17. _____. 1965. Influence of nutrition on flower production, keeping quality, disease susceptibility, and chemical composition of *Chrysanthemum morifolium*. *Proc. Amer. Soc. Hort. Sci.* 86:650-655.
18. _____and C. A. Conover. 1969. Chrysanthemum production in Florida. *Univ. of Florida Agr. Expt. Bul.* 730.
19. Wilson, D. L. 1977. Filtration in drip irrigation. *Seventh Intern. Agr. Plastics Congr.* p. 160-165.

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Sensory Characteristics of Apple Fruit[1,2]

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Abstract. **A profile was developed to describe sensory characteristics of 'Golden Delicious', 'Miller Spur', 'Redspur', 'Rome Beauty', and 'York Imperial' apples (*Malus domestica* Borkh.). Ten sensory attributes were selected and the intensities of the attributes were plotted on a circular graph. The patterns of the plots differed among cultivars and patterns of some cultivars changed with successive harvests and storage of apples. The patterns were used to describe the general sensory characteristics of apples.**

The quality of apples is difficult to describe simply because apples have many divergent attributes that are associated with acceptability and/or desirability. Firmness, soluble solids and titratable acid contents are measured routinely to determine relative condition and to determine time of harvest, based on findings of Haller et al. (3) and Wright and Whiteman (5). These measurements do not necessarily characterize the quality of an apple.

Although many scientists have used taste panels to determine quality of apples, most studies dealt with preference or differences among samples. Some researchers have used hedonic scales (1, 6) or intensity scales (2) to correlate sensory measurements with other measurements but only a few attributes were evaluated. Williams and Carter (4) made an extensive study of attributes that panelists recognized in 'Cox's Orange Pippin' apples. The quality of apples can be characterized best by identifying the significant attributes, as undertaken by Williams and Carter (4), and then determining the intensities of these attributes.

In this paper, we describe quality characteristics of apples based on a semi-profile method for selecting and measuring intensities of important sensory attributes. Firmness and soluble solids and titratable acids contents were also measured to describe conditions of apples as objectively determined.

Materials and Methods

Fruit of 5 apple cultivars, harvested at 4 weekly intervals and stored for 3 periods, were used for the study. The cultivars, which included 'Golden Delicious', 2 'Delicious' sports ('Miller Spur' and 'Redspur'), 'Rome Beauty', and 'York Imperial' were obtained from growers in the apple-growing region of southcentral Pennsylvania, western Maryland and the eastern panhandle of West Virginia. (Only the first part of a 2 part name of a cultivar will be used for identification in this paper.) Apples were harvested at weekly intervals, starting 2 weeks before and ending 1 week after the estimated optimum harvest date as indicated by the grower. 'York' apples were harvested only 3 times, beginning 1 week before optimum date. Harvested fruit were treated with ethoxyquin (Stop Scald), placed in slit-polyethylene-lined fiberboard cartons and stored at $1^{\circ} \pm 1^{\circ}$C for 0, 2.5 and 5 months. Apples were removed from the cartons after storage, placed at 18° for a 7-day ripening period in trays, and then evaluated for sensory attributes, firmness, soluble solids and titratable acid. Each treatment consisted of two 10-fruit samples. All analyses except pressure tests were made on the composite of the 10 fruit.

Objective measurements. Pressure tests were made with a 11-mm (7/16-inch) diameter Magness-Taylor probe mounted in an Instron testing machine and driven 7.9 mm into the pared apple flesh at a speed of 2.54 cm/min. Force measurements were converted to newtons with the conversion formula 1 pound = 4.448 newtons (N). The average of 2 maximum force measurements (on the blushed side and its opposite side) was used as the pressure test value for each apple. The average of measurements from 10 fruit was used for the composite value in statistical analyses. For chemical analysis, juice from apple slices was extracted with a Juicerator and centrifuged. Soluble solids content of the juice was determined with a bench-top model Bausch and Lomb Abbe-56 refractometer. The titratable acid content was determined by titrating the apple juice to pH 7.0 with 0.1N NaOH; the results are reported as percent malic acid.

Sensory evaluation. The taste panelists, who were selected on the basis of interest and ability to communicate sensory responses, had no special knowledge of apple quality criteria. During the development of the profile, all 15 panelists met together; however, only 6-10 panelists met for routine testing and each scored a given sample.

To develop the subjective quality profile, we asked the panelists to describe apples of various cultivars and maturities (1 or 2 at a time) in terms that were clear to someone completely unfamiliar with apples. After each panelist had tasted a representative sample and written his or her description, the group of panelists discussed selected terms until they reached a consensus on the meaning of each term. Food samples and chemicals – for example cinnamon and nutmeg for spiciness, and different quality beef steaks for toughness – were used to demonstrate some of the terms. Redundant terms, including antonyms, were eliminated. Attributes selected for describing the apple are shown on the ballot (Fig. 1). At each session, reference standards were provided for direct comparison with

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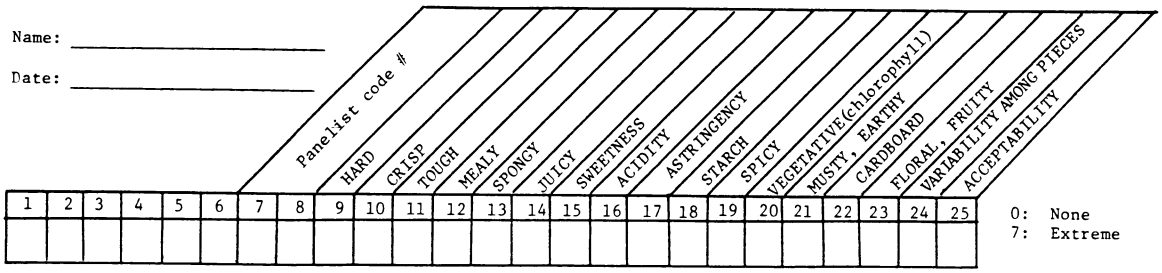

Fig. 1. Form used to record intensities of attributes. Columns 1 through 6 were used to identify cultivars, harvest date, storage period and sample number. Data was key punched directly from this form.

Table 1. Average pressure test readings and titratable acid content of 5 apple cultivars harvested at different times before, at, and after the estimated optimum harvest date, stored for different periods at 0°C, and ripened for 7 days at 18°C.

Cultivar	Length of storage (months)	Pressure test readings (newtons)				Malic acid (%)			
		−2 wk	−1 wk	0	+1 wk	−2 wk	−1 wk	0	+1 wk
Golden Delicious	0	65	64	61	43	.46	.43	.39	.39
	2.5	34	33	31	28	.33	.31	.28	.27
	5.0	32	31	28	27	.20	.25	.22	.17
Miller Spur	0	76	79	73	72	.29	.27	.26	.26
	2.5	63	56	50	47	.24	.23	.24	.24
	5.0	59	48	42	42	.21	.21	.20	.20
Redspur	0	60	56	55	52	.22	.21	.21	.19
	2.5	55	48	43	40	.20	.18	.17	.18
	5.0	52	46	40	40	.17	.17	.17	.16
Rome Beauty	0	68	61	58	52	.46	.45	.42	.43
	2.5	44	42	42	42	.35	.32	.36	.32
	5.0	43	42	41	41	.31	.33	.30	.28
York Imperial	0	–	79	74	72	––	.48	.45	.44
	2.5	–	56	58	56	––	.37	.32	.34
	5.0	–	51	51	47	––	.31	.27	.30

the apples to anchor the "moderate" scale points for sweetness (0.35% sucrose solution) and for acidity (0.075% malic acid solution). Because acidity, bitterness, and astringency are often confused, solutions of caffeine (0.045 and 0.09%) and alum (0.1%) were provided as reminders of bitterness and astringency, respectively. However, these chemicals were not used to anchor specific scale points because thresholds of detection differed widely among panelists.

After pressure test measurements were completed, 3 one-eighth-apple wedges from each of 10 apples were mixed in a large bowl. Each panelist randomly selected 3 wedges and removed the skin from half of each piece. The portions with skin removed were evaluated for textural attributes, and the portions with skin intact were evaluated for taste and flavor characteristics. This was done because the skin was removed from the areas where pressure tests were made, but was not removed from areas that were chemically analyzed. Duplicate panels were run in the morning and afternoon of the same day.

Results

Objective measurements. Pressure test readings of apple cultivars at first harvest ranged from 60 N for 'Redspur' to 79 N for 'York' (Table 1). The range probably would have been greater if the first harvest of 'York' was made 2 weeks before the optimum date like the other cultivars. The firmness of all cultivars decreased with successive harvests, i.e., advanced maturity. The extent of decrease was greatest for 'Golden' (22 N) and least for 'Miller' (4 N). Firmness of all cultivars decreased during the 5-month storage period, with most of the decrease occurring during the first half of the storage period.

The soluble solids content of the apple cultivars ranged from 10% in 'Redspur' to 12.5% in 'Miller' (data not presented). The content did not change significantly with harvest dates or storage periods.

The malic acid content of the apple cultivars ranged from 0.22% in 'Redspur' to 0.48% in 'York' at first harvest and decreased an average of 0.01 to 0.02 percentage points each week during successive harvest dates (Table 1). The titratable acid content decreased with storage and the rate of decrease was greater in cultivars with higher initial content. The average rates of decrease per 100 g fruit over the 5-month period were 1.05 mg/week in 'Golden', 0.2 to 0.3 mg/week in 'Delicious' sports, 0.65 mg/week in 'Rome' and 0.85 mg/week in 'York'.

Sensory evaluation. Ten attributes were selected to describe the apple characteristics: fruitiness, acidity, sweetness, juiciness, crispness, hardness, toughness, mealiness, vegetativeness, and astringency. Other attributes, i.e., sponginess, starchiness, spiciness, mustiness, and cardboard flavor, were scored inconsistently among panelists. Scores on acceptability are not included in this manuscript.

Plots of sensory evaluation scores on circular graphs were used to describe the apple characteristics (Fig. 2). