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Quality Characteristics of Five Disease-Resistant Apple Cultivars

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Abstract

The integration of disease-resistant cultivars (DRCs) into commercial apple production offers a realistic approach for reducing pesticide use in fruit production. Appearance and flavor are key attributes determining whether consumers will accept new cultivars. Five DRCs, 'NY74828-12', 'NY75414-1', 'NY65707-19', 'Liberty', and 'McShay', were tested at harvest over two seasons (1994,1995). In 1994, chemical and physical characteristics of five cultivars were significantly ($P \leq 0.05$) different except glucose, total sugar content, and Hunter L and b values. Sensory scores were significantly different in firmness, sweetness and tartness. Cultivar '707' was more preferred in appearance but no significant ($P \leq 0.05$) difference was found in flavor and overall acceptance. In 1995, cultivar '414' had lower titratable acidity, Hunter L, a, b values, hue angle and chroma. Cultivar '707' had significantly higher peak force both peeled and unpeeled. Sensory scores were significantly different in firmness. Cultivar '414' had higher preference scores in both flavor and overall acceptance while appearance was equally preferred for all five cultivars. Correlations indicated that apple flavor was highly correlated with percent soluble solids content in 1994 ($r = 0.882$), and total sugar content in 1995 ($r = 0.904$). Flavor was also highly correlated with overall acceptance in both 1994 ($r = 0.895$) and 1995 ($r = 0.991$).

Introduction

The United States is among the leading apple producing countries in the world, producing about 15% of the world annual production (32). Apples receive the highest amount of agricultural chemicals on a per-unit basis of any major food crop grown in the United States (20). The integration of DRCs into commercial apple production offers a realistic approach for reducing pesticide use in fruit production (9).

Newly introduced apple cultivars with resistance to apple scab, as well as some other diseases, provide growers an opportunity to reduce disease control costs, lessen the risk of environmental contamination, and meet consumer demands. Despite these obvious advantages, growers have been reluctant to plant DRCs because of the uncertainty of consumer acceptance (34). Attributes related to apple quality and acceptability include chemical, physical and sensory characteristics. Among them, apple appearance and flavor are key attributes determining consumer acceptance of a new cultivar (29). In addition, enzymatic browning of raw fruits and vegetables is important to food preservation and processing and is generally considered to be an undesirable reaction because of the unpleasant appearance and concomitant development of off-flavors. The ob-

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jective of this study was to compare the fruit quality and sensory characteristics of four potential DRC selections with 'Liberty', a high-quality DRC that has been widely planted in recent years.

Materials and Methods

Apples: Five apple DRCs ('NY74828-12', 'NY75414-1', 'NY65707-19', 'Liberty' and 'McShay') were grown at the University of Maine's Highmoor Farm, Monmouth, ME, as described previously (27). Apples were harvested in Fall 1994 and 1995. 'Liberty' (15), 'McShay' (19), 'NY74828-12' ('828') and 'NY75414-1' ('414') were 'McIntosh' types, while 'NY65707-19' ('707') was more similar to 'Delicious'. They were planted in a randomized complete block design.

In 1994, apples were tested shortly after harvest, and chemical, physical and sensory attributes were determined. In 1995, apples were tested shortly after harvest and in addition to the above attributes, degree of enzymatic browning and phenolic content were also examined. Twelve fruits per selection, (three/tree from each of four replicates) were harvested periodically as the predicted date for each selection neared. The starch degradation pattern (SDP) of equatorial slices of each selection was evaluated by comparison with generic starch-iodine chart developed for apples (5). Fruits were harvested when the mean SDP reached a value of five. Fruit from the earlier maturing selections were stored at 1° C until all selections had been harvested.

Analytical determinations: Nine apples of each cultivar were weighed and hand diced, and the pH value of nine randomly chosen segments for each cultivar was measured directly using a Beckman pH Meter Model Φ32 equipped with a combination surface electrode (Fullerton, CA). The above sample was then extracted in an Acme Supreme Juicerator Model 6001 (Lemoyne, PA). Percent soluble solids content was measured on a Fisher Tabletop Refractometer (Pittsburgh, PA) using AOAC method 932.12 (2).

Titratable acidity was calculated using the AOAC glass electrode method 942.15 (2).

Sugars (sucrose, fructose and glucose) were determined by HPLC (33).

Sugar: acid ratio was calculated as [(sucrose + fructose + glucose)/titratable acidity].

Physical analyses: Color was measured on nine apples of each cultivar, with three replicate readings per apple, using a Hunterlab LabScan II Spectrocolorimeter (Reston, VA) with 10 degree D65 (daylight) illuminant and a 1 3/4" aperture. Chroma was calculated as $(a^2 + b^2)^{1/2}$, and hue angle was calculated as arctan (b/a).

