10. NC-140. 1996. Performance of the NC-140 cooperative apple rootstock planting. I. Survival, tree size, yield and fruit size. Fruit Var. J. 50(1):6-10.

11. Robinson, T. L., A. N. Lakso and Z. Ren. 1991. Modifying apple tree canopies for improved production efficiency. HortScience 26:1005-1112.

Fruit Varieties Journal 52(4):205-210 1998

Sensory Characteristics of Four Strains of 'Fuji' Apples

MARGARET A. CLIFF,[1] MARJORIE C. KING AND RICHARD A. MACDONALD

Abstract

Four strains of 'Fuji' apples were profiled over two growing seasons for their visual and flavour/texture characteristics using descriptive analysis techniques. Trees had similar yield (number and weight of fruit) and were grown in a randomized plot at Agriculture and Agri-Food Canada, Summerland, British Columbia. Twelve judges evaluated five visual attributes (ground color, percent red, red-color saturation, stripe density and lenticels), and six flavor/texture attributes (crispness, firmness, juiciness, fruitiness, sweetness and sourness). In both years (1994, 1995), 'Fuji' strains differed in all visual attributes and crispness and sourness. There were instrumental color differences (L, a, and b measurements), but no pH, soluble solids, titratable acidity (TA) and pressure differences. In general, apples harvested in 1995 were less mature than those from 1994. This was reflected by higher TA and pressure values and lower sweetness, fruitiness and juiciness scores.

Introduction

There is interest in establishing plantings of new apple cultivars where the fruit have a high return, good storage capability and superior eating quality (9, 12). 'Fuji' ('Rails Janet' X 'Delicious') (14) is one such cultivar (12). Numerous red-striped and solid-red color strains are available (9). While mutant strains of 'Gala' (8), 'Jonagold' (8, 5) and 'Delicious' (3) have been evaluated, limited information is available (9) about the flavor and texture of 'Fuji' strains. Therefore, the purpose of this research was to document the nature and magnitude of the visual and flavor/texture differences among four 'Fuji' strains.

Materials and Methods

Apples: Four strains of 'Fuji' apples ('Fuji,' 'Redsport #1,' 'Redsport #2,' and 'Nagano #1') were grown on M.26 rootstock in a randomized plot at Agriculture and Agri-Food Canada, Research Station Summerland. Trees were established in 1991 and trained as slender spindles. Trees were cropped in 1993. Fruit from the 1994 and 1995 growing seasons were obtained from spur buds and harvested, at the same time, on the last possible commercial harvest date (limited by local weather conditions). In 1994, full bloom and harvest occurred on April 27 and Oct 14. In 1995, full bloom and harvest occurred on May 6 and Oct 16.

In 1994, apples from four trees were evaluated for each strain; in 1995, only two trees of each were available. The yield and number of apples per tree were recorded. Apples were stored for four months in air storage at 0 C until sensory evaluation.

From each tree, 12 defect-free apples of a similar size and shape were selected. Six of these apples were polished and used for the visual evaluation; the rest were used for the flavor/texture and analytical evaluations.

Received for publication ________. Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre, Summerland, BC V0H 1Z0, Canada. Contribution no. 979.
[1]Corresponding author.

Table 1. Definition of sensory attributes used for the evaluation of the 'Fuji' apples. All attributes were evaluated on 10 cm line scales, labelled at 1 and 9 cm as outlined.

Visual Attributes		Definition
1. Ground color	➤	the background color of the apple. Evaluated from green-green (a, b; -0.47, -0.38) to yellow-green (a, b; 0.28, 4.13)
2. Percent red	➤	the relative proportion of the apple surface with red coloration. Evaluated from low (10%) to high (90%).
3. Red-color saturation	➤	the relative saturation of the red color of the apple. Evaluated from brown-red (a, b; -11.07, 5.43) to red-red (a, b; 18.01, -5.39).
4. Stripe density	➤	the relative apple stripe density. Evaluated from low to high, anchored with published (1) photographic references for 'Fuji' apples at 1 (low), 6 (medium) and 9 cm (high).
5. Lenticels	➤	the relative quantity of lenticels on the skin surface. Evaluated from low to high.

