Journal of the American Pomological Society 60(1):9-19 2006

Sensory Characteristics of 21 New Apple Cultivars After Short-Term Cold Air Storage

C.R. Hampson[1, 2] and D.L. McKenzie[1]

Abstract

Sensory evaluation of fruit from twenty-one new apple (*Malus* × *domestica* Borkh.) selections and cultivars was conducted for three consecutive years after several weeks of regular air cold storage (1ºC), relative to the standard cultivars 'Royal Gala', 'Golden Delicious' and 'Liberty'. The cultivars were: 'Ambrosia', 'Autumn Gold', BC 8S-26-50, 'Chinook', 'Co-op 25' (Scarlet O'Hara™), 'Co-op 29' (Sundance™), Co-op 39 (Crimson Crisp™), CQRT10T17, CQR12T50, 'Cripp's Pink', 'Delblush', 'Hampshire', 'Jubilee Fuji' (September Wonder™), NJ 90, NJ 109, NY 65707-19, NY 79507-49, NY 79507-72, 'Pinova', 'Silken' and 'Runkel'. Four texture attributes (crispness, hardness, juiciness, skin toughness) and three flavor attributes (sweetness, sourness, flavor intensity) were assessed by twelve trained judges in blind panels, using unipolar 10-point scales. Analytical measurements of fruit flesh firmness were also made at harvest and immediately before the sensory evaluation. The objective was to identify cultivars with the best texture and flavor retention during air storage. The cultivars that rated highest in sensory characteristics were 'Ambrosia', BC 8S-26-50, 'Chinook', 'Co-op 25' (Scarlet O'Hara™), 'Co-op 29' (Sundance™), Co-op 39 (Crimson Crisp™), CQRT10T17, 'Cripp's Pink', 'Delblush', 'Jubilee Fuji' (September Wonder™) and 'Pinova'. These cultivars represent a wide range of juiciness, appearance, and flavor attributes, and several are disease-resistant. The applicability of the results to different growing environments is discussed.

Introduction

Internal fruit quality is very important to apple consumers (7, 11). The ongoing erosion of the market share of traditional cultivars, such as 'Golden Delicious' and 'Delicious', is often attributed to the superior internal sensory quality of newer cultivars like 'Fuji', 'Braeburn' and 'Gala' (4, 11, 13).

Several studies have focused on identifying the internal quality aspects most important to consumers. Using very different approaches, both Daillant-Spinnler et al. (4) and Hampson et al. (6) identified crispness as a texture component of critical importance. Hampson et al. (6) also found hardness and juiciness to be positively related to texture liking, while flavor liking was a complex integration of many sensory aspects, including sweetness, sourness, aromatics and juiciness. Regression analysis has shown that sensory ratings of sweetness and sourness are better predictors of flavor liking than instrumental measurements of soluble solids and titratable acidity (6). Nevertheless these regression models only accounted for about half of the observed variation in flavor liking scores. This may be partially due to consumer sub-groups with distinctive flavor preferences (4).

Recognizing the importance of detailed, systematic evaluation of new apple cultivars, the U.S. Department of Agriculture has sponsored a regional research project on apple cultivar evaluation, named the NE-183 regional project. The Agriculture and Agri-Food Canada (AAFC) research facility in Summerland, British Columbia (BC), Canada, has participated in both plantings with this project. The regional apple industry in the Okanagan Valley of BC is interested in new cultivars that will perform well in markets that are largely wholesale, distant from production areas, and geographically scattered. Because of the

[1] Agriculture and Agri-Food Canada, Pacific Agri-Food Research Centre, P.O. Box 5000, Summerland, BC, Canada V0H 1Z0. We sincerely thank our volunteer sensory evaluation judges for their efforts on our behalf.
[2]To whom correspondence should be addressed. E-mail HampsonC@agri.gc.ca

low regional population, direct sales are of limited importance and decrease markedly after early September as tourist traffic declines. Therefore, storage ability is critical to the market success of any new apple cultivar for commercial usage in BC.

The present study analyzed the sensory attributes of fruit from cultivars in the 1999 NE-183 trial after a period of cold storage. The new cultivars were evaluated relative to a successful commercial cultivar of the region ('Royal Gala') and the NE-183 trial standard ('Golden Delicious'). The objective was to determine which cultivars best maintained internal fruit quality after cold storage.

Materials and Methods

Cultivars and Cultural Practices

The cultivars in the NE-183 trial were planted in 1999 in a randomized complete block design (RCBD) with five replicate trees per cultivar at a tree spacing of 1.2 m × 4.0 m. The trees were easily contained within this spacing. Guard trees were planted at both ends of each row. The cultivars and selections were: 'Ambrosia', 'Autumn Gold', 'Co-op 29' (Sundance™), Co-op 39 (Crimson Crisp™), CQRT10T17, CQR12T50, 'Cripp's Pink' (Pink Lady®), 'Delblush', 'Hampshire', 'Jubilee Fuji' (September Wonder™), NJ 90, NJ 109, NY 65707-19, NY 79507-49, NY 79507-72, 'Pinova' and 'Runkel', plus the comparator 'Golden Delicious' (Gibson strain). These trees were propagated at Wafler Farms Inc. (Wolcott, NY, USA) on M.9 rootstock. Four cultivars ('Co-op 25' (Scarlet O'Hara™), 'Chinook', BC 8S-26-50, 'Silken') that were part of the NE-183 trial were not distributed to the BC site due to a tree shortage. Fruit for these four selections was gathered from trees growing in other replicated trials in the same field, as were the 'Royal Gala' and 'Liberty' fruit used as additional comparators in the sensory evaluations. All these latter cultivars were propagated at the AAFC research facility. All but 'Chinook', 'Silken' and BC 8S-26-50 were on M.9 rootstocks; the other three were on Bud.9 rootstocks.