Texture of each cultivar was evaluated on an Instron Model 1000 (Canton, MA) using the Magness Taylor Puncture test with the probe diameter of 7/16" and weigh beam of 50 kg. Each apple was first run in duplicate in the unpeeled condition, then was run in duplicate in the peeled condition on another side of the apple.

Sensory evaluations: A consumer panel of 54 people was offered apples of five cultivars. Apples were washed, wiped dry, cored, cross cut, then cut into pieces and presented in coded 2 oz. plastic cups in a randomized complete block design. Firmness, sweetness and tartness were evaluated using attribute 'just right' scaling. Scale values progressed from a score of 1 (not enough attribute), to 3 (just right), through 5 (too much attribute) (23). Apple appearance, flavor and overall acceptance were evaluated using a 7 point hedonic scale where 1=dislike very much, 2=dislike moderately, 3=dislike slightly, 4=Neither like nor dislike, 5=like slightly, 6=like moderately, 7=like very much (3).

Enzymatic browning analyses:Degree of browning was measured by the method described by Burda (6) using a Hunterlab LabScan II colorimeter with 10-degree D65 illuminant and a 1" aperture.

Determination of total phenolics: Phenolics in apples were extracted using a modification of the procedure of Mapson (17), as described by Coseteng and Lee (8).

Total phenolics were determined by the procedure described by Weurman and Swain (31). The optical density of the prepared solution at 640 nm was measured

after 1 hr using a Beckman DU® Series 60 Spectrophotometer (Fullerton, CA). The amount of total phenolics was calculated from a standard curve of chlorogenic acid prepared at the same time (8).

Determination of individual extractable phenolics: Extraction, fractionation and HPLC analysis of phenolics were done following a modification of the procedure of Jaworski and Lee (14), as described by Coseteng and Lee (8).

Individual phenolic compounds were analyzed using a high performance liquid chromatography system. The system consisted of a HP Series-1050 Pump, a VICI Injector, a Hitachi L-205 Dual Wavelength Detector (San Jose, CA), and a HP3396A Integrator. Separation of phenolics was carried out on a Phenomenex Spherex 5 C_{18} column (Size: 250 x 4.6 mm, 5 micron. Series No.: 60760) (Torrance, CA) at room temperature and detected at 280 nm and 320 nm for neutral fraction and acidic fraction phenolics, respectively. The phenolics were eluted using a linear solvent gradient of 0-100% solvent (40% acetonitrile in water) for 70 min at a flow rate of 1 ml/min.

The phenolic compounds were identified by running co-chromatograms with a standard containing chlorogenic acid for the acidic fraction, and another standard containing (+)-catechin, (-)-epicatechin, catechol, and phloridzin (Sigma Chemical Co., St. Louis, MO) for the neutral fraction.

Statistical analyses: Data from chemical and physical analyses, sensory evaluation and enzymatic browning assay were analyzed by the analysis of variance method (ANOVA) using the SAS package (25). Those from the 'just right' scale in sensory evaluation were first calculated to the percentage of subjects who responded in each category of the attribute, then analyzed using χ^2-test to compare the distribution of responses for each cultivar (7, 18). Demographic data were analyzed by the Wilcoxon test using the SAS package (25). Correlation analyses between chemical, physical and sensory attributes were conducted using the Pearson's test with SYSTAT package (30).

Results and Discussion

Chemical attributes of five DRC's over two seasons:

There were seasonal differences in pH, titratable acidity, soluble solids content, and the concentrations of sucrose, fructose and glucose (Table 1). These differences can be explained as seasonal variations in crop load, fruit maturity or environmental conditions (1, 4).

Total sugar: Although the five cultivars varied in sugar content, there was no significant difference in total sugar content overall.

Sugar: acid ratio: Sugar: acid ratio was higher in 1995 than in 1994. Titratable acidity varied among cultivars, which resulted in varied sugar: acid ratio among cultivars.

Fourie (10) and Ackermann (1) have both reported that fructose was the major sugar present in all apple cultivars they studied. Results from current research indicated that sucrose and fructose were the major sugars present in these cultivars for both harvest seasons. Work et al. (34) reported that 'Liberty' had 50% and 20% higher fructose content than sucrose in 1989 and 1990 season, respectively. The results from current research indicated that 'Liberty' had 10% and 30% higher fructose content than the sucrose in 1994 and the 1995 season, respectively.

Fourie (10) also reported that the contribution of total sugars to total soluble solids (% Brix) varied between 58.0% and 72.0%. This may explain why total sugars were not significantly different among the five cultivars but their percent soluble solids content was different.