Flavor/texture Attributes		Definition
1. Crispness	➤	when biting into the apple, the relative degree of pressure build-up, resulting in a 'crunching' sound. Evaluated from low to high.
2. Firmness	➤	when chewing the apple, the relative degree of hardness. Evaluated from soft to hard.
3. Juiciness	➤	when compressing the sample evenly with the back molars, the relative juice release. Evaluated from low to high.
4. Fruitiness	➤	the relative fruitiness. Evaluated from low to high.
5. Sweetness	➤	the relative sweet taste. Evaluated from low to high.
6. Sourness	➤	the relative sourness. Evaluated from low to high.

Analytical determinations: A Minolta Color Meter [Hunterlab color system (L, a, b)] was used to determine skin color on each apple designated for the visual evaluation. The mean of six readings were recorded from the circumference of the apple. For each apple in the flavor/texture evaluation, pressure was determined using a Magnus-Taylor type pressure tester (EPT-1 Electronic Pressure Testing System), equipped with a 1 cm tip. The mean pressures from the 'blush' and 'non-blush' sides of the apple were recorded. Apples were held at room temperature until sensory analysis the following day. After sensory analyses a 2.5 cm wide longitudinal section was cut from the remaining apple. Soluble solids (SS), pH and titratable acidity (TA) values were determined on a composite juice sample extracted from apple sections from each tree. TA was determined by titrating 20 ml of juice with 0.1 M NaOH to a pH of 8.1 and expressed as mg malic acid per 100 ml juice.

Sensory Analysis: In each year, twelve judges (employees of Agriculture and Agri-Food Canada) participated in an initial training session to discuss reference standards (Table 1) and to become familiar with the sensory protocol. In 1994, sensory (visual and flavor/texture) attributes were assessed on two days, with two sessions per day (morning and afternoon), whereas in 1995, only morning sessions were required. All attributes were evaluated on 10 cm horizontal line scales, labelled at 1 and 9 cm as outlined in Table 1. Reference apples were selected during round table discussion to anchor the color scales. Instrumental color measurements (L, a, b) were recorded for these apples (Table 1) for future reference. The degree of stripe density was evaluated using a 9-point stripe-density scale, anchored at 1, 6 and 9 cm with photographic references (1)

Table 2. Horticultural and analytical characteristics of 'Fuji' strains in 1994 and 1995.

	Yield		Hunterlab Color*			Pressure*	Composition per/tree		
	Average fruit/tree	Fruit Wgt. (kg)	L	a	b	Newtons (N)	pH	SS (percent)	TA (mg/100 ml)
1994									
Fuji	42.00	0.318	52.02b	15.21bc	26.32b	73.25	3.84	15.8	0.32
Redsport #1	41.75	0.308	56.09a	11.02c	30.37a	71.61	3.87	16.6	0.33
Redsport #2	44.50	0.316	50.14bc	18.07b	23.98bc	69.43	3.93	15.8	0.31
Nagano #1	41.75	0.344	47.57c	26.55a	21.28c	70.90	3.84	15.6	0.29
p	ns	ns	.0026	.0036	0.0006	ns	ns	ns	ns
1995									
Fuji	34.00	0.253	56.73a	18.13c	28.69a	73.96	3.74	16.7	0.35
Redsport #1	19.50	0.262	50.28b	20.68c	23.30b	70.99	3.72	16.1	0.35
Redsport #2	28.50	0.284	49.71b	25.18b	22.51b	78.54	3.65	16.8	0.41
Nagano #1	32.50	0.274	42.06c	31.39a	16.88c	74.68	3.82	16.4	0.33
p	ns	ns	0.0001	0.0001	0.0001	ns	ns	ns	ns

*4 trees x 6 apples.
**2 trees x 6 apples.

for 'Fuji' apples. These references standardized the evaluation process.

For the visual evaluation, the six apples from each of the strains were placed on a white polyethylene tray labelled with a three-digit random numbers. Judges evaluated the trays of apples in random order for five visual attributes under natural light.

The flavor/texture attributes of the remaining apples of each strain were evaluated in individual tasting booths under red light. Judges evaluated 2.5 cm wide longitudinal sections sampled from the transition zones (regions between the 'blush' and 'non-blush' sides of the apple) on each of six apples (12 samples). Apples were sectioned and peeled just prior to tasting to prevent oxidation and to avoid flavor/texture biases arising from differences in skin color. Judges evaluated four samples placed on white polyethylene trays and then took a short break before evaluating a second set of samples. To ensure independence of the visual and flavor/texture assessments, trays were labelled with three digit random numbers, which were different than the random numbers used for the visual assessment. Judges indicated the magnitude of the six flavor/texture attributes by marking the line scale with a vertical line labelled with the sample code. Sensory scores were quantified (max = 10) using a digitizing pad.