All trees used in the sensory work received the same cultural care, which has been described previously (3). Briefly, the trees were individually supported with wooden posts, drip-irrigated and trained as slender spindles. Pest control and fertilization followed local recommendations, except that no calcium was applied, in keeping with the NE-183 protocol. Fruit were thinned with a single application of carbaryl (Sevin XLR, Bayer, Inc.) applied at the 10-15 mm stage of 'Golden Delicious', followed by hand thinning to single king fruit 15 cm apart.

Maturity Testing, Harvest Sampling and Storage

Trees were harvested when the starch index of the fruit reached 3.5 to 6.5 on the Cornell generic chart (1). At that time, samples of 10 fruit per tree were taken from the cultivars in the NE-183 plot for quality analysis. For 'Royal Gala', 'Liberty' and the four selections not distributed to the BC site, a composite 10-fruit sample from four or more available trees was collected rather than individual-tree samples. The starch index, flesh firmness, percent soluble solids (SS) and titratable acidity (TA) were measured on the harvest-time samples as described in detail by Miller et al. (10). After the 10-fruit samples were collected, damaged or undersized fruit were discarded, and the remaining fruit were pooled and stored at 1ºC ± 0.5ºC in regular air storage in stacked ventilated plastic 19-kg boxes. The room had 89-91% relative humidity and air-circulating fans. No fruit shriveling was observed.

Sensory Procedures

The cultivars were divided into three groups of ten. All yellow-skinned cultivars were evaluated together, with 'Golden Delicious' and 'Royal Gala' as comparators. Because there were fewer than 10 yellow cultivars in the NE-183 trial, unnamed yel-

low breeding selections from the Summerland program were used to complete the set (data not shown). Red or bicolored cultivars resistant to apple scab (*Venturia inaequalis* (Cooke) G. Wint.) were evaluated together against 'Golden Delicious', 'Royal Gala' and 'Liberty'. Red or bicolored scab-susceptible cultivars were evaluated together against 'Golden Delicious' and 'Royal Gala'. 'Royal Gala' was included as a standard (1) because it is a cultivar of major commercial importance in BC, that would be in direct competition with any new cultivar; and (2) to facilitate comparisons with other taste panels routinely done at Summerland as part of the apple breeding program. 'Liberty' was included as a familiar scab-resistant standard that is grown commercially in some parts of North America.

Five fruit per cultivar were drawn randomly from the pooled samples, washed, and allowed to equilibrate to 20ºC overnight before organoleptic evaluation. Fruit firmness was measured on each fruit immediately before the taste panel, and wedges from the same apples were then tasted by judges. Evaluations were conducted as described previously (6, 8). Briefly, 12 trained judges (drawn from a larger pool for each panel) assessed 10 coded samples (fruit wedges) in one session, using anchored unipolar scales. Most of the judges have been evaluating apples for more than 5 years using these same procedures. Tasting was done in individual booths under red light to help disguise skin color differences. Sample order was randomized among judges to eliminate position bias. Four texture attributes (skin toughness, flesh crispness, hardness, juiciness) and three flavor attributes (sweetness, sourness and flavor intensity) were rated on 0 (low) to 9 (high) scales (Table 1). On the scale, 0=not detectable, 1=barely detectable, 3=slight, 5=moderate, 7=intense and 9=extreme. Fractions were allowed.

Each panel was analyzed as an RCBD with judges as blocks and cultivars as treatments. This is a conservative test because any judge × cultivar interaction will inflate the error term. The results of panels were combined over three years and analyzed as described previously (8). Means and the differences between means were weighted in inverse proportion

Table 1. Definitions of sensory attributes assessed in this study.

