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Comparison of Sensory, Chemical and Color Attributes of Disease-Resistant Apple Cultivars[1]

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Abstract

In 1989 and 1990, the sensory preference, chemical and color attributes of three disease resistant apple cultivars (DRC), 'Liberty,' 'Nova Easygro,' and 'Jonafree,' were compared to 'McIntosh' at harvest and following three months storage at 2°C. Throughout the testing period panelists equally preferred the flavor of 'Liberty' and 'McIntosh.' Liberty was significantly ($P \leq 0.05$) preferred for texture during the four sampling periods. 'Jonafree' was significantly ($P \leq 0.05$) less preferred when compared to 'McIntosh.' The color of 'McIntosh' was preferred overall, followed by 'Liberty.' 'Jonafree' was least preferred for color. The % soluble solids, titratable acidity, fructose, and sucrose concentrations decreased over time. Glucose and the sugar:acid ratio increased with time. Significant differences in chemical and color evaluations were found from year to year.

Introduction

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 associated with fungicide applications, and meet consumer demands for reduced pesticide residue on produce. Despite these obvious advantages, growers have been slow to plant disease-resistant cultivars (DRC).

A recent survey of the New England Apple Industry indicated that DRC comprised less than 1% of the respondents' acreage in 1989 and would account for 10% of the acreage planted in 1990-1994 (2). Growers have been reluctant to plant DRC because of the uncertainty of consumer acceptance. Appearance and flavor are key attributes determining whether consumers accept a new cultivar (15). Little information is available on fruit quality and consumer preferences for DRC.

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Preliminary results (3) and informal taste tests (13, 14) suggested that recently released DRC may be acceptable to consumers. Stebbins et al. (15) found that 'Liberty' and several other cultivars with 'McIntosh' parentage were rated higher by taste panels than 'McIntosh' but the supra-optimal growing temperatures for 'McIntosh' in Eastern Oregon affect its quality. Their taste panel also found 'Liberty' ranked higher than 'Delicious' and equal with 'Empire.' Durner et al. (5) reported that panelists preferred DRC 'Freedom' and 'Liberty' over 'Spur Red Delicious,' and the DRC 'Priscilla' and 'Prima.' The objective of this study was to assess the sensory, chemical and color attributes of three promising DRC, compared with high quality, properly mature 'McIntosh.'

Materials and Methods

Four apple cultivars ('McIntosh,' 'Nova Easygro,' 'Liberty' and 'Jonafree') were grown at the University of Maine's Highmore Farm, Monmouth, Maine, in 1989, a light cropping year and in 1990, a full crop year. The DRC were planted in 1983. Fruit were harvested from: 1) 'Rogers McIntosh'/M.7, planted in 1979; 2) 'Nova Easygro'/M.9/MM.111; 3) 'Liberty'/M.7A and 4) 'Jonafree'/M.9/MM.111 trees. All trees were grown using standard horticultural and pest management practices, except the DRC received no fungicide sprays either year. The DRC trees were planted in adjacent rows, but not in a randomized or replicated design. The 'McIntosh' trees were planted in a separate block growing nearby. 'McIntosh' fruit were harvested on a calculated optimum harvest date, using bloom and degree dates for the given season as described by Eggert (6). The DRC were harvested according to recommended dates given by Lamb (8, 9), adjusted for local conditions. The fruit were harvested from various parts of the canopy of several trees and divided into two samples. One sample was tested shortly after harvest and the other was tested after storage at 2°C for three months.

Chemical and color analyses

Color of each cultivar was measured on ten apples per cultivar (three replicate readings per apple) using a Hunter LabScan II spectrocolorimeter (Raston, VA) with 10 degree D65 (daylight) illuminant and a 4-5 cm aperture. Sugar concentrations (sucrose, glucose and fructose) were determined by HPLC methods (16). Percent soluble solids was determined using AOAC procedure (1). Titratable acidity was calculated using AOAC methodology (titration was pH 8.1 endpoint) (1). All analyses were performed in triplicate.