Statistical analysis: The samples were evaluated according to a randomized complete block design with individual trees used as replications. A two way analysis of variance (ANOVA) was used to determine the effects of strain, judge, and strain x judge for the five visual and six flavor/texture attributes. ANOVA (one-way) was used to document the effects of strain for horticultural (yield: number and weight) and analytical (L, a, b, pressure, pH, TA, SS) measurements. Mean scores and least significant differences (LSD $p \leq 0.05$) were calculated. All statistical calculations were performed using SAS (10).

Results and Discussion

'Fuji' strains did not differ in yield (number or weight of fruit), pressure, pH, TA, or SS, for both years, but did vary in color measurements (L, a, and b) (Table 2). In both years, Redsport #1 and 'Fuji' were the least red (lowest a) and most yellow (highest b). The significantly lower L, higher a, and lower b values for 'Nagano #1' reflect the dark bright red coloration of this strain compared to the other strains. In fact, 'Nagano #1' was uniformly red rather than striped. While the in-

Table 3. Mean[1] visual and flavor/texture scores[2] for 'Fuji' strains in 1994 (n = 48, 12 x 4 reps) and 1995 (n = 24 12 x 2 reps).

	Ground color[3]	Percent red[4]	Red saturation[5]	Stripe density[6]	Lenticels	Crisp-ness	Firm-ness	Juici-ness	Fruiti-ness	Sweet-ness	Sour-ness
1994											
Fuji	3.7c	5.2c	3.9bc	6.0a	5.7a	6.0b	6.1ab	6.3	6.3	6.6	4.1ab
Redsport #1	3.9bc	4.2d	3.8c	5.8a	4.4b	5.2b	5.5b	6.3	5.9	6.1	3.8b
Redsport #2	4.3b	6.0b	4.4b	4.9b	5.4a	6.8a	6.7a	5.8	5.0	5.8	4.7a
Nagano #1	5.2a	7.6a	7.0a	1.6c	5.9a	5.7b	5.9ab	6.0	5.8	6.1	4.2ab
p[7]	0.00012	0.0001	0.0001	0.0001	0.0002	0.0017	0.0412	ns	ns	ns	0.0465
1995											
Fuji	5.4a	3.9d	5.4b	5.6b	3.3b	5.9a	5.7	5.1	4.2	4.3b	4.2a
Redsport #1	3.4b	5.6c	4.3c	6.5a	5.0a	4.8c	5.0	4.6	4.3	5.0a	4.1ab
Redsport #2	6.3a	6.6b	4.9bc	5.1b	4.6a	5.7ab	5.2	4.9	3.9	4.8ab	3.6bc
Nagano #1	6.0	8.5a	7.1a	1.4c	5.3a	5.2bc	5.2	4.9	4.5	5.0a	3.4c
p	0.0001	0.0001	0.0001	0.0001	0.0001	0.0021	ns	ns	ns	0.0281	0.0175

[1]numbers within a column followed by a different letter are significantly different at p 0.05.
[2]all sensory scales were evaluated on 10 cm line scales, labelled at 1 and 9 with the terms low and high, respectively, except where otherwise noted.
[3]the ground color scale was labelled at 1 and 9 cm with the terms green-green (a, b; -0.47, -0.38) and yellow-green (a, b; 0.28, 4.13), respectively.
[4]the percent red scale was labelled at 1 and 9 cm with the 10% and 90%, respectively.
[5]the red-color scale was labelled at 1 and 9 cm with brown-red (a, b; -11.07, 5.43) and red-red (a, b; 18.01, -5.39), respectively.
[6]the strip density scale was labelled at 1, 6 and 9 cm with published photographic references (1).
[7]the exact probability for significant differences among the strains. ns = non-significant

strumental color measurements did differentiate among the strains, a full visual description was necessary to characterize ground color, percent red, stripe density and lenticels.

In the sensory evaluation, judges were a significant ($p < 0.05$) source of variation for all visual attributes (data not shown). While individual judge differences are expected and tolerated, judge consistency, as reflected by the interaction term (judge*strain) is much more important (6, 7). In both years, the interaction term for the visual and flavor/texture attributes were not significant ($p > 0.05$). Judge performance is therefore not discussed and only strain differences are reported (Table 3).