Attribute	Definition
Skin toughness	-the relative ease of penetration of the skin with front teeth -the relative ease of the breakdown of the skin in the mouth after repeated chewing
Crispness	-when biting into the apple with the front teeth, the relative degree of build-up of pressure resulting in a "crunching" sound
Hardness	-when chewing the sample on the back molar teeth, the relative resistance to pressure
Juiciness	-when compressing the sample evenly with the molars, the relative juice release
Sweetness	-the relative degree or intensity of sweet sensation upon chewing
Sourness	-the relative degree or intensity of sour sensation upon chewing
Flavor intensity	-the relative strength of all aromatic flavor components not covered under "sweet" and "sour"

to the error mean square of each panel. The significance of the difference between means was assessed by hand calculation of the t-test statistic ($p \leq 0.05$). The dates of the taste panels were Nov. 15, 20 and 21 in 2002, Nov. 25, 26 and 28 in 2003, and Nov. 18, 19 and 22 in 2004. (Exceptions: 'Co-op 29' (Sundance™) and CQR12T50 were biennial and did not have enough fruit for panels in 2002 and/or 2004. 'Cripp's Pink' fruit froze on the tree before they were mature in 2003. To compensate, results from 2001 were included for these three cultivars. Only two years of data were available for 'Chinook' (2003, 2004) and 'Silken' (2002, 2003)). Panels were conducted in mid- to late November, the point at which 'Gala' fruit begins to soften; we felt that any new cultivar should last at least this long to be of interest for regional commercial usage.

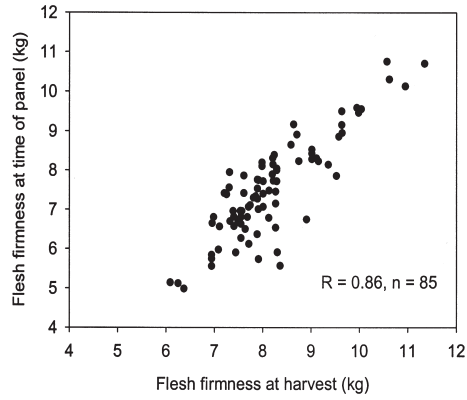
Results

Objective Measurements

Table 2 shows the range in mean values, over the three years in which taste panels were conducted, for starch index, SS, TA and flesh firmness at harvest. Most cultivars were picked within the correct target starch index range (3.5-6.5), but some exceptions occurred. NJ 90 was subject to severe preharvest drop and was picked early in order to gather sufficient fruit. 'Cripp's Pink' was difficult to mature within the growing season in Summerland. BC 8S-26-50 and 'Chinook' were harvested at a lower starch index in certain years, but were judged to be at commercial maturity based on previous experience with these selections in the Summerland breeding program.

'Delblush' had especially high SS (always above 16.5%), and 'Cripp's Pink' had particularly high TA (Table 2). All cultivars but NJ 109 exceeded 6.8 kg (15 lb) firmness at harvest, and several were exceptionally firm. 'Co-op 25' (Scarlet O'Hara™), 'Co-op 29' (Sundance™), Co-op 39 (Crimson Crisp™), CQR10T17, 'Cripp's Pink', 'Delblush', NY 65707-19 and NY 79507-72 exceeded 9.1 kg (20 lb) at harvest in at least one year. Firmness declined in an approximately linear fashion over storage, but some cultivars softened more quickly than others, as indicated by the spread on the graph (Table 2, Fig. 1). Only NJ 109 averaged below 5.4 kg (12 lb) at the time of the taste panel. A firmness of 12 lb is considered minimum for acceptable sale in some regions, such as Washington State.

Figure 1. Change in fruit flesh firmness between harvest and the time of the taste panels.



Sensory Profiles

Yellow-skinned cultivars. Taste profiles for the yellow cultivars are shown in Fig. 2. NJ 109, an early cultivar harvested about the same time as 'Royal Gala', fell significantly below either standard in scores for crispness, hardness and juiciness after 8 to 10 wk of storage. 'Silken', usually harvested a few days before 'Royal Gala', is intended for direct sales only, and should be sold within 6 to 8 weeks of harvest (12). After 9 to 11 weeks of storage, it was still perceived as crisper than 'Gala' but less hard, suggesting a limited shelf life after such long storage. Although 'Golden Delicious' was picked 20-25 days after 'Silken', and its measured flesh firmness was similar at the time of the panels (Table 2), 'Golden Delicious' was perceived

Table 2. The range (over 2002, 2003 and 2004) in mean values for fruit quality attributes of cultivars evaluated in taste panels. Cultivars used as comparative standards are in italics.

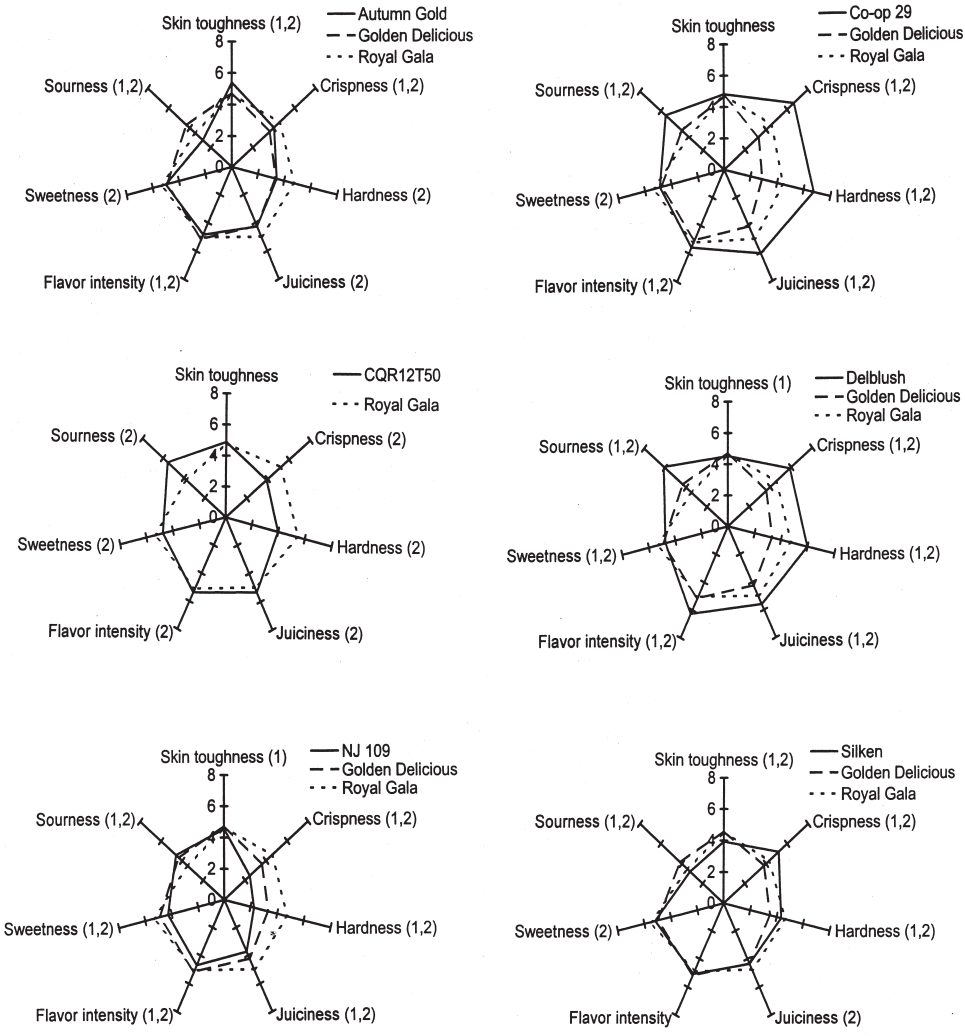
Cultivar	Starch index[z]	Soluble solids[z] (%)	Titratable acidity[z] (% malic acid)	Firmness at harvest[z] (kg)	Firmness on day of panel[y] (kg)	Firmness on day of panel[y] (kg)
Ambrosia	2.8-5.1	12.6-15.4	0.5-0.6	7.8-8.2	7.0-8.2	45-62
Autumn Gold	5.1-5.8	13.9-15.7	0.4-0.6	7.4-8.1	5.9-7.0	31-49
BC 8S-26-50	2.9-3.6	14.1-14.3	0.5	7.0-7.9	6.6-7.3	35-48
Chinook[x]	2.6-4.6	13.6-16.4	0.4-0.8	8.2-8.6	8.4-9.2	30-35
Co-op 25	4.2-7.0	15.3-15.5	0.8-1.0	8.7-10.0	8.2-9.5	32-49
Co-op 29[w]	3.6-5.8	14.9-15.2	1.1-1.3	8.2-9.6	7.7-9.5	12-45
Co-op 39	4.8-6.2	13.3-15.2	1.1-1.3	8.7-9.6	8.9-9.2	64-66
CQR10T17	6.2-6.4	13.6-15.4	0.9-1.0	10.6-11.3	10.1-10.8	41-59
CQR12T50[x]	6.0-6.1	12.8-13.6	1.3	7.7-8.4	5.6-7.1	43-83
Cripp's Pink[w]	3.2-3.8	15.2-16.7	1.6-2.0	10.0-10.6	9.6-10.3	12-32
Delblush	4.2-5.2	16.6-19.9	1.3-1.5	7.9-9.1	7.8-8.7	21-51
Gala, Royal[w]	3.9-6.0	12.4-14.7	0.5-0.8	7.8-9.0	6.5-8.5	37-83
Golden Del.	3.9-4.8	14.7-18.1	0.8-1.2	6.9-7.9	5.6-7.8	39-62
Hampshire	4.3-6.2	13.6-15.7	0.7-0.8	7.1-8.3	6.0-8.0	31-55
Jubilee Fuji	5.5-6.3	13.7-15.4	0.7-0.8	7.0-7.4	6.8-7.4	57-69
Liberty	4.1-5.2	13.1-14.5	1.2-1.4	7.4-7.5	6.6-7.0	43-59
NJ 90	3.0-3.7	13.0-15.7	0.9-1.1	7.6-8.3	5.9-6.5	45-62
NJ 109	2.9-5.1	13.1-16.0	0.9-1.1	6.1-6.4	4.9-5.1	56-76
NY 65707-19	4.2-4.7	13.9-15.3	0.8-1.0	7.5-9.4	6.3-8.1	36-52
NY 79507-49	4.2-4.3	13.5-14.2	0.6-0.7	7.9-8.1	5.7-7.5	55-80
NY 79507-72	6.1-6.2	13.2-15.0	0.7-0.8	8.9-9.5	6.7-8.2	55-73
Pinova	4.0-5.0	15.3-17.2	1.0-1.3	7.3-8.2	7.6-7.9	42-67
Runkel	4.6-5.3	14.7-16.2	0.5-0.6	7.3-7.7	7.0-8.0	37-50
Silken[x]	4.1-4.9	14.4-14.6	0.6-0.7	7.7-7.9	6.4-6.8	64-77