Sensory evaluation

Ten apples per cultivar per replication were washed, peeled, cored and sliced into 1/4 in slices for flavor and texture preference ranking. The samples were coded, placed in white paper baking cups and presented in a randomized complete block design (4) with four replications to sensory panels of 17-19 members. Panelists were asked to rank the four apple cultivars in their order of preference for flavor and texture (11). For color preference evaluation, six apples per cultivar per replication were washed, wiped dry and presented on coded white plates in an randomized complete block design with four replications. Panelists were asked to rank the color of the samples in order of their preference.

Statistical analyses

Data from the sensory tests were analyzed by the analysis of variance method (ANOVA) using the Statistical Analysis System package (12). The sensory preference ranks for color, flavor and texture were converted to scores according to Fisher and Yates (7) to normalize the data. The experimental design of the sensory evaluation data did not allow for a repeated effects model to examine year and time effects due to the variation in

panelist participation. Mean separation for each sampling period was calculated using Duncan's multiple range test.

A mixed effects analysis of variance model was used to determine the significant main effects and interactions for the chemical and color data. To account for the random effect of year, year*variety was used as the error term to test the significance of variety. Year*time was used to test the effect of time and year*cultivar*time was used to test the time*cultivar effect. Least-squares means and probability values for the hypothesis H_0:LSM(i) = LSM(j) for the significant interactions in the color and chemical data were obtained using the General Linear Model Procedure (GLM) (12).

Results

Chemical and color analyses

A summary of the statistical significance of the main and interaction effects for the chemical and color analyses is presented in Table 1. The effect of year was highly significant. Cultivar differences were found in the glucose and sugar:acid ratios, with 'Nova Easygro' significantly higher in both characteristics throughout the study (Table 2). The nonsignificant cultivar*time interaction illustrates that the cultivars had similar responses to chemical changes during storage. All four cultivars showed decreases in % soluble solids, titratable acidity, fructose and sucrose along with increases in glucose and the sugar:acid ratio over time (Table 2).

The significant interaction of cultivar and year (Table 3) show the % soluble solids for 'McIntosh' were significantly $P \leq 0.05$ lower in both years. In 1989, 'Jonafree' was not significantly $P \leq 0.05$ different in solids when compared to 'McIntosh.' In 1989, 'McIntosh' had the highest titratable acidity followed by 'Liberty.' In 1990, 'Jonafree' acid levels were the highest followed by 'Liberty.' 'Nova Easygro' had the lowest acidity level during both sampling years.

'McIntosh' had significantly less glucose and sucrose than the others, while 'Nova Easygro' consistently had the highest concentration of glucose. The sugar:acid ratio of 'Nova Easygro' was significantly higher than the other three cultivars during both years. In 1989, 'Jonafree' had the next highest ratio, however, in 1990 'Liberty' had the next highest sugar:acid percentage.

The Hunter L,a,b system expresses color data in a three dimensional space (Table 4). Positve a values corresponds to the amount of red on the apple, and positive b values correspond to the amount of yellow. Hue angle represents the relationship of a/b, where a smaller hue angle indicates more red than yellow. Chroma or saturation index indicates the intensity of the color; the greater the value the greater the color saturation of the sample (10).

In 1989, 'Jonafree' followed by 'McIntosh' were more red than yellow

Table 1. Summary of the statistical significance of the main and interaction effects for the chemical and color analysis of four apple cultivars.

	% Soluble solids	Titratable acidity	Sucrose	Fructose	Glucose	Sugar:acid	Chroma	Hue
Year	**z	**	**	NS	*	**	**	**
Cultivar	NS	NS	NS	NS	*	*	NS	NS
Time (storage)	NS	NS	*	NS	NS	NS	NS	*
Cultivar*time	NS	NS	NS	NS	NS	NS	NS	NS
Cultivar*year	**	**	**	NS	*	**	**	**
Year*time	**	**	NS	**	**	**	*	NS
Cultivar*year*time	**	**	**	**	**	NS	*	*

z**, *, NS: Significant at $P \leq 0.01$, $P \leq 0.05$ or nonsignificant, respectively.

Table 2. Soluble solids, titratable acidity, sugar content and sugar:acid ratios of McIntosh, Nova Easygro, Liberty and Jonafree at harvest and following three months storage.