'Fuji' strains differed in all visual attributes for both years (Table 3). 'Nagano #1' had the most yellow ground color, greatest percent red, deepest red color (red saturation) and the lowest stripe density. In contrast, 'Redsport #1' had the most green ground color and highest stripe density with lower percent red and red saturation. The high degree of lenticels for 'Nagano #1' (Table 3) was believed to be partially due to the enhanced visibility or contrast of the lenticels against the dark red background.

Cultivars/sports of equal (similar) maturity should be compared (2) to avoid confounding the effects of maturity and strain. Commercially, starch index, development of watercore, a change in background color (green to yellow), the number of days between bloom and harvest and compositional analyses (SS, TA, pH) are used to determine harvest maturity. In this study, there were differences in yellow ground color, but there were no significant compositional (TA, SS, pH) differences among the strains (Table 2), for either 1994 or 1995. However, evaluations of yellow ground color development were difficult due to the lack of visible ground color for the 'Nagano #1' strain. All strains showed some watercore development (data not shown), but pressures were not significantly different.

In 1994 and 1995, the number of days between bloom and harvest was 170 and 160 days, respectively. Apples in 1995 were slightly less mature, due to a shorter growing season and had higher pressure and TA (Table 2) and lower sweetness, fruitiness and juiciness scores (Table 3).

Flavor/texture differences among the strains were less apparent than visual differences. Crispness and sourness (Table 3) were the only attributes to vary significantly ($p < 0.05$) in both years. Differences in crispness were consistent over the 2 years: Redsport #2 showed high crispness (i.e. 'crunch' on first bite) and 'Redsport #1' had low crispness. In 1994, 'Redsport #2' was firmer (hardness on repeated bites) than 'Redsport #1.' Other research has documented a high correlation between crispness and firmness in 'McIntosh' and 'Jonagold' apples (4). In contrast, the sourness ratings were not consistent from year to year, with 'Redsport #2' having low scores in 1994 and being the most sour in 1995. Juiciness and fruitiness did not differ among the strains in either year, but were in general higher in 1994 than in 1995. This lack of flavor differences among 'Fuji' strains is consistent with findings reported for mutant strains of 'Gala' and 'Jonagold' (8).

In 1994, 'Fuji' fruit had lower sweetness and higher sourness ratings and 'Nagano #1' fruit had higher sweetness and lower sourness scores. In 1995, this same trend was not apparent, 'Fuji' apples had a higher sweetness score and 'Nagano #1' apples a higher sourness score. Like other research (4, 10, 13), simple trends in sweetness and sourness evaluations (Table 3) did not directly correspond with the trends in SS and TA (Table 2). However in 1994, the low SS/TA ratio for 'Fuji' (49.4) was consistent with the low sweetness and high sourness ratings. Similarly, the high SS/TA ratio for 'Nagano #1' (53.8) reflected its high sweetness and low sourness scores.

Conclusions

Instrumental and sensory analyses were successful in documenting differences among four strains of 'Fuji' apples. Strains differed significantly in visual (ground color, percent red, red color saturation and coloration [L, a, b]) and flavor/textural (crispness, sweetness and sourness) attributes. Crispness, sweetness and sourness differences could be documented using sensory analyses, but in general the flavor/texture differences were not as apparent as the visual differences. Strain textural differences appeared to have some consistency over the two years while sweetness and sourness differences did not. Although analytical measurements of SS and TA were not good indicators of the sweetness and sourness ratings, SS/TA ratios more closely parallelled the sensory scores. Seasonal differences were observed.

