Eating Quality of ‘Gala’ and ‘Fuji’ Apples from Multiple Harvests and Storage Durations

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Abstract. Eating quality of ‘Gala’ and ‘Fuji’ apples (*Malus domestica* Borkh.) from multiple harvests and storage durations was assessed using an untrained consumer panel. Apples were harvested at weekly intervals for 6 weeks and stored in air. Changes due to harvest maturity and storage for overall liking (OL), sweetness, tartness, firmness, and flavor intensity were evaluated over 8 months. A multivariate factor analysis revealed multicollinearity for OL, sweetness, and flavor intensity ratings in both cultivars. These attributes had the highest loadings in the first factor, explaining 51% and 52% of the variance of ‘Gala’ and ‘Fuji’ data sets, respectively, and were interpreted as a quality factor. Tartness and firmness had the highest loadings in the second factor for ‘Gala’, explaining an additional 23% of the variability and reducing that cultivar’s data set to two factors. For ‘Fuji’, however, tartness and firmness were independent and included in factors 2 and 3, respectively. Factors 2 and 3 were interpreted as maturity factors, which explained 23% and 12% of the variance. The plots of the mean factor scores provided a multivariate technique to illustrate that panelists could differentiate between the stages of maturity of apples. Canonical correlations were calculated between the sensory and instrumental data. Only firmness measurements were correlated with sensory ratings for firmness ($r = 0.53$ and 0.44 for ‘Gala’ and ‘Fuji’, respectively).

Sensory science has been used to describe apple cultivars (Watada et al., 1980) or measure the effect of storage on fruit quality (Williams and Langron, 1983). Some maturity studies have also included taste panels to determine the effect of harvest date on fruit quality (Blanpied, 1979; Knee and Smith, 1989; Saltveit, 1983; Watada and Abbott, 1985). In most of the published reports, however, panel-

ists were either trained or staff of the research facility, which is not desirable for unbiased preference responses. Only a few studies (Stebbins et al., 1991; Williams and Langron, 1983) used a large number of consumers.

‘Gala’ and ‘Fuji’ cultivars are recent introductions to the Pacific Northwest region of the United States. There is little information relating maturity of these cultivars at harvest with consumer acceptance after 0 to 8 months’ storage (Plotto, 1993). Hedonic tests have indicated the optimum time of harvest for short- and long-term storage of these cultivars (Plotto et al., 1995), but not the consumer’s perception of simple taste attributes such as flavor, sweetness, tartness, and firmness. In this report, changes in sensory perception of ‘Gala’ and ‘Fuji’ apples are described over storage time for six harvest dates. Multivariate statistical analysis was used to describe the relationship among those attributes. Instrumental measurements were taken on individually tasted fruit in an attempt to correlate sensory with instrumental data.

Plant materials. ‘Royal Gala’ and ‘Fuji’ (‘Morio-fu #2’ strain) apples were sampled weekly from a commercial orchard near Wenatchee, Wash. (Plotto, 1993). Fruits that appeared to be the most mature, based on ground color and fruit size, were picked on each sampling date, and stored in air at 0 °C. Four and five consumer taste tests were conducted at ≈4- and 8-week intervals for ‘Gala’ and ‘Fuji’, respectively, in the Sensory Science Laboratory at Oregon State Univ. Twenty fruits of each harvest date were removed from storage and held 4 d at 20 °C before testing. Only one cultivar was tested per taste panel.

Sensory evaluation. Unpeeled apples were cut longitudinally and each panelist was presented immediately with six slices, one from an apple from each of the six harvest dates in a balanced, completely randomized block design. Each apple served three panelists and was cut into five sections: three for the taste test and two for analysis described below. Overall liking (OL) was rated using a nine-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike, and 9 = like extremely. Firmness, sweetness, tartness, and apple flavor intensities were rated on a nine-point category scale with the words low and high anchored at each end. Panelists were seated in individual booths lit with a red light to mask the variation in fruit peel color. Spring water (Aqua Cool, Portland, Ore.) was provided for rinsing between samples. Fifty to 60 untrained students and staff from a diversity of science and art courses at Oregon State Univ. participated in the tests.

