	3.97	10.18
13S-18-10	8	10 July	11.0	16.2	12.8	---	3.92	3.19
Lapins—2nd harvest	12	12 July	10.6	17.3	12.1	17.7	3.95	9.62
Sylvia—2nd harvest	---	---	---	---	12.5	18.1	4.02	8.03
13S-42-49	3	18 July	10.3	16.4	---	19.9	3.90	9.82
Lambert	8	17 July	10.5	19.2	12.3	19.9	3.98	8.35
13S-16-29	7	26 July	9.8	17.9	9.7	21.1	3.90	11.02
13S-21-01	1	6 Aug.	11.3	16.6	10.8	20.0	4.11	11.62
13S-20-09	2	1 Aug.	12.2	18.9	10.4	21.1	3.78	9.81
Sweetheart	9	25 July	9.7	18.0	10.0	21.7	3.85	10.84
13S-25-25	3	27 July	12.0	17.3	11.3	15.5	3.87	8.32

^zSSC = soluble solids concentration; TA = titratable acidity, expressed as malic acid.

^yn = 100.

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13, and 20 July; and 2 Aug. 1994); however, for the analytical and the sensory analyses, these dates were classified as three harvest periods: early (23 and 28 June), midseason (6 and 13 July), and late (20 July and 2 Aug) (Table 1).

The trees were grown in one of three evaluation blocks with sandy loam soil and 3-m spacing within and between rows. Trees varied in age from 4 to 14 years and were propagated on the rootstock F12/1. All plots received the same irrigation and fertilization (NH_4NO_3 at $165 \text{ kg} \cdot \text{ha}^{-1}$) scheduling. None of the cultivars were treated with growth regulators.

All samples were harvested from one tree by randomly picking 0.5 kg (400 to 500 fruit) from the upper and lower branches. Harvesting was completed before noon; samples were sorted, and a representative collection of 100 fruit was stored overnight at room temperature (22C) for sensory evaluation the next day.

Analytical data. Average weight was calculated from three 100-fruit samples. Soluble solids concentration (SSC) and pH were determined on juice extracted from a random sample of 15 cherries. Titratable acidity (TA) was determined by titrating 10 ml of juice with 0.1 N NaOH to a pH endpoint of 8.1.

Sensory analysis. Eighteen subjects (employees of Agriculture and Agri-Food Canada, Summerland, B.C.) evaluated the cherry cultivars, in duplicate, in six sensory evaluation sessions. One training session was conducted to familiarize judges with attribute definitions, reference standards, and sensory protocol (Cliff et al., 1996).

In each evaluation session, subjects scored six visual attributes on a collection of 10 cherries per cultivar (Table 2). Each collection was labeled with a three-digit random number and was evaluated in random order under natural light. Judges first scored the magnitude of each visual attribute and then quantified their degree of liking of the cultivars based on visual appearance and perceived firmness by touch only.

Flavor/texture evaluations were conducted in individual tasting booths under red light.

The same six cherry cultivars were coded with different three-digit random numbers and were presented in random order. Judges scored the magnitude of the five attributes (Table 2) and then quantified their degree of liking.

Visual and flavor/texture attributes were assessed on a 10-cm line scale and were quantified by measuring the location of the mark from the origin. References for the line scale were developed and identified (Table 2). Unpasteurized cherry juice (30 ml) was prepared, frozen, and thawed just before sensory analysis for sweetness and sourness references.

Statistical analysis. Sensory evaluation was conducted using a randomized complete-block design. A preliminary analysis of variance (ANOVA) showed a significant harvest period effect ($P \leq 0.001$) for all visual and flavor/texture attributes except sourness. Therefore, separate ANOVA were conducted on the data from each harvest period to delineate within harvest cultivar differences. Because hedonic responses, based on eight to 20 tasters, have been considered adequate for a preliminary estimate of consumer response (Basker, 1977), liking mean scores were used to select five cultivars (North American criteria) from each of the harvest periods. However, cultivars were not ranked according to liking because the number of judgements ($n = 36$) was considered insufficient for a reliable prediction of consumer preference (Kramer and Twigg, 1970).