Physical attributes of five DRCs over two seasons:

Hunter L: Hunter L values had different patterns but similar ranges in the two seasons (Table 2). In 1994, Hunter L values ranged from 27.35 to 31.45 and were not significantly different from each other, which means that cultivars were similar in lightness. In 1995, Hunter L values varied among the five cultivars, ranging from 29.40 to 35.32. Plotto (24) reported that

ground color L variation was small over the maturity range studied on three apple cultivars. This could explain the similar ranges for Hunter L values over the two seasons. An additional explanation may be that perhaps ground color was used as a maturity criterion for determining when to harvest.

Hunter a: Hunter a values had similar patterns in both years with variety 414 having the lowest value. Saure (26) reported that the red color varied with environmental factors. Lau (16) also reported that the degree of red color development of 'Jonagold' apples varied greatly with year. In his research, surface area intensity of well-exposed fruits harvested in October were about 50% red in 1984 and 1986, compared to 80% red in 1985.

Hunter b: Hunter b values of five DRCs were all positive in both seasons, which means that they all had yellow character. The values, similar to those of Hunter L, were different between two seasons. The patterns for Hunter b values were exactly the same as for Hunter L values in both years. In 1994, Hunter b values ranged from 6.65 to 8.48 and were not significantly different from each other. In 1995, Hunter b values varied among five cultivars and ranged from 6.00 to 10.41. Cultivar '707' had the highest b value, which means it was more yellow; while '414' had the lowest b value, which means it was less yellow. This pattern was exactly the same as that of Hunter L ($r = 0.998$), which is not difficult to understand: if we change the yellowness of the sample while keeping the redness constant, the lightness (Hunter L) of the sample will be proportional to the yellowness (Hunter b). Lau (16) reported that yellow ground color increased with 'Jonagold' apple maturation and ripening in 1985 and 1986. Thus, the difference in the picking date would cause a difference in Hunter b values. Late picking would result in more yellow ground color and higher positive Hunter b values.

Chroma: Chroma patterns were similar among the five cultivars in both seasons. Again, '414' showed the lowest values in both years. Lower a and b values could explain this difference. Chroma was determined by Hunter a and b, thus any factors discussed previously which affect red and yellow color development would affect chroma.

Hue angle: Hue angle patterns were different among the five cultivars between the two years. Plotto (24) reported that for different apple cultivars, the change of ground color hue angle was different. This was due to the cultivar variation. Again, hue angle is determined by Hunter a and b, so factors affecting Hunter a and b would also affect hue angle.

Texture: As expected, all five cultivars had higher peak force when in the unpeeled condition than in the peeled condition. In 1994, 'Liberty' and '707' had higher peak force and '828' and 'McShay' had lower peak force when unpeeled than when peeled. The only change in this pattern was that '414' was no longer significantly ($P \geq 0.05$) different from '707' in peak force when peeled. In 1995, cultivar '707' had the highest peak force, followed by 'Liberty', 'McShay', '414' and '828' when unpeeled and peeled. The Pearson's test indicated that peak force for the five DRCs when unpeeled was highly correlated to peak force when peeled in both 1994 ($r = 0.975$) and 1995 ($r = 0.942$). The patterns of peak force were also similar between the two years: In 1994, 'Liberty' and '707' had higher peak force, '828' and 'McShay' had lower peak force; while in 1995, '707' still had higher peak force, and '828' and 'McShay' again had lower peak force. The range of the peak force was similar between two years. In 1994, it ranged from 0.83 kg to 1.51 kg when unpeeled and from 0.53 kg to 1.29 kg when peeled; in 1995, it ranged from 0.75 kg to 1.55 kg when unpeeled and from 0.51 kg to 1.19 kg when peeled. However, the peak force varied greatly for some cultivars between the two years. This might be due to seasonal variation and harvest date. Ingle and D'Souza (12) also reported in their research that firmness of the five 'Red Delicious' strains immediately after harvest had rather large differences between 1983 and 1984. They explained this by the fact that the higher

temperature in 1984 possibly accelerated softening on the tree. Greene and Autio (11) also reported that five 'Gala' apple strains differed in flesh firmness but the differences were not consistent in the two years evaluated.

Sensory attributes:

Appearance: In 1994, appearance scores were significantly different among the five DRCs, ranging from 4.15 to 5.98 (Table 3). Color is an important factor affecting appearance. The results from this study showed that only '707' was rated better than 'Liberty'. Factors other than color, such as shine and shape will also affect appearance. In 1995, there were no significant differences.

Flavor: In 1994, sensory scores for flavor were not significantly different among five DRCs and ranged from 4.55 to 5.13, which means that they were rated around "like slightly". In 1995, flavor scores ranged from 4.35 to 5.74. Work et al. (34) reported that 'Liberty' received the highest preference scores but was not significantly different from 'McIntosh'. The result of this study showed that the four new DRCs were equal or more preferred for flavor to 'Liberty', except '828' which was less preferred in 1995.

Overall acceptance: In 1994, sensory scores for overall acceptance were not significantly different from each other and ranged from 4.48 to 5.14, which means that they were all rated around "like slightly". In 1995, overall acceptance scores ranged from 4.22 to 5.72. Durner (9) reported 'Liberty' was rated between "good" and "very good" and was more preferred than 'Red Delicious' for overall quality. The results from this study indicated that the four newer DRCs were equal or more preferred to 'Liberty' for overall acceptance except that in 1995, '828' was less preferred.

Firmness: Chi-square tests indicated percentage response distribution for firmness was significantly different among five cultivars in both seasons (Figure 1). The only seasonal change noted here was that in 1995, more panelists considered both 'Liberty' and 'McShay' just right for firmness while less considered them too firm and too soft, respectively. Durner (9) reported that the texture of 'Liberty' was harder than optimum, but still acceptable. This agrees with the results from this study. Work, et al. (34) reported 'Liberty' was significantly preferred for texture in both 1989 and 1990. The results from this study indicated that '414' was consistently more preferred than 'Liberty' in 1994.

Sweetness: Chi-square tests indicated that percentage response distribution for sweetness was significantly ($P \leq 0.05$) different among five cultivars in 1994, but not in 1995 (Figure 2). The distribution patterns were different between two years. In 1994, 'McShay' was considered just right for sweetness by more than 60% of panelists, followed by '828' and '707', which were both considered just right for sweetness by about half of the panelists. 'Liberty' received the least "just right" scores for sweetness and was considered not sweet enough by most of the panelists. In 1995, all five cultivars had similar distribution patterns: a higher percentage of panelists scored 3 ("just right") for each cultivar; second highest percentage of panelists scored 2 and 4; while lowest percentage of panelists scored 1 and 5. This resulted in similar bell-type distribution for each cultivar. One thing was also common in both seasons: besides those voted for "just right", most of the remaining panelists considered all five cultivars were not sweet enough. 'Liberty' was considered not sweet enough in both years, this agrees with the results reported by Durner (8).

Tartness: Chi-square test indicated that percentage response distribution for tartness was significantly ($P \leq 0.05$) different among five cultivars in 1994, but not different in 1995 (Figure 3). The distribution patterns were relatively similar between the two years. In 1994, '707' and '828' received more "just right" scores for tartness than the other three cultivars, the difference was that the former was considered too tart, the latter was considered not tart enough by most of the remaining panelists. 'Liberty' received the least "just right"

Table 1. Chemical characteristics of five disease resistant apple cultivars[X,Y] 1994 and 1995 harvest seasons

Chemical Characteristics	NY74828-12	NY75414-1	NY65707-19	Liberty	McShay
1994					
pH	3.12 [ab]	2.99 [bc]	3.19 [a]	2.91 [c]	3.19 [a]
Soluble solids (%)	13.63 [a]	13.57 [a]	13.73 [a]	13.20 [b]	13.73 [a]
Titratable acidity (as % malic acid)	0.51 [bc]	0.61 [ab]	0.53 [bc]	0.66 [a]	0.46 [c]
Sucrose (mg/g)	31.37 [b]	28.03 [b]	39.17 [a]	30.16 [b]	31.56 [b]
Fructose (mg/g)	26.44 [b]	29.50 [ab]	29.16 [ab]	33.31 [a]	26.26 [b]
Glucose (mg/g)	10.59 [a]	11.01 [a]	12.09 [a]	11.30 [a]	13.63 [a]
Total sugar (mg/g)	68.40 [a]	68.53 [a]	80.42 [a]	74.77 [a]	71.46 [a]
Sugar:acid	13.60 [a]	11.27 [b]	15.18 [a]	11.33 [b]	15.66 [a]
1995					
pH	3.39 [a]	3.25 [bc]	3.30 [ab]	3.17 [c]	3.34 [ab]
Soluble solids (%)	14.10 [c]	14.87 [b]	15.40 [ab]	15.50 [a]	14.27 [c]
Titratable acidity (as % malic acid)	0.54 [a]	0.51 [b]	0.51 [b]	0.57 [a]	0.55 [a]
Sucrose (mg/g)	28.45 [d]	34.59 [bc]	42.93 [a]	30.88 [cd]	36.30 [b]
Fructose (mg/g)	35.97 [b]	40.88 [a]	36.30 [b]	40.30 [a]	36.32 [b]
Glucose (mg/g)	13.64 [ab]	16.30 [a]	9.53 [b]	16.21 [a]	17.46 [a]
Total sugar (mg/g)	78.06 [a]	91.77 [a]	88.75 [a]	87.39 [a]	90.09 [a]
Sugar:acid	14.38 [d]	17.87 [a]	17.28 [ab]	15.44 [cd]	16.28 [bc]

[X]Data are means of 9 replications.
[Y]Means in same row followed by different letters are significantly different ($P \leq 0.05$).

scores for tartness and was considered too tart by most of the panelists. In 1995, '414' and '707' received the most "just right" scores for tartness, while 'Liberty' received the least and again was considered too tart. All five cultivars had similar bell-type distribution for percentage responses, which resulted in no significant difference.

Enzymatic browning and phenolic content:

Enzymatic browning: 'Liberty' and '707' had a significantly higher degree of browning than the three other cultivars (Table 4). Burda et al. (6) used the same method to measure degree of browning. They reported Hunter L value differences for three apple cultivars at harvest ranging from 2.5 to 5.0 with 'Golden Delicious' having a value of 2.5. The results from this study showed Hunter L value differences ranging from 4.8 to 12.1, which were higher than the results reported by Burda et al. (6). This might be characteristic of these disease-resistant cultivars.

Phenolic content: Total phenolic content ranged from 1044 μg/g to 2478 μg/g with '828' being significantly lower (less than half that of the other four cultivars). Coseteng and Lee (8) reported in their research that 'McIntosh' apples had total phenolics of about 2000 μg/g at harvest. The results from this study were slightly higher but in the same magnitude.

Many researchers have reported that chlorogenic acid was the major phenolic compound in apples (21, 28, 35). The results from this study agree that chlorogenic acid had the highest concentration among

Table 2. Physical characteristics of five disease resistant apple cultivars[W,X,Y] 1994 and 1995 harvest seasons

Physical Characteristics	NY74828-12	NY75414-1	NY65707-19	Liberty	McShay
1994					
Hunter L	27.35 [a]	31.35 [a]	30.25 [a]	30.01 [a]	28.82 [a]
Hunter a	24.25 [a]	17.12 [b]	22.00 [a]	21.24 [a]	21.89 [a]
Hunter b	6.65 [a]	7.49 [a]	8.48 [a]	7.34 [a]	7.03 [a]
Chroma	25.14 [a]	18.7 [b]	23.62 [a]	22.49 [ab]	22.99 [a]
Hue angle	15.32 [c]	23.50 [a]	21.30 [ab]	19.04 [abc]	17.83 [bc]
Peak force N (unpeeled) [Z]	8.3 [d]	12.9 [b]	14.3 [a]	15.1 [a]	9.10 [d]
Peak force N (peeled)	6.0 [c]	11.3 [c]	11.4 [c]	12.9 [b]	5.30 [c]
1995					
Hunter L	32.06 [b]	29.40 [c]	35.32 [a]	32.38 [b]	32.02 [b]
Hunter a	22.45 [a]	16.56 [b]	22.20 [a]	22.30 [a]	19.04 [b]
Hunter b	8.19 [b]	6.00 [c]	10.41 [a]	8.21 [b]	7.89 [b]
Chroma	23.92 [a]	17.63 [c]	24.55 [a]	23.76 [b]	20.61 [bc]
Hue angle	20.14 [b]	19.82 [b]	25.25 [a]	20.21 [b]	22.45 [ab]
Peak force (unpeeled N) [Z]	7.50 [c]	8.40 [d]	15.5 [a]	12.3 [b]	10.2 [c]
Peak force (peeled N)	5.10 [g]	6.40 [f]	11.9 [b]	10.5 [c]	5.9 [fg]

[W]Color data are means of 9 apples analyzed in triplicate.
[X]Texture data are means of 9 apples analyzed in duplicate.
[Y]Means in same row followed by a different letter are significantly different ($P \leq 0.05$).
[Z]Peeled peak force data pooled; unpeeled peak force data pooled.

the individual phenolic compounds examined in this study. The range was from 35.2 μg/g to 211.8 μg/g.

Burda et al., (6) reported that epicatechin was present in a higher concentration than chlorogenic acid. Epicatechin concentrations were lower than chlorogenic acid in the samples analyzed in this study. Epicatechin concentrations ranged from 4.2 μg/g to 64.3 μg/g. The results from this study do not agree with previous research.

Catechin concentrations were lower than epicatechin. The range was from 3.0 μg/g to 47.2 μg/g. Coseteng and Lee (8) reported a range of 5.2 μg/g to 18.4 μg/g for seven apple cultivars with 'McIntosh' and 'Golden Delicious' having 8.0 μg/g and 5.2 μg/g, respectively. The current study showed higher concentrations. This may be a characteristic of disease-resistant apple cultivars.