Instrumental analysis. Two sections of the tasted fruit were analyzed for firmness and chemical characteristics. For ‘Gala’, all of the 20 tasted fruits on the first three panels and a subsample of five fruits on the last panel were analyzed. For ‘Fuji’, five fruits from the first two panels and 10 fruits from the last three panels were used. A Magness–Taylor penetrometer equipped with an 11-mm tip was used to measure firmness on two opposite, pared sides of the apple before the fruit was sliced for sensory evaluation. The punctured sections were juiced and soluble solids concentration (SSC) was measured with a handheld refractometer (Atago N1, Japan). Ten milliliters of juice was titrated with 0.1 N NaOH to a malic acid endpoint of pH 8.2 for titratable acidity (TA) measurements (Metrohm AG, Herisau, Switzerland).

Statistical analysis. All statistical analyses were performed using Statistical Analysis System (SAS Institute, Cary, N.C.). For each sensory attribute, the separation of means for harvest date effect was performed using analysis of variance (ANOVA) with the Waller–Duncan k ratio t test, $K = 100$, for each taste test. Pearson correlation coefficients between sensory attributes, within each taste test and for each cultivar, were calculated. Factor analysis (FA) with the principal component method (Tabachnick and Fidel, 1989) was performed on all sensory data in three steps. First, to remove the variability due to the harvest date,

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we used the residuals of a general linear model (GLM) with harvest date as main effect, panelist as block, and overall liking, firmness, sweetness, tartness, and flavor intensities as dependent variables, instead of the raw data. To meet the assumption of independent and identically distributed random vectors required for factorability of a statistical matrix, FA was first performed on the covariance matrix of the residuals of the GLM for each individual taste test and cultivar. Significant factors explaining more than 10% of the variation were retained. Secondly, a FA was run on the covariance matrix of the pooled residuals of all taste tests because the significant factors had similar patterns for all taste tests within a cultivar. To understand the underlying meanings of the linear combinations, the significant factors of the pooled residuals were extracted and rotated with the varimax technique. Finally, to examine the data distribution (exploratory use of FA), the mean factor scores for the experimental blocks (raw data) were plotted on graphs whose axes were the rotated significant factors. Linear regression using the stepwise method and canonical correlations was performed where firmness, SSC, and TA were the independent variables and sensory ratings were the dependent variables. The sensory data used in the regression and correlation analyses were those corresponding to the fruit analyzed for firmness, SSC, and TA.

Results

Structure of the sensory data set. Panelist effect was significant within all taste tests for both cultivars. No mean separation was performed across taste tests because different panelists were participating at each tasting session. For each taste test, ANOVAs showed

significant harvest date effects on 'Gala' sensory attributes (Fig. 1). Late harvests, expressed as days after full bloom (DAFB), were preferred at the early taste tests, and midseason harvest dates were preferred after mid- to long-term storage. The OL ratings across storage were most consistent for the fruit harvested 122 DAFB. In general, flavor intensity ratings were similar to OL ratings. Sweetness intensity was rated higher for the later harvests, with the first two harvest dates being significantly lower. In contrast, when sweetness ratings were low, tartness ratings were high. Firmness ratings decreased across harvest dates and storage duration. Harvest date differences were larger with longer storage.

Harvest date effects on sensory attributes of 'Fuji' fruit were also significant, except for flavor, and OL and flavor for the February and April taste tests, respectively (Fig. 2). OL and flavor intensity ratings had decreased considerably after 6 and 8 months of storage. 'Fuji' ratings for sweetness were high overall (above 6), except for the first harvest date. No trend was observed in sweetness ratings for the other harvest dates. Tartness was rated below 3 for apples from the last two harvest dates at the last taste test. Firmness intensity ratings decreased with storage duration, from above 7 to 5.5 for the last two harvest dates. They remained constant (above 7) for the first two harvest dates.

High positive correlations ($P \leq 0.001$) were found between OL and flavor ($r = 0.7$ to 0.8 , $n = 50$ to 60), OL and sweetness ($r = 0.5$ to 0.6), and sweetness and flavor ($r = 0.5$ to 0.6) across all taste tests in both cultivars.

FA provided a method to understand how all the attributes were interrelated, and how the samples were separated into like groups. Factor scores for 'Gala' and 'Fuji' data sets were

plotted in the two- and three-factor coordinate system, respectively (Figs. 3 and 4). On each plot, the data points are labeled with numbers for harvest dates and letters for taste tests. The angle of the variable vectors reflects the attribute correlations and the vector lengths reflect the relative contribution of the attributes to each factor. The circles grouping datapoints were drawn arbitrarily, based on our interpretation.