References

1. Cliff, M. A., M. C. Dever, R. A. McDonald, and W.W. Fleming. 1995. Development of a sensory scale for the visual evaluation of apple stripe density. Food Quality J. 19:31-40.
2. Cliff, M. A., M. C. Dever, J. W. Hall, and B. Girard. 1996. Development and evaluation of multiple regression models for prediction of cherry cultivar liking. Food Res Int. 28:583-589.
3. Crassweller, R. M. and R. A. Hollender. 1989. Consumer evaluations of 'Delicious' apple strains. Fruit Var. J. 43(4):139-142.
4. Dever, M. C., M. A. Cliff, and J. W. Hall. 1995. Analysis of variation and multivariate relationships among analytical and sensory characteristics in whole apple evaluation. J. Sci. Food Agri. 69:329-338
5. Goddrie, P. D. 1986. The taste of Jonagold and several of its mutants. Fruitteelt 76(21):663.
6. Goniak, O. J. and A. C. Noble. 1987. Sensory study of selected volatile sulfur compounds in wine. Amer. J. Enol. Vitic. 38:223-227.
7. Guinard, J. X. and M. Cliff. 1987. Descriptive analysis of Pinot noir wines from Carneros, Napa and Sonoma. Amer. J. Enol. Vitic. 39:211-215.
8. Kappel, F., M. Dever, and M. Bouthillier. 1992. Sensory evaluation of 'Gala' and 'Jonagold' strains. Fruit Var. J. 45(1):37-44.
9. Norton, R. A., R. L. Stebbins, W. D Lane, and J. A. Ballard. 1989. The strains of Gala, Fuji and Jonagold described. Good Fruit Grower 4:7,40-42.
10. SAS Institute Inc. 1993. SAS User's Guide: Statistics. Version 6.0. Edition. SAS Institute Inc. Cary, NC.
11. Plotto, A., A. N. Azarenko, M. R. McDaniel, P. W. Crockett, and J. P. Mattheis. 1997. Eating quality of 'Gala' and 'Fuji' apples from multiple harvests and storage durations. HortScience 32(5):903-908.

12. Stebbins, R. L., A. A. Duncan, O. C. Compton, and D. Duncan. 1992. New apple varieties with greater consumer appeal. Compact Fruit Tree 25:76-83.
13. Watada, A. E., J. A. Abbott, R. E. Hardenburg, and W. Lusby. 1981. Relationship of apple sensory attributes to headspace volatiles, soluble solids and titratable acids. J. Amer. Soc. Hortic. Sci. 106:130-132.
14. Yoshida, Y. and G.I. Mink. 1974. Japanese apple varieties. Fruit varieties and horticultural digest. 28:7-8.

Fruit Varieties Journal 52(4):210 1998

Preserving a Healthy Fruit Crop Industry in the United States

KIM E. HUMMER[1] AND CURT R. ROM[2]

Introduction to these proceedings

On Saturday July 26, 1997, in Salt Lake City, Utah, the American Pomological Society, in collaboration with the Fruit Breeding Working Group and the Pomology Working Group of the American Society for Horticultural Science, presented a workshop entitled: A Healthy Fruit Crop Industry for North America. This workshop discussed the status of the United States Plant Germplasm Quarantine for temperate fruit crops. Kim E. Hummer, Research Leader, U. S. Department of Agriculture (USDA), Agricultural Research Service (ARS), National Clonal Germplasm Repository, introduced the topic and speakers and moderated the post-presentation discussion. Sally McCammon, Science Advisor for USDA Animal and Plant Health Inspection Service (APHIS) described the federal quarantine regulations for temperate fruit crops. Dave Weil, Tree Connection in Dundee, Oregon, presented the fruit industry perspective. Maxine Thompson, Professor Emeritus from Oregon State University, described her personal experiences in introduction of foreign plant material for domestic research. John Hartung, Unit Leader for the USDA, ARS Plant Germplasm Quarantine Office (PGQO), described recent changes in administration at the Quarantine Unit. Suzanne Hurtt, Plant Pathologist, USDA, ARS PGQO, described procedures used at the laboratory during the past 10 years to test foreign fruit crops for exotic diseases. The final speaker, Gaylord Mink, presented a summary of the procedures used at the National Research Support Project-5 (NRSP-5), Prosser, Washington. This unit detects and eliminates viruses from deciduous fruit crop cultivars on a fee-based service. An hour of discussion with many questions from the audience followed the oral presentations.

We present the written reports from the speakers in a two-part series. The following includes the presentations from Kim Hummer, Dave Weil and Maxine Thompson, and the final summary points resulting from the audience discussion session. Reports from the remaining speakers will be published in a future volume.

[1]Research Leader, USDA-ARS National Clonal Germplasm Repository, 33447 Peoria Road, Corvallis, OR, 97333
[2]Horticulturist, University of Arkansas, 316 Pit Science Bldg. Dept. of Horticulture. Fayetteville, AR 72701.