	% Soluble solids	Titratable acidity[z]	Sucrose[y] (mg/g)	Fructose[y] (mg/g)	Glucose[y] (mg/g)	Sugar:acid
1989						
At harvest						
McIntosh	10.75b	1.07a[x]	33.68b	54.46	8.65c	9.02d
Nova Easygro	13.46ab	0.53d	45.55a	64.59	19.12a	24.25a
Liberty	14.58a	0.97b	48.30a	72.53	15.27ab	14.04c
Jonafree	11.20b	0.58c	26.79b	67.61	11.86bc	18.40b
Three months storage						
McIntosh	8.94	0.66a	19.95b	52.09a	10.69b	12.47b
Nova Easygro	9.84	0.32c	21.34b	54.13a	19.66a	29.45a
Liberty	8.57	0.59b	21.28b	45.68ab	12.87b	13.53b
Jonafree	9.43	0.64a	38.12a	37.01b	12.75b	13.75b
1990						
At Harvest						
McIntosh	10.94c	0.79b	31.40c	61.37a	8.78c	12.87c
Nova Easygro	12.50a	0.53c	46.85b	59.94a	12.91a	22.73a
Liberty	11.88b	0.80b	45.30b	54.66b	10.90b	13.92b
Jonafree	12.10b	1.07a	62.18a	38.82c	9.31c	10.31d
Three months storage						
McIntosh	9.34b	0.37c	21.94c	54.85c	12.91b	24.62bc
Nova Easygro	12.18a	0.31d	34.72b	60.78b	23.24a	38.73a
Liberty	11.95a	0.41b	27.03c	67.47a	20.95a	28.43b
Jonafree	13.44a	0.63a	55.28a	52.46c	20.39a	20.46c

[z]Reported as % malic acid.
[y]Mean of three replications.
[x]Means followed by similar letters do not differ significantly at $P \leq 0.05$ using Duncan's multiple range test.

with less color saturation than 'Liberty' and 'Nova Easygro' (Table 4). In 1990, 'McIntosh' had the highest degree of redness but was not significantly different from 'Liberty.' 'Jonafree' had the higher yellow to red ratio and the greater saturation index in 1990.

Sensory Evaluation

The means scores for preference evaluation of 'McIntosh,' 'Nova Easygro,' 'Liberty' and 'Jonafree' are shown in Table 5. 'Liberty' received the highest preference scores but was not significantly different from 'McIntosh.' 'Jonafree' was rated least preferred for flavor and was significantly different from 'McIntosh' in three of the four testings. Although 'Nova Easygro' had a significantly higher sugar:acid ratio than the other three cultivars, it was rated third for flavor in most tests.

'Liberty' was significantly preferred for texture throughout the four sampling periods. Texture preference for 'Nova Easygro' declined from harvest to three months storage. Panelists generally preferred the color of 'McIntosh.' 'Jonafree' was ranked significantly "least preferred" for color during all the sampling periods except for the 1989 harvest evaluation.

Discussion

The primary objective of this research was to examine the sensory qualities, chemical and color properties of three disease-resistant cultivars ('Liberty,' 'Nova Easygro' and 'Jonafree') as they compare to the more widely accepted Northeast U.S. culti-

Table 3. Chemical and color cultivar*year least square means for four apple cultivars.

	Year	McIntosh	Nova Easygro	Liberty	Jonafree
% Soluble Solids	1[z]	9.84a[y]	11.65b	11.58b	10.31a
	2	10.14a	12.34b	11.92b	12.77b
Titratable acidity	1	0.87d	0.43a	0.78c	0.61b
	2	0.58b	0.42a	0.60c	0.85d
Sucrose	1	26.81a	33.45b	34.79b	32.45b
	2	26.67a	40.79c	36.16b	58.73d
Glucose	1	9.67a	19.39c	14.07b	12.30b
	2	10.84a	18.08c	15.92b	14.84b
Sugar:acid	1	10.75a	26.85d	13.78b	16.07c
	2	18.74b	30.72d	21.17c	15.39a
Chroma	1	18.31a	19.76b	19.45b	19.33ab
	2	20.90a	22.85b	22.48b	24.93c
Hue	1	41.54ab	45.54b	42.07ab	38.15a
	2	24.83a	33.98bc	29.54ab	38.09c

[z]Year 1 = 1989, Year 2 = 1990.
[y]LSMEANS within a row with different letters are significantly different at the 5% level of significance.

var, 'McIntosh.' The findings of this study indicate that the chemical and color characteristics of the cultivars respond similarly over time. The soluble solids, titratable acidity, fructose and sucrose concentrations decreased with time as compared to increases in glucose and sugar:acid ratios. 'McIntosh' was consistently lower in soluble solids and was also rated least preferred for texture. 'Nova Easygro' had the lowest acid concentration throughout the sampling period.