Variability in the 'Gala' data set was reduced to two dimensions, where factor 1 explained 51% of the variation and was a linear combination of OL, flavor, and sweetness (Fig. 3). Factor 2, orthogonal to factor 1, explained 23% of the variation and was a linear combination of tartness and firmness. Taste tests scores (letter symbol) tended to decrease along factor 1, which means that as fruit stayed in storage, the ratings for OL, flavor, and sweetness decreased (Fig. 3). Scores for harvest dates (numeric symbols) decreased along factor 2 (tartness and firmness), meaning that as fruit ripened, lower ratings were given to tartness and firmness. Fruit harvested 129, 136, and 143 DAFB (#4, 5, and 6), and stored until October (a), were given the highest ratings in OL, flavor, and sweetness, resulting in the highest scores on factor 1. Fruit harvested early, 108 and 115 DAFB (#1 and 2) had negative scores on factor 1 (OL, flavor, and sweetness) and the highest scores on factor 2 (tartness and firmness). Intermediate harvests were clustered at the intersection of the factors, mostly on the positive side of factor 1 (OL, flavor, and sweetness). Harvests at 136 and 143 DAFB (#5 and 6) at the November (b), December (c), and January (d) taste tests, as well as 122 and 129 DAFB (#3 and 4) on the January (d) taste test, had negative scores on factor 2 (tartness and firmness). Fruit harvested late, at 143 DAFB

Fig. 1. Sensory ratings for overall liking (9-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely), flavor, sweetness, tartness, and firmness intensities (scale: 1 to 9 = low to high) for 'Gala' apples harvested on six dates, expressed as days after full bloom (DAFB), and tested on four dates. Means of 58, 59, 49, and 60 panelists are reported within the October, November, December, and January taste panels, respectively. Separation of means was performed with the Waller-Duncan k ratio t test, $K = 100$.

Fig. 2. Sensory ratings for overall liking (9-point hedonic scale where 1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely), flavor, sweetness, firmness, and tartness intensities (scale: 1 to 9 = low to high) for 'Fuji' apples harvested on six dates, expressed as days after full bloom (DAFB), and tested on five dates. Means of 59, 58, 57, 60, and 57 panelists are reported within the November, January, February, April, and June taste panels, respectively. Separation of means was performed with the Waller-Duncan *k* ratio *t* test, *K* = 100.

(#6) and held in long-term storage until 21 Jan. (d), had negative scores on both factors, indicating low ratings in all attributes.

The variability of 'Fuji' data set was spread in a three-dimensional system, best pictured in two, two-dimensional plots (Fig. 4). Factor 1 (52% of the variation) was, as in 'Gala', a linear combination of OL, flavor, and sweetness, factor 2 (23% of the variation) repre-

sented tartness only, and factor 3 (12% of the variation), firmness. The first harvest for all taste tests (#1), and all harvest dates for the last taste test (e) [except 173 DAFB (#4)], had negative scores on factor 1 (OL, flavor, and sweetness) (Fig. 4A). Fruit from the first harvest had positive scores along factor 2 (tartness), while fruit with the longest storage time (d, e) had negative scores. Intermediate har-

vest dates and taste tests had positive scores on factor 1. Values decreased along factor 2 at later harvest dates and taste tests. Extracting the third factor (firmness) showed the separation between early harvests (#1 and 2) and intermediate harvests (#3 and 4) at early panels (a and b), and between late harvests (#5 and 6) and late taste panels (c, d, and e) along the firmness axis (Fig. 4B). Fruit harvested 180 DAFB (#5) and tested by the January panel (b) had the highest score on factor 1 and a near zero score on factors 2 and 3. The last harvest dates, 180 and 187 DAFB (#5 and 6, respectively), for the late panels in April (d) and June (e), had negative scores on the three factors.

Relation between sensory and analytical data. 'Gala' firmness ranged from 87.6 to 63.2 N in October and decreased to 74.7 to 52.5 N in January (Table 1). The differences between harvest dates for sweetness did not follow a particular trend; sweetness ranged from 9.2% to 11.9% SSC. A decrease in TA due to harvest date occurred in October and December. For 'Fuji', differences for firmness were less pronounced between harvest dates (Table 2). Firmness ranged from ≈ 82 to 68 N one and 3 months after harvest (November and January), and decreased to 74.7 to 58.3 N after 8 months in storage (June). Sweetness ranged from 11.7% to 15.6% SSC, without specific trend due to harvest date or storage. TA of late harvested fruits decreased after 4 months in storage. Low levels of TA were observed in June for all 'Fuji' fruit after 8 months in storage (June).