Catechol concentrations were the lowest among the individual phenolic compounds examined. In fact, its range was much lower than previously reported. Coseteng and Lee (8) reported the range of catechol concentrations for seven apple cultivars were between 2.8 μg/g and 14.0 μg/g, with 'McIntosh' and 'Golden Delicious' having 5.6 μg/g and 2.8 μg/g, respectively. The current study showed that catechol concentrations ranged between 0.05 μg/g and 0.5 μg/g, with '828' having the lowest, followed by 'McShay'. The cultivars in the current study all have *Malus floribunda* parentage, while most apples do not. Perhaps low catechol is an inherited trait.

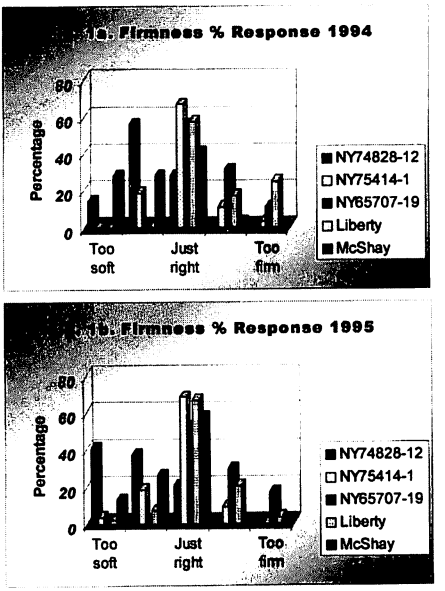

Figure 1. 1994, 1995Firmness Scores of Five Disease Resistant Cultivars by Percent Response.

Phloridzin range was between 6.3 μg/g and 13.3 μg/g. Cultivar '828' had the lowest phloridzin concentration, but was not significantly different from '414' and '707', while 'Liberty' had the highest concentration. Coseteng and Lee (8) reported a range between 4.4 μg/g and 18.8 μg/g for phloridzin for seven apple cultivars with 'McIntosh' and 'Golden Delicious' having 4.4 μg/g and 9.6 μg/g, respectively. The results from this study are in agreement with those reported in the literature.

The Pearson's test indicated that total phenolics content was highly correlated with chlorogenic acid content (r = 0.889), catechol content (r = 0.953), and epicatechin content (r = 0.916); chlorogenic acid content was also highly correlated with catechol content (r = 0.983). This means that the proportion of these phenolic compounds to total phenolic content is maintained among these five cultivars.

Relation between degree of browning and phenolic content:

No high correlation was found between each individual phenolic compound tested and browning implying that the contribution of phenolic compounds to degree of browning could be a combined reaction. If one considers the varied susceptibility of different phenolic compounds to polyphenol oxidase (PPO), the enzymatic browning is seen as a much more complex reaction.

Phenolic compounds are a complex group and individual phenolic compounds have been shown to vary in their browning rate (21). Varied browning rate must be examined to more clearly understand the relation between degree of browning and phenolic content.

Table 3. Sensory characteristics rating for five disease resistant apple cultivars[W,X,Y] 1994 and 1995 harvest seasons

1994	NY74828-12	NY75414-1	NY65707-19	Liberty	McShay
Appearance	4.7 ^{c}	4.2 ^{d}	6.0 ^{a}	5.2 ^{b}	5.5 ^{ab}
Flavor	5.1 ^{a}	5.0 ^{a}	5.0 ^{a}	4.5 ^{a}	5.0 ^{a}
Overall	5.0 ^{a}	5.1 ^{a}	5.0 ^{a}	4.5 ^{a}	4.8 ^{a}
1995					
Appearance	5.4 ^{a}	4.9 ^{a}	5.5 ^{a}	5.3 ^{a}	5.1 ^{a}
Flavor	4.4 ^{c}	5.7 ^{a}	5.1 ^{b}	5.2 ^{b}	5.1 ^{b}
Overall	4.2 ^{c}	5.7 ^{a}	5.2 ^{b}	5.2 ^{b}	5.0 ^{b}

[W]Rating scale = 1-dislike very much, 2-dislike moderately, 3-dislike slightly, 4-Neither like nor dislike, 5-like slightly, 6-like moderately, 7-like very much.
[X]Data are means from 64 panelists in 1994, 54 in 1995.
[Y]Means in same row followed by different letters are significantly different (P≤0.05).