[z] based on a 10-fruit sample taken at harvest
[y] based on a 5-fruit sample the day of the taste panel. The same fruit were used for tasting.
[x] only 2 years of data
[w] data other than acidity include 2001 measurements

as less crisp and less hard (Fig. 2). 'Autumn Gold' was considered less sour than 'Golden Delicious', but did not appear to have any advantage in texture (Fig. 2), and its cumulative yield was significantly lower (30.7 kg per tree, compared to 48.1 kg for 'Golden Delicious' after 4 cropping years). Both 'Delblush' and 'Co-op 29' (Sundance™) were rated as crisper, harder, juicier and more flavorful than either standard. Both were also rated as more sour, in keeping with their greater TA at harvest (Table 2). CQR12T50 was severely biennial and no fruit were available for taste panels in 2002 or 2004; over 2 years it was rated softer and less crisp than 'Royal Gala' (Fig. 2). It was rated significantly harder and crisper than 'Golden Delicious' in 2001 (data not shown).

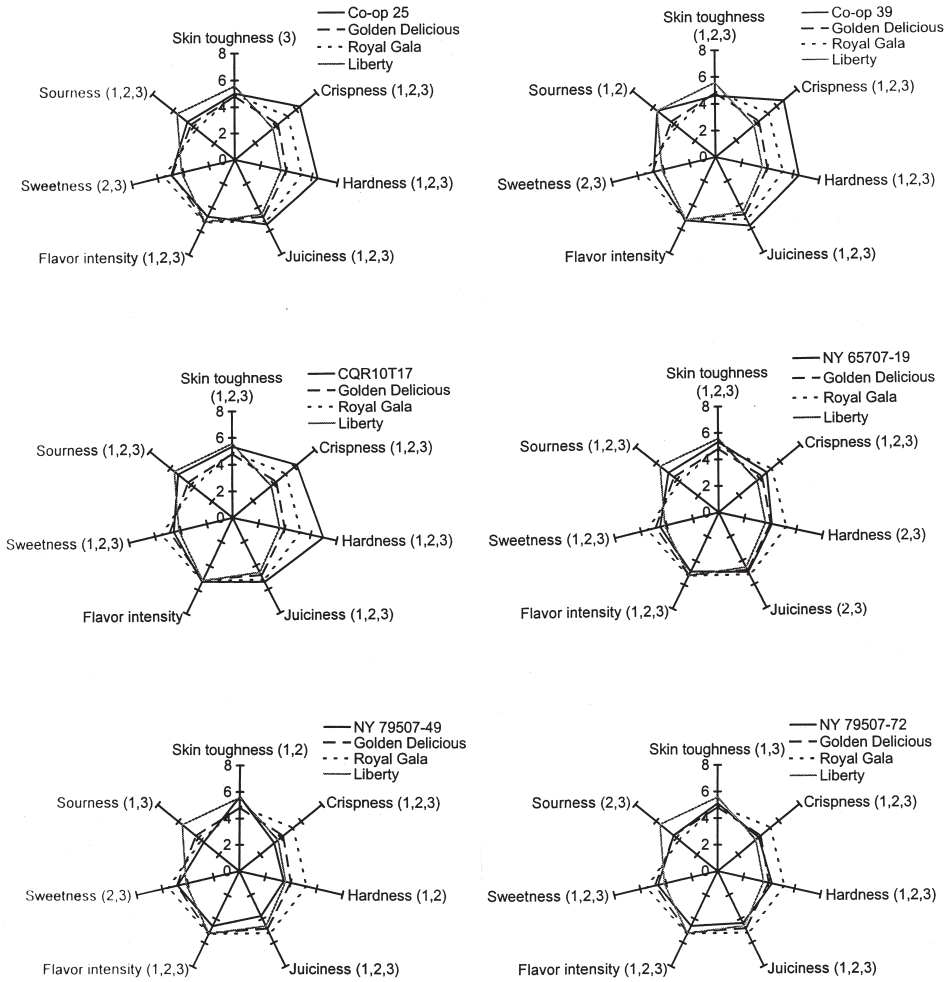
Red or bicolored scab-resistant cultivars. 'Co-op 25' (Scarlet O'Hara™), Co-op 39 (Crimson Crisp™), and CQR10T17 far ex-

Figure 2. Sensory profiles for yellow-skinned apples in the study. Numbers in parentheses after axis labels refer to significant differences ($p \leq 0.05$) by t-test: 1=the selection is significantly different from 'Golden Delicious'; 2=the selection is significantly different from 'Royal Gala'; no number=no statistical difference between the test cultivar and either standard.



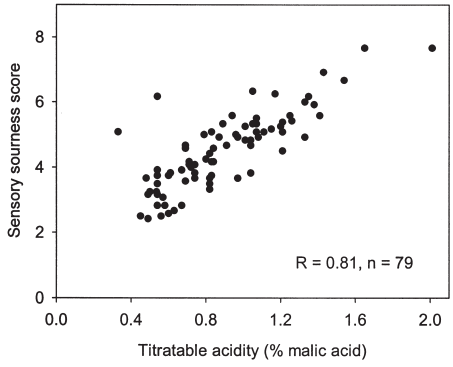
ceeded 'Liberty' in crispness, hardness and juiciness scores after cold storage (Fig. 3), and were also judged as crisper, harder, and juicier than 'Golden Delicious' or 'Royal Gala'. Only 'Co-op 25' had lower flavor intensity than any of the three standards. All three cultivars were considered sweeter than 'Liberty', and both CQR10T17 and 'Co-op 25' (Scarlet O'Hara™) were considered less sour. Generally, perceptions of sourness matched trends in TA at harvest (Table 2, Fig. 4). All three New York selections tended to be firmer at harvest than 'Liberty', and some also retained firmness well, exceeding 7.3 kg

Figure 3. Sensory profiles for red and bicolored scab-resistant apples in the study. Numbers in parentheses after axis labels refer to significant differences ($p \leq 0.05$) by t-test: 1=the selection is significantly different from 'Golden Delicious'; 2=the selection is significantly different from 'Royal Gala'; 3=the selection is significantly different from 'Liberty'; no number=no statistical difference between the test cultivar and any standard.



(16 lb) after storage in at least some years (Table 2). NY 65707-19 was judged to be crisper, harder and juicier than 'Liberty', but NY 79507-49 was softer and less juicy than 'Liberty' (Fig. 3). All three New York selections were sweeter and less sour than 'Liberty'. However, all of them rated lower than 'Royal Gala' in crispness, firmness, and juiciness; presumably they would need to compete with 'Gala' in retail outlets. Low productivity was a concern for all of the scab-resistant selections. Cumulative yields of scab-resistant apple trees ranged from 26% (for NY 65707-19) to 60% (for Co-op 29 [Sundance™]) of that for 'Golden Delicious' after 4 cropping years. CQR10T17 tends to have severe wa-

Figure 4. The relation between titratable acidity measurements at harvest and sensory sourness scores for fruit after cold storage.



tercore at harvest (D.L. McKenzie, observations recorded during quality analysis), but it seems to dissipate in storage. NY 79507-49 had a propensity for bitter pit in BC growing conditions.

Red or bicolored scab-susceptible cultivars. The scores for textural attributes of 'Runkel', NJ 90 and 'Hampshire' did not exceed those of 'Royal Gala' (Fig. 5), despite having been in storage for 3-6 fewer weeks than 'Gala' at the time of the taste panels. 'Runkel' stood out for its tough skin and low sourness scores. NJ 90 may achieve better fruit quality if picked later, but pre-harvest drop is severe for this cultivar under BC growing conditions. 'Jubilee Fuji' (September Wonder™) was rated crisper and juicier but softer than 'Royal Gala', suggesting that its texture was not as good as standard 'Fuji'. 'Pinova', 'Cripp's Pink', 'Ambrosia', BC 8S-26-50 and 'Chinook' all received higher scores for crispness and hardness than either standard. 'Cripp's Pink' was judged to be more hard than crisp, and rather low in juiciness. Trained judges in New Zealand also rated 'Cripp's Pink' (Pink Lady®) as fairly low in juiciness, but in that study the apple was judged to be crisp (2). The difference may be related to the longer growing season in New Zealand, which would likely benefit this cultivar. Among the five cultivars listed above, 'Pinova' and 'Ambrosia' scored highest for flavor intensity.

Although crispness and hardness appear to be correlated (Fig. 6), they are distinct qualities and judges can distinguish between the two. For example, 'Cripp's Pink' and CQT10T17 were considered more hard than crisp, whereas 'Silken' and BC 8S-26-50 were rated more crisp than hard (Fig. 2, 3 and 5). Instrumental measurements of firmness correlated better with sensory scores of hardness (R=0.84) than crispness (R=0.68, Fig. 6). Sweetness scores bore no relationship to percent SS at harvest (R=0.01, n=83). The ratio of SS/TA at harvest was not a very precise predictor of sweetness (R=0.44, n=79), but gave a fair prediction of sourness (R=-0.71, n=79) scores. A better test of these relationships would be to re-measure the SS and TA at the time of the taste panel. Nevertheless, sensory perceptions of sweetness and sourness are better predictors of flavor liking than analytical measurements (6), which supports the need for taste testing.