Multiple linear regressions of sensory ratings to analytical measurements revealed models with low R^2 values for OL, flavor,

Fig. 3. Mean factor scores of sensory attributes given to 'Gala' apples harvested on six dates, expressed as days after full bloom (DAFB) and tested on four dates, after varimax rotation. Vector coordinates are the loadings of sensory attributes they represent in the factors 1 and 2 coordinate system. OL = overall liking, FL = flavor, S = sweetness, T = tartness, and F = firmness. Factors 1 and 2 represent 51% and 23% of the total variation, respectively. Numbers represent DAFB and letters, the day of the taste panel. Means of 58, 59, 49, and 60 panelists are reported within each taste panel, respectively.

Fig. 4. Mean factor scores of sensory attributes given to 'Fuji' apples harvested on six dates, expressed as days after full bloom (DAFB), and tested on five dates, after varimax rotation. Vector coordinates are the loadings of sensory attributes they represent in factors 1, 2, and 3 coordinate system. OL = overall liking, FL = flavor, S = sweetness, T = tartness, and F = firmness. Factors 1, 2, and 3 represent 52%, 23%, and 12% of the total variation, respectively. Numbers represent DAFB and letters, the day of the taste panel. Means of 59, 58, 57, 60, and 57 panelists are reported within each taste panel, respectively.

sweetness, and tartness ranging from 0.003 to 0.1 for both cultivars (data not shown). Firmness was the instrumental measurement that was the best correlated with the sensory variable firmness. Still, only 23% and 16% of the variation in firmness ratings was explained by firmness measurements for 'Gala' and 'Fuji', respectively. Canonical correlation analysis extracted two pairs of canonical variates for 'Gala' and 'Fuji' (Table 3). For 'Gala', significant correlation ($r = 0.53$) was found between the first pair of canonical variates represented by sensory and instrumental firmness measurements. The second canonical variate was tartness and flavor for the sensory data, and TA for the analytical data. In 'Fuji', the first pair of canonical variates were linear combinations of tartness and firmness of sensory ratings, and TA and firmness measurements, and were correlated with $r = 0.44$. The second canonical variate was primarily sweetness and SSC. In both cultivars, the correlation coefficients between analytical measurements and

the second canonical variate of sensory ratings were too low to account for any significant relationship between sensory and analytical variables. The proportion of variability in the set of sensory variables that was explained by the set of analytical variables was 6.4 and 7.1 for 'Gala' and 'Fuji', respectively, indicating that neither set was a good predictor of the other.

Discussion

Effect of apple maturity on the sensory ratings. Correlations and FA revealed multicollinearity between OL, flavor, and sweetness in both cultivars; factor 1 was a linear combination of these three attributes. Indeed, ratings for OL and flavor had similar patterns across harvest date per taste panel (Fig. 1). Flavor is the result of the perception of a combination of volatile and nonvolatile components, the former resulting in sensory aroma and the latter in taste sensation (Will-

iams, 1979). Individual differences in the understanding and perception of apple flavor probably existed in the study. Panelist variability may, therefore, explain the variability and nonsignificance in the means of flavor ratings on two panels out of five for 'Fuji'. Nevertheless, apples rated high for flavor were generally rated high for OL. Similarly, apples that were perceived sweet were preferred to others.

The similarities between factor patterns for both cultivars suggest that panelists were consistent in rating apples, but also that our ballot might have been too simple. To understand the underlying reasons why fruit are given a particular rating, it is important to ask as many specific questions as possible (Williams and Langron, 1983). The use of FA as a variable reduction tool would have been more appropriate with at least 10 sensory attributes. However, a questionnaire for a consumer panel must be simple and short (Meilgaard et al., 1991). Adding attributes, such as juiciness or fruitiness, to our score sheet might have provided extra information without complicating the ballot.