Apple PPO has a different specificity for different phenolic compounds. Chlorogenic acid, epicatechin and catechin were considered as good substrates for PPO activities (22). Janovitz-Klapp et al. (13) showed that apple PPO was at least twice as active with chlorogenic acid than with epicatechin or catechin, and they indicated that chlorogenic acid was the best natural substrate of apple PPO among the hydroxycinnamic compounds. The results of this study showed that although 'McShay' was not different from '707' and 'Liberty' in total phenolic content, its chlorogenic acid concentration was significantly ($P \leq 0.05$) lower compared with the other two cultivars. This might explain why it had a significantly ($P \leq 0.05$) lower degree of browning. Cultivar '828' was significantly ($P \leq 0.05$) lower in chlorogenic acid concentration, which could have contributed to its lower degree of browning. However, cultivar '414' was not significantly different from '707' and 'Liberty' in both total phenolic and chlorogenic acid content, yet it still had a lower degree of browning. So other individual phenolic compounds need to be examined. Another possible explanation is differences in PPO activity; cultivar '414' could have lower PPO activity compared with 'Liberty' and '707', which resulted in a lower degree of browning. Additional research is needed to confirm PPO activity and degree of browning.

Catechin was considered the major contributor to browning, because its oxidative product showed higher intensity of color

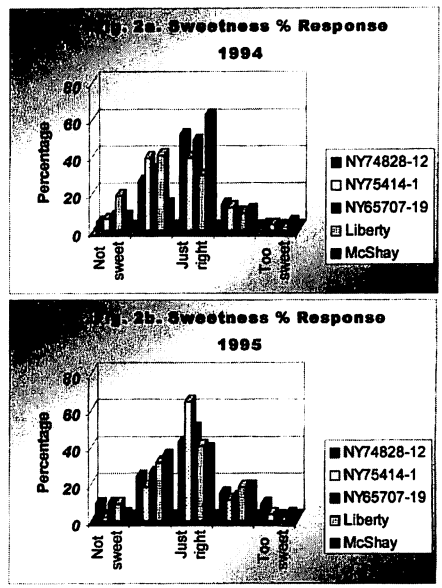

Figure 2. 1994, 1995 Sweetness Scores of Five Disease Resistant Cultivars by Percent Response.

than that of chlorogenic acid (22). The results from this study showed that although there was no difference in total phenolic and chlorogenic acid content among 'Liberty', '707', and '414', cultivar '414' had significantly ($P \leq 0.05$) lower catechin content compared to '707' and relatively lower catechin content compared to 'Liberty'. This might explain why it had a

Table 4. Enzymatic browning and phenolic acid content of five DRCs (1995)[X,Y,Z]

	NY74828-12	NY75414-1	NY65707-19	Liberty	McShay
Total phenolics (μg/g)	1044[b]	2478[a]	2278[a]	2539a	2428[a]
Chlorogenic acid (μg/g)	35.15[c]	211.8[a]	173.9[a]	214.0a	121.7b
Catechol (μg/g)	0.051[c]	0.46[a]	0.40[ab]	0.50a	0.33[b]
Catechin (μg/g)	3.02[d]	19.36[bc]	47.18[a]	27.72b	13.63[c]
Epicatechin (μg/g)	4.19[c]	60.28[a]	54.96[ab]	43.04b	64.29[a]
Phloridzin (μg/g)	6.26[c]	6.55[c]	7.57[bc]	13.27a	10.34[ab]
Delta L surface browning	4.82[c]	8.12[b]	10.41[a]	12.07a	6.32[bc]

[X]Phenolic data are means of 3 replications subsampled in triplicate.
[Y]Means in same row followed by different letters are significantly different ($P \leq 0.05$).
[Z]Browning data are means of 3 replications.

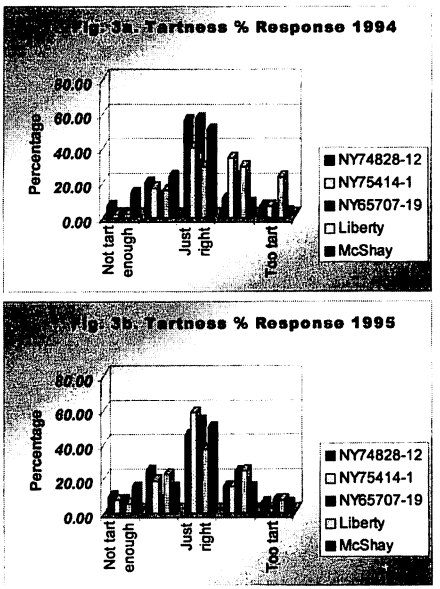

Figure 3. 1994, 1995 Tartness Scores of Five Disease Resistant Cultivars by Percent Response.

lower degree of browning compared with the other two. The significantly ($P \leq 0.05$) lower catechin content of '828' and 'McShay' could support this explanation. Epicatechin had no clear relationship with degree of browning in this case, because '414' and 'McShay' both had higher epicatechin content, but a lower degree of browning. Catechol and phloridzin were not mentioned as good substrates of apple PPO in previous research. The results from this study showed that the catechol content among the five cultivars was similar in pattern to that of chlorogenic acid ($r = 0.983$). The pattern for phloridzin content was dramatically different and its relationship to browning was difficult to interpret without PPO activity data.

The browning reaction in apples appears to be a complex process involving several factors. Substrate levels, enzyme activity, presence of ascorbic acid and other inhibitors or promoters that influence the browning reaction. PPO activity and its substrate concentrations appeared to be the two major factors involved. The extent to which each will contribute to the browning reaction is cultivar dependent. The emphasis of the current study was on substrate concentrations. However, without knowing the PPO activity results, it is difficult to fully understand the relationship between phenolic content and degree of browning, as in the case of epicatechin and phloridzin.

Correlations between chemical, physical, and sensory characteristics:

Few correlations were found between chemical, physical and sensory attributes. Some of the high correlations were simply due to apparent relationships, e.g., pH vs. titratable acidity, pH vs. sugar: acid ratio, chroma vs. Hunter a, and Hue angle vs. Hunter a, etc. Some others were presumably due to correlation analysis itself and so are not very meaningful, e.g., catechin content vs. peak force, etc.

In 1994, percent soluble solids content was highly correlated to apple flavor ($r = 0.882$). Percent soluble solids content is usually related to sugar concentration. Sweetness is one of the many factors affecting flavor. This result implied that sweetness could have played an important role in apple flavor. However, no high correlation was found between sugar concentration and apple flavor.

Apple flavor was highly correlated to apple overall acceptance in both 1994 ($r = 0.895$) and 1995 ($r = 0.991$), while apple appearance did not show high correlation to overall acceptance. Thus, although panelists indicated that they considered both color and flavor were the most important attributes in their purchasing decision, flavor seemed to be more important. Color is just one of the many factors affecting appearance.

In both 1994 and 1995, sensory scores on firmness were related to texture peak force. In 1994, the raw data indicated that cultivar '414' received the most "just right" scores for firmness, while cultivar '828' and 'McShay' were considered relatively "too soft" by most of the panelists. 'Liberty' and '707' received less "just right"

scores than '414' and was considered slightly "too firm" by most of the panelists. In 1995, a similar pattern was observed. These results paralleled peak force data.

In 1995, apple appearance was highly correlated with color measurements, proving that color is a very important factor with respect to apple appearance. Flavor was highly correlated to total sugar (r = 0.904), which was not surprising, but it was also highly correlated to chlorogenic acid (r = 0.907) and catechol (r = 0.890) content. Usually, high phenolic content will give an undesirable flavor. However, if the concentration is not too high, phenolic compounds might improve the flavor in terms of sourness and tartness, as shown in this case. Overall acceptance was highly correlated with total sugar content (r = 0.919) and sugar:acid ratio (r = 0.885). Sugar: acid ratio have long been considered a good indicator of apple quality and acceptability, while sugar content seemed to play an important role in regards to apple acceptability in this study. Overall acceptance was also highly correlated with chlorogenic (r = 0.914) and catechol (r = 0.895) content, which was not difficult to understand because flavor was highly correlated to overall acceptance.

Although it appeared that some high correlations did exist between chemical and sensory attributes in 1995, very few were found in 1994. For example, in 1995, cultivar '414' was higher in sugar: acid ratio and lower in titratable acidity, and it received the highest score on flavor. However, in 1994, although there were differences in sugar: acid ratio and titratable acidity, the sensory scores on flavor were not significantly different among five cultivars. Thus, relationships among these characteristics are still not easy to interpret.

Conclusion

Four new disease-resistant apple cultivars were better than or equivalent to 'Liberty' (except cultivar '828' in 1995). 'Liberty' served as a control cultivar in this study due to its high preference in previous research, compared to widely accepted cultivar 'McIntosh' (34). Moreover, cultivar '414' had the greatest potential for the fresh market due to its high preference in both years, even if its appearance was not highly rated. Cultivar '828' may have potential as a processing cultivar because of its lower degree of browning.

The relationships between instrumental measurements and sensory evaluation were difficult to interpret, although high correlations were found in some cases. The reason for this difficulty may be due to the complexity of the sensory terms used in the study, which are not easily correlated with single attributes measured by instruments. Sugar content appeared to be an important factor affecting apple flavor, which seemed to play a major role in determining the overall acceptance in both years, while appearance did not have such an affect.

Enzymatic browning was related to phenolic content except for McShay. Chlorogenic acid, the major individual phenolic compound found in this study, and catechin were the major contributors to degree of browning. Total phenolics and other individual phenolic compounds are not always good indicators of browning. To further elucidate a relationship between enzymatic browning and phenolic content, investigation of enzyme (PPO) activity and other phenolic compounds would be necessary.

Cultivar-dependent seasonal variation was quite evident for some attributes tested in this study, especially when considering the absolute values of the attributes. However, attribute patterns among the five cultivars were similar between the two seasons.

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