Discussion

A taste profile was developed for each cultivar in the study. The cultivars varied in their ability to maintain crispness, firmness and juiciness during air storage. The cultivars that retained texture the best in these tests were 'Delblush', 'Co-op 29' (Sundance™), CQR12T50, Co-op 25 (Scarlet O'Hara™), Co-op 39 (Crimson Crisp™), CQR10T17, 'Jubilee Fuji' (September Wonder™), 'Pinova', 'Cripp's Pink', 'Ambrosia', BC 8S-26-50 and 'Chinook'. These cultivars represent a wide range of appearance and flavor attributes that could conceivably interest different consumer segments. Some of the cultivars have production-related problems such as biennial bearing, low yield, long growing season, bitter pit, watercore, or poor tree survival that would need to be taken into consideration. Some of the cultivars that did not perform well may

Figure 5. Sensory profiles for red and bicolored scab-susceptible apples in the study. Numbers in parentheses after axis labels refer to significant differences ($p \leq 0.05$) by t-test: 1=the selection is significantly different from 'Golden Delicious'; 2=the selection is significantly different from 'Royal Gala'; no number=no statistical difference between the test cultivar and either standard.

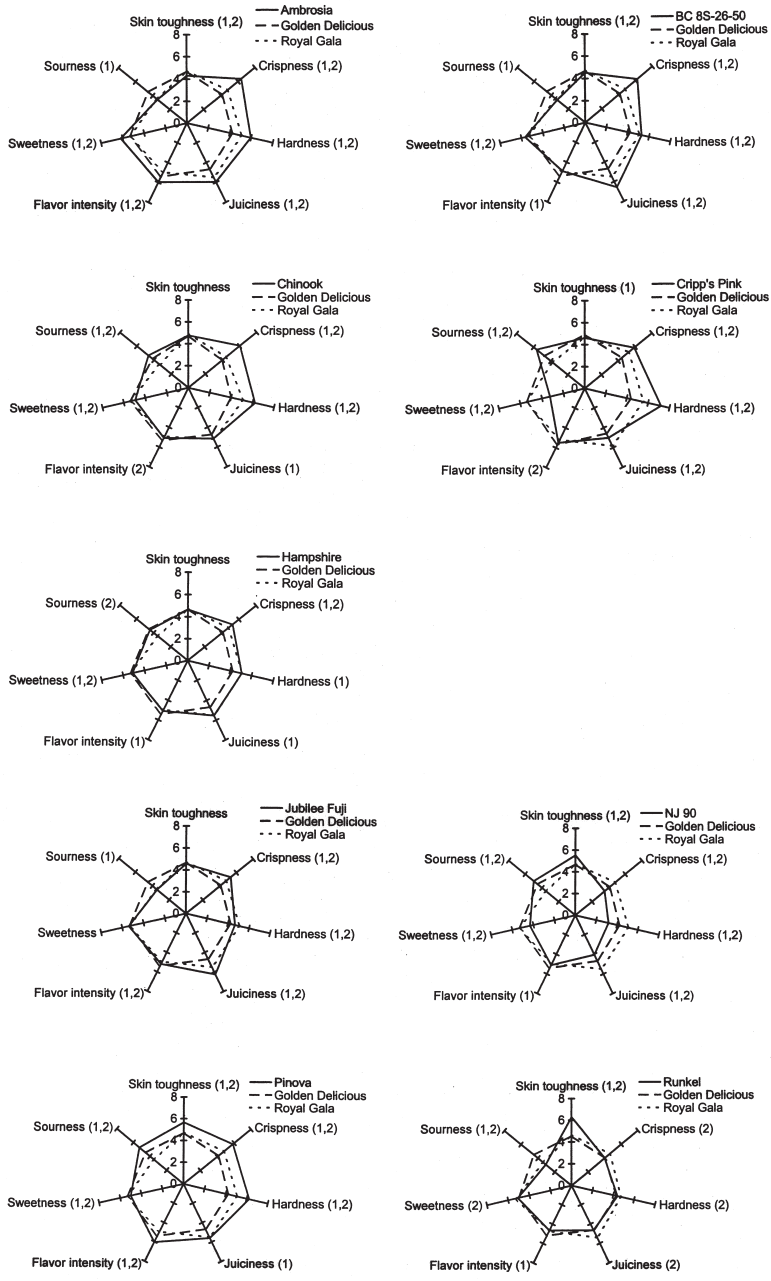
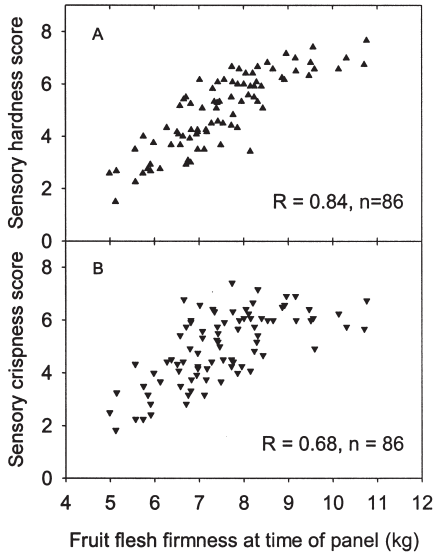


Figure 6. The relation between fruit flesh firmness at the time of the taste panel and sensory scores for flesh crispness and firmness. The Pearson correlation coefficients for the relationship are shown on the graph panels.



still be candidates for direct sales if their texture and flavor at harvest are sufficiently appealing to generate consumer demand.