The distribution of the scores along the first two and three factors for 'Gala' and 'Fuji' suggests that panelists could perceive the differences associated with harvest date and time in storage. The variability of both cultivars' data sets was explained by FA, and the distribution of factor scores suggested that the first extracted factor could be interpreted as an overall quality factor and the last two factors as maturity factors. In practice, U.S. Dept. of Agriculture inspectors evaluate maturity of apples by judging firmness (Abbott et al., 1992). High ratings for tartness and firmness for the first two harvest dates of 'Gala', and the first harvest date of 'Fuji', were invariably associated with low ratings for OL, flavor, and sweetness, thus locating these scores on the higher left quadrant of the plot. This distribution of the scores suggests that early harvested fruit had not developed full flavor and that high values for tartness and firmness do not necessarily imply high quality and consumer acceptance. Late harvested fruit after short-term storage received high ratings for OL, flavor, and sweetness and intermediate ratings for firmness and tartness, locating their scores on the center right of the plot. These data suggest that tartness and firmness were optimum and did not negatively or positively influence OL. According to Williams (1981), if fruit has optimum texture, overall quality will be improved by better taste and aroma, which was the case in the tree-ripe and unstored 'Gala' fruit (harvests of 129, 136, and 143 DAFB at the October panel). Factor scores for intermediate harvest dates and storage time were centered at the factors' intersection, indicating that panelists could not differentiate between these samples. When late harvested fruit was stored for a long time (January for 'Gala' and June for 'Fuji'), all attributes were given lower ratings, locating the factor scores at the lower left of the quadrant. These data imply that fruit had passed the stage of optimum eating quality.

Table 1. Fruit firmness, soluble solids concentration (SSC), and titratable acidity (TA) of 'Gala' apples harvested on six dates, expressed as days after full bloom (DAFB), and tested on four dates.^z

Taste test date	DAFB	Quality attribute		
		Firmness (N) ^y	SSC (%) ^x	TA (% malic) ^x
7 Oct.	108	87.6 a	10.6 bc	0.266 a
	115	82.7 b	10.6 bc	0.247 ab
	122	77.4 c	11.6 a	0.238 bc
	129	74.7 c	11.4 a	0.250 ab
	136	65.8 d	11.1 ab	0.222 c
	143	63.2 d	10.4 c	0.220 c
11 Nov.	108	84.5 a	9.4 b	0.196 bc
	115	79.6 b	11.0 a	0.235 a
	122	75.2 c	9.2 b	0.172 c
	129	72.1 d	10.1 ab	0.201 bc
	136	66.3 e	10.5 ab	0.210 ab
	143	63.2 f	9.8 ab	0.190 bc
7 Dec.	108	75.6 a	11.5	0.232 a
	115	74.7 a	10.8	0.224 ab
	122	75.6 a	11.7	0.209 a-c
	129	66.3 b	11.7	0.207 bc
	136	61.8 c	11.1	0.178 d
	143	59.6 c	10.9	0.193 cd
21 Jan.	108	74.7 b	11.2 ab	0.189
	115	79.2 a	10.7 ab	0.177
	122	68.1 c	11.9 a	0.188
	129	60.9 d	10.6 b	0.199
	136	57.4 e	11.3 ab	0.192
	143	52.5 f	10.7 ab	0.165

^zMean separations within a column and taste test were by the Waller-Duncan k ratio *t* test, K = 100.

^yn = 20 fruit.

^xn = 20 fruit on the taste tests of 7 Oct., 11 Nov., 7 Dec.; n = 5 fruit on the taste test of 21 Jan.

Table 2. Fruit firmness, soluble solids concentration (SSC), and titratable acidity (TA) of 'Fuji' apples harvested on six dates, expressed as days after full bloom (DAFB), and tested on five dates.^z

Taste test date	DAFB	Quality attribute		
		Firmness (N) ^y	SSC (%) ^x	TA (% malic) ^x
12 Nov.	152	81.8 a	13.2 ab	0.251 ab
	159	75.2 b	11.9 b	0.222 b
	166	75.2 b	12.4 b	0.242 ab
	173	74.3 b	13.8 ab	0.257 ab
	180	76.1 b	14.9 a	0.282 a
	187	67.6 c	12.5 b	0.208 b
14 Jan.	152	82.7 a	12.3 b	0.169 b
	159	79.2 a	13.8 ab	0.275 a
	166	73.8 bc	13.9 ab	0.219 ab
	173	74.3 b	12.0 b	0.217 ab
	180	71.2 cd	15.6 a	0.285 a
	187	68.1 d	14.2 ab	0.212 ab
25 Feb.	152	77.8 a	12.4	0.228 a
	159	78.3 a	12.5	0.223 ab
	166	68.5 bc	12.8	0.187 bc
	173	69.8 b	12.3	0.186 bc
	180	65.8 cd	11.7	0.173 c
	187	62.7 d	12.0	0.157 c
25 Apr.	152	77.4 a	13.5	0.308 a
	159	76.5 a	13.6	0.265 b
	166	68.5 b	14.0	0.171 c
	173	65.8 b	13.4	0.135 d
	180	65.4 b	13.9	0.134 d
	187	57.4 c	13.4	0.090 e
2 June	152	74.7 a	13.2 ab	0.163 a
	159	73.4 a	13.1 ab	0.165 a
	166	68.1 b	13.5 ab	0.130 b
	173	68.1 b	13.3 ab	0.100 c
	180	62.3 c	13.8 a	0.114 bc
	187	58.3 c	12.5 b	0.085 c

^zMean separations within a column and taste test were by the Waller-Duncan k ratio *t* test, K = 100.