Principle component analysis (PCA) (Meilgaard et al., 1991) was used to determine the relationship among the flavor/texture and analytical attributes and provided a graphical description of cultivar flavor/texture characteristics. Factor scores (sum of each attribute factor loading $\times$ the original attribute mean score) were calculated for each of the cultivars. Although cultivar factor scores were calculated from a single analysis, scores for the three harvest periods were plotted on separate figures to facilitate interpretation. These figures then provided a visual representation of the dominant characteristics for each cherry cultivar. All analyses were performed using SAS (SAS Institute, 1990).

Results and Discussion

Analytical data for 1994, as well as average values (2 to 13 years) for harvest date, mean fruit weight ($n = 100$), and SSC, were compiled (Table 1). Average harvest dates showed that the 1994 harvest periods were typical for the various cultivars. In general, the 1994 cultivar means for SSC and weight ($n = 100$) were similar to the average data. ANOVA showed significant within-harvest differences ($P \leq 0.001$) for the visual attributes (firmness, size, and color intensity) that previously had been identified as components of liking (Cliff et al., 1996; Sloulin, 1990). Firmness ratings >5.0 and high scores for size and color were associated with high liking scores from the panel (data not shown). Means for five cultivars from each harvest period with high scores for these attributes are reported (Table 3). Although the mean size scores for early cultivars were <7.5 , while the midseason size score was >8.0 , all cultivars were larger than the industry standard, 'Bing' (data not shown).

ANOVA showed significant cultivar differences ($P \leq 0.001$) within each harvest period for all internal attributes. In general, five cultivars with high liking scores from each harvest period had high scores for cherry flavor and sweetness and low scores for sourness (Table 4).

PCA of the flavor/texture and analytical attributes showed that Factor I and Factor II accounted for 39.1% and 29.1% of the variation in the data set, respectively (Fig. 1). Factor I had heavy positive loadings for flesh firmness, sourness, cherry flavor, TA, liking, the sum of perceived sweetness and sourness, and negative loadings for pH. Factor II had positive loadings for sweetness, juiciness, flavor, and liking and negative loadings for TA, sourness, and flesh firmness. In PCA diagrams, the relative orientation among the attribute vectors reflects the attribute correlations. In this

Table 2. Definition of visual and flavor/texture sensory attributes. All attributes scored on 10-cm line scales.

Variable	Definition
Visual	
Intensity	Color intensity from light to dark. The Cherry Color Comparator (three and 34), developed by B.C. Research, was used for anchors at 1 cm and 9 cm, respectively.
Uniformity	Uniformity of skin color from uneven to even.
Speck	Speckling of the skin surface from low to high.
Size	Size of the cherries from small to large. A collection of 10 cherries with an average weight of 9 and 14 g were provided as anchors at 1 cm and 9 cm, respectively.
Stem length	Length of the stem from short to long. Diagrams of cherry stems, measuring 3.5 and 6 cm in length, were used as anchors at 1 cm and 9 cm, respectively.
Firmness	Firmness (by hand) from very soft to very firm.
Flavor and texture	
Flesh firmness	Firmness from very soft to very firm.
Juiciness	Juiciness of the cherries from low to high.
Sweetness	Sweetness from low to high. The soluble solids concentration of the reference juice, located at 6.5 cm, was 30.3%.
Sourness	Sourness from low to high. The titratable acidity of the reference juice, located at 7.5 cm, was 11.1 mg-liter ⁻¹ , expressed as malic.
Flavor	Cherry flavor from low to high.

Table 3. Mean scores^a ($n = 36$) for visual attributes for the five cultivars with high scores for firmness, size, and color intensity.

Cultivar	Score		
	Firmness	Size	Intensity
Early harvest			
13S-24-28	5.7	7.4	9.0
13S-5-22	7.2	6.0	9.5
13S-8-33	6.2	7.5	8.4
13S-17-20	8.0	7.1	6.9
11W-16-50	6.1	7.1	7.8
LSD _{0.05}	0.89	0.67	0.54
Midseason harvest			
Summit	6.0	8.5	7.4
13N-6-59	6.7	8.8	9.2
Lapins—1st harvest	8.4	8.0	7.8
13S-11-34	8.1	8.3	8.8
Sylvia—1st harvest	7.7	8.2	9.3
LSD _{0.05}	0.73	0.60	0.48
Late harvest			
13S-18-10	8.1	7.8	7.7
13S-42-49	9.0	8.6	7.7
Lambert	6.9	8.2	8.3
13S-21-1	7.2	7.3	8.3
13S-25-25	6.4	7.7	6.8
LSD _{0.05}	0.82	0.61	0.52

^aMaximum score = 10.

analysis, small angles (high correlations) existed between the vectors for liking, flavor, SSC, and juiciness. Located at about right angles to these attributes, pH was unrelated to them. In contrast, the 180° orientation between pH and TA showed they were negatively correlated.

The factor score (sum attribute loading × original mean score) that located each cultivar on the PCA plot represented cultivar characteristics graphically. For example, high mean sensory scores for sweetness and juiciness and lower scores for sourness and TA positioned 13S-10-40 high to the right in the two-dimensional plot (Fig. 2), close to the juicy and sweetness vectors. Correspondingly, high mean scores for TA, flavor intensity, and sourness and low score for sweetness positioned 13S-11-34 low in the PCA plot in the positive direction along Factor I, close to the TA vector (Fig. 2).

Although degree of liking ($n = 36$) was a preliminary evaluation, it was included in the PCA plot because of its correlation with flavor and, to some extent, sweetness—two attributes that have predicted flavor/texture cherry liking (Cliff et al., 1996). The three PCA plots demonstrated harvest period differences. The early cherry cultivars tended to score lower in juiciness, sweetness, and flavor and were located negatively along Factor II (Fig. 1). Mid-season increases in these attributes were reflected by a positive shift on Factors I and II (Fig. 2). Increased sourness and flesh firmness of the late-harvest cherries positioned these cultivars closer to the sourness and firmness vectors (Fig. 3).

While early harvest cultivars appeared to be less desirable than midseason cherries, it was important to evaluate individual cultivars within their harvest period. For example, 'Bing' may be an industry standard for a quality cherry, but it does not mature early enough to compete with early harvest cultivars (Fig. 1). Analytical values (data not shown) determined on fruit harvested 1 week after the evaluation session suggested that the lack of flavor and increased sourness for some late-harvest cherries may have been partially due to a lack of maturity.

Preliminary results from this sensory profiling indicated that several numbered cultivars had mean scores for size, firmness, flavor intensity, and sweetness that compared favorably with commercial cultivars (Tables 3 and 4). An early harvest cultivar that scored well compared to 'Newstar' (a cultivar that has been grown commercially in France and Italy) was 13S-24-28. This cultivar, which matures before 'Newstar', had high juiciness and sweetness and low sourness scores. Cultivar 13S-17-20 had high scores for cherry flavor and flesh firmness, the two attributes shown by PCA to be most closely related to the attribute "liking." Visually, all the early harvest numbered cultivars had higher size scores than 'Newstar', which was rated as one of the smaller cherries.

For the midseason harvest, there were three numbered cultivars with flavor/texture attributes similar to 'Bing' harvested at com-

mercial maturity. Cultivars 13S-10-40 and 13N-6-59 had high scores for juiciness, cherry flavor, and sweetness with a sourness score similar to that of 'Bing'. For these attributes, 13S-36-18 had slightly lower scores but was located close to 'Bing' on the PCA plot for midseason cherries (Fig. 2). Also, 13N-6-59

scored high for firmness, size, and color, attributes previously shown to predict visual liking (Cliff et al., 1996). Although 13S-10-40 had high color and size scores, it had a low score for external firmness (4.7). The late-harvest cultivars generally received lower scores for flavor, juiciness, and sweetness and

Fig. 1. Plot of the principal component analysis showing the relationship among the internal sensory attributes and analytical values and the location of individual early harvest cherry cultivars on the attribute vectors. (x) 13N-04-51, (+) 13S-05-22, (♦) 11W-16-50—first harvest, (☆) 13S-17-20, (x) 'Bing'—first harvest, (▲) 2C-61-22, (○) 'Newstar', (●) 13S-24-28, (▼) 'Bing'—second harvest, (□) 13S-08-33, (■) 13S-21-20, (★) 11W-16-50—second harvest.

Fig. 2. Plot of the principal component analysis showing the relationship among the internal sensory attributes and analytical values and the location of individual midseason harvest cherry cultivars on the attribute vectors. (x) 13N-06-59, (+) 13S-39-51, (♦) 13S-11-34, (☆) 13S-18-15, (x) 'Summit', (▲) 13N-07-19, (○) 13S-10-40, (●) 'Bing'—fourth harvest, (▼) 13S-36-18, (□) 'Bing'—third harvest, (■) 'Sylvia'—first harvest, (★) 'Lapins'—first harvest.

Fig. 3. Plot of the principal component analysis showing the relationship among the internal sensory attributes and analytical values and the location of individual late-harvest cherry cultivars on the attribute vectors. (x) 'Lapins'—second harvest, (+) 'Lambert', (♦) 13S-21-01, (☆) 13S-20-09, (X) 13S-16-29, (▲) 'Sylvia'—second harvest, (○) 13S-18-10, (●) 13S-25-25, (▼) 13S-42-49, (□) 'Bing'—fifth harvest, (■) 'Sweetheart'.

Table 4. Mean scores^a (n = 36) for flavor/texture attributes for the five cultivars with high scores for juiciness, sweetness, and cherry flavor.

Cultivar	Score				
	Flesh firmness	Juiciness	Sweetness	Sourness	Cherry flavor
Early harvest					
13S-24-28	5.5	6.8	6.5	3.1	5.4
13N-4-51	6.1	6.4	5.9	4.1	5.7
Newstar	5.9	6.4	6.0	3.6	6.2
13S-8-33	5.5	7.4	5.2	4.8	5.9
13S-17-20	7.2	6.1	5.3	5.2	6.4
LSD _{0.05}	0.87	0.72	0.86	0.96	0.95
Midseason harvest					
13S-10-40	4.6	7.7	6.7	4.2	7.2
Bing—3rd harvest	6.3	6.9	6.1	4.3	6.4
13N-6-59	6.5	7.2	6.4	4.8	7.1
Summit	5.7	6.3	6.6	3.1	5.9
13S-36-18	6.7	6.3	5.9	4.0	6.2
LSD _{0.05}	0.87	0.77	0.93	0.91	0.97
Late harvest					
Sylvia—2nd harvest	6.1	7.2	6.1	2.6	5.4
13S-16-29	5.6	6.8	5.4	4.4	6.3
Lapins—2nd harvest	6.1	7.2	6.0	3.2	5.8
Lambert	6.2	7.5	5.3	5.4	6.4
Bing—5th harvest	4.4	7.0	6.8	4.2	7.4
LSD _{0.05}	0.86	0.89	0.98	1.0	0.92

^aMaximum score = 10.

higher scores for sourness and flesh firmness. As previously indicated, this may have been due to immaturity rather than an intrinsic characteristic of these cultivars.

Descriptive analysis method coupled with multivariate statistics provides useful sensory profiles for plant breeding. New cultivar performance can be compared with existing commercial cultivars, including identification of specific attribute strengths and weaknesses. This sensory profiling identified several numbered cultivars with attributes similar to those of established commercial cultivars.

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