The question arises as to how broadly the results from this study would apply to other production regions. Cultivar performance differs across sites and no single site produces the best fruit quality for all cultivars (9, 10). Conversely, some cultivars perform more consistently than others over a range of environments (10). Nevertheless, previous work has shown that cultivar affects firmness, TA and SS more strongly than site or site × cultivar interaction (5, 9). The results of our evaluation were quite consistent over three years at this site. While these results may not apply to all growing environments, reasonable consistency of fruit taste seems likely. In other words, BC may not grow the best possible fruit of 'Cripp's Pink', but 'Cripp's Pink' from BC is more likely to resemble 'Cripp's Pink' from another location than it is to resemble 'Jubilee Fuji' from BC.

Good eating quality is necessary but not sufficient for commercial acceptance. For example, the cultivar must still have adequate yield and fruit size, and be capable of maturing within the growing season. Attractive appearance is another attribute whose importance should not be underestimated. All these factors vary with growing conditions (3, 10).

Literature Cited

1. Blanpied, G.D. and K.J. Silsby. 1992. Predicting harvest date windows for apples. Information Bulletin 221. Cornell Cooperative Extension, Geneva, NY. 12 pp.
2. Corrigan, V.K., P.L. Hurst and G. Boulton. 1997. Sensory characteristics and consumer acceptability of 'Pink Lady' and other late-season apple cultivars. NZ J. Crop Hort. Sci. 25: 375-383.
3. Crassweller, R., R. McNew, A. Azarenko, B. Barritt, R. Belding, L. Berkett, S. Brown, J. Clemens, J. Cline, W. Cowgill, D. Ferree, E. Garcia, D. Greene, G. Greene, C. Hampson, I. Merwin, D. Miller, S. Miller, R. Moran, J. Obermiller, D. Rosenberger, C. Rom, T. Roper, J. Schupp and E. Stover. 2005. Performance of apple cultivars in the 1995 NE-183 regional project planting: I. Growth and yield characteristics. J. Amer. Pomol. Soc. 59(1): 18-27.
4. Daillant-Spinnler, B., H.J.H. McFie, P.K. Beyts and D. Hedderley. 1996. Relationships between perceived sensory properties and major preference directions of 12 varieties of apples from the Southern Hemisphere. Food Qual. Pref. 7: 113-126.
5. Hampson, C.R., R. McNew, A. Azarenko, L. Berkett, B. Barritt, R. Belding, S. Brown, J. Clements, J. Cline, W. Cowgill, R. Crassweller, E. Garcia, D. Greene, G. Greene, I. Merwin, D. Miller, S. Miller, R. Moran, J.D. Obermiller, C. Rom, T. Roper, J. Schupp and E. Stover. 2004. Performance of 'Braeburn', 'Golden Delicious' and 'Yataka Fuji' apple on Mark and M.9 rootstocks at multiple locations across North America. J. Amer. Pomol. Soc. 58(2): 78-89.
6. Hampson, C.R., H.A. Quamme, J.W. Hall, R.A. MacDonald, M.C. King and M.A. Cliff. 2000. Sensory evaluation as a selection tool in apple breeding. Euphytica 111: 79-90.
7. Harker, R. 2002. Improve fruit quality to increase demand. Good Fruit Grower 53(3): 27.

8. Miller, S., C. Hampson, R. McNew, L. Berkett, S. Brown, J. Clements, R. Crassweller, E. Garcia, D. Greene and G. Greene. 2005a. Performance of apple cultivars in the 1995 NE-183 regional project planting: III. Fruit sensory characteristics. J. Amer. Pomol. Soc. 59(1): 28-43.
9. Miller, S.S., R.W. McNew, B.H. Barritt, L. Berkett, S.K. Brown, J.A. Cline, J.M. Clements, W.P. Cowgill, R.M. Crassweller, M.E. Garcia, D.W. Greene, G.M. Greene, C.R. Hampson, I. Merwin, D.D. Miller, R.E. Moran, C.R. Rom, T.R. Roper, J.R. Schupp and E. Stover. 2005b. Effect of cultivar and site on fruit quality as demonstrated by the NE-183 regional project on apple cultivars. HortTechnology, in press.
10. Miller, S., R. McNew, R. Belding, L. Berkett, S. Brown, J. Clements, J. Cline, W. Cowgill, R. Crassweller, E. Garcia, D. Greene, G. Greene, C. Hampson, I. Merwin, R. Moran, T. Roper, J. Schupp and E. Stover. 2004. Performance of apple cultivars in the 1995 NE-183 regional project planting. II. Fruit quality characteristics. J. Amer. Pomol. Soc. 58(2): 65-77.
11. Moxham, H. 2003. Consumer research 2003. Tree Fruit and Pome Fruit Aust. Aug., p.12.
12. Quamme, H.A., R.A. MacDonald, W.D. Lane and C.R. Hampson. 1999. Silken apple. Can. J. Plant Sci. 79: 295-297.
13. Stebbins, R.L., A.A. Duncan O.C. Compton, and D. Duncan. 1991. Taste ratings of new apple cultivars. Fruit. Var. J. 45: 37-44.

❖ ❖ ❖ ❖ ❖