^yn = 20 fruit.

^xn = 5 fruit for the taste tests of 12 Nov. and 14 Jan.; n = 10 fruit for the remaining taste tests.

Relating sensory data to instrumental measurements. Only firmness measurements were correlated with sensory ratings for firmness, although the R^2 values were low (0.23 and 0.16). For 'Fuji', losses of acidity and firmness occurring during maturation and senescence equally affected perceived tartness and firmness, as suggested by the first pair of canonical variates. However, because of the small proportion of variability in one set of variables explained by the other set in canonical correlation analysis, the apparent predictive value of TA and firmness measurements to sensory ratings was nonsignificant. For both cultivars, differences were more apparent for sweetness ratings than for SSC, suggesting that SSC is not the best measure of the intensity of perceived sweetness. With differences as low as 1% SSC between samples, Knee and Smith (1989) suggested that panelists were measuring differences in acidity when rating for sweetness intensity. Our results implied a similar conclusion, as sweetness ratings tended to be lower for unripe fruit that had a higher TA. However, correlations of TA with sweetness ratings were not significant, nor were SSC:TA ratios for either cultivar. Untrained panelists, the absence of any reference standard in our panel, and the variation of chemical composition and texture within a fruit, could also explain the lack of correlations between sensory and instrumental measurements. Higher correlations were found by Dever et al. (1995) who simultaneously analyzed pieces representing one-eighth of an apple with instrumental and sensory measurements with a trained panel.

OL was not explained by instrumental or sensory measurements in our study. Diverse and contradictory results are found in the literature relating sensory and analytical data. Williams (1979) points out that statistical relationships are usually applicable within the experimental data. In one study, OL of 'Delicious' apples was correlated with firmness and TA (Wills et al., 1980), and negatively correlated with TA in another study (Ananthakrishna et al., 1983). In a European consumer survey, overall quality of 'Golden Delicious' and 'Granny Smith' was related to sugars and to sugars and acidity combined (Crochon, 1989).

A multivariate FA illustrated overall how apples harvested over 6 weeks and tested for 4 to 8 months were perceived by untrained panelists, while the Waller-Duncan k ratio *t* test of means separation described the differences perceived for each attribute. The principal component extraction method revealed that OL, flavor, and sweetness attributes were defining factor 1, which could be interpreted as a quality factor. Tartness and firmness were describing factor 2 in 'Gala' fruit, which could be interpreted as a ripening factor. Tartness and firmness were unrelated and defined factors 2 and 3 in 'Fuji'. Multiple linear regression showed no practical predictive value of firmness, TA, and SSC on the sensory attributes. Canonical correlation analysis, while potentially appropriate for these data, did not yield any additional insight into the nature of

Table 3. Canonical structure of 'Gala' and 'Fuji' data sets: Correlations between the sensory ratings and the analytical measurements, and their respective canonical variables; and canonical significant correlations between the two sets of variables.^a

Variables	Cultivar			
	Gala		Fuji	
	Variate		Variate	
	1	2	1	2
Sensory rating				
OL	0.09	0.35	0.39	0.52
Flavor	0.02	0.65	0.39	0.54
Sweetness	-0.20	0.31	0.08	0.79
Tartness	0.47	0.77	0.67	-0.45
Firmness	0.90	0.04	0.88	0.41
Analytical measurement				
Firmness	0.96	-0.12	0.89	0.35
SSC	-0.13	0.56	0.12	0.87
TA	0.44	0.89	0.89	-0.09
Canonical correlation ^a	0.53	0.11	0.44	0.19

^aCorrelations significant at $P \leq 0.05$. P value for test of hypothesis that current canonical correlation and all below are zero. Values in bold highlight important correlations between variables and their corresponding canonical variates.

the sensory vs. instrumental variables.

Watada and Abbott (1985) and Williams (1979) insisted on the importance of methodology, first identifying quality criteria that characterize the tested product, and then rating for the intensity (Watada et al., 1980) or acceptance (Williams and Langron, 1983) of those factors. The failure of a few analytical measurements to explain sensory ratings indicates the complexity of human sensory receptors as well as variability between and within fruit.

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