Overall, panelists equally preferred the flavor of 'Liberty' and 'McIntosh' and rated 'Jonafree' "least preferred." The texture of 'Liberty' was consistently most preferred over the other three cultivars. 'McIntosh' was preferred for color followed by 'Liberty.' The selections preferred, "McIntosh" and "Liberty," were higher in titratable acidity. Generally in this study, titratable acidity appeared to be a better objective indicator of preference than did the sugar analysis. Hunter color readings were not a good predictor of overall color preference.

The most promising disease resistant cultivar evaluated in this study was 'Liberty.' Stebbins et al. (15) and Durner et al. (5) reported similar findings for 'Liberty.' 'Jonafree' received lower preference ratings for flavor, texture and color. Although some of the cultivars were rated lower in the preference evaluations, they still may be acceptable to some consumers. In the future it would be important to investigate the acceptability of these cultivars using large-scale consumer panels.

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Table 4. Lightness (L), Chroma and Hue of McIntosh, Nova Easygro, Liberty and Jonafree at harvest and following three months storage.

	L Value[z,y]	Chroma[z]	Hue[z,x]
1989			
At harvest			
McIntosh	34.73c[w]	16.76c	40.38b
Nova Easygro	38.07a	19.03a	43.79a
Liberty	36.48b	17.39b	45.17a
Jonafree	34.04c	17.68b	35.32c
Three months storage			
McIntosh	39.42b	19.88d	42.73b
Nova Easygro	42.17a	20.51c	47.28a
Liberty	39.30b	21.53a	38.97c
Jonafree	39.82b	21.07b	40.97bc
1990			
At Harvest			
McIntosh	33.08bc	20.79b	26.56b
Nova Easygro	36.05b	21.42b	34.84ab
Liberty	32.01c	20.99b	25.87b
Jonafree	39.67a	24.13a	36.43a
Three months storage			
McIntosh	34.67b	21.01b	23.11b
Nova Easygro	39.44ab	24.29a	33.12ab
Liberty	37.81ab	23.98a	33.22ab
Jonafree	41.58a	25.94a	39.29a

[z]Mean of three readings on ten different apples/cultivar.
[y]The greater the value the lighter the color (L).
[x]Reported as hue angle.
[w]Means followed by similar letters do not differ significantly at $P \leq 0.05$ using Duncan's multiple range test.

Table 5. Mean scores for sensory evaluation of McIntosh, Nova Easygro, Liberty and Jonafree at harvest and following three months.

	Flavor	Texture	Color
1989			
At Harvest			
McIntosh	0.23a[z,y]	-0.30c	0.41a
Nova Easygro	-0.01ab	0.18b	-0.73c
Liberty	0.15a	0.49a	-0.08b
Jonafree	-0.37b	-0.37c	0.40a
Three months storage			
McIntosh	0.25a	-0.11b	0.51a
Nova Easygro	-0.25b	-0.27b	-0.24b
Liberty	0.51a	0.74a	0.39a
Jonafree	-0.51b	-0.36b	-0.66c
1990			
At Harvest			
McIntosh	-0.01a	-0.21b	0.11b
Nova Easygro	0.11a	-0.03b	0.61a
Liberty	0.34a	0.43a	0.30b
Jonafree	-0.44b	-0.19b	-1.02c
Three months storage			
McIntosh	-0.02ab	-0.57d	0.85a
Nova Easygro	-0.29b	-0.22c	0.11b
Liberty	0.19a	0.64a	0.07b
Jonafree	0.12ab	0.15b	-1.03c

[z]Values, which ranged from +1.16 = "most preferred" to -1.16 = "least preferred," are means for 17-19 judges, four replications.
[y]Means followed by similar letters do not differ significantly at $P \leq 0.05$ using Duncan's multiple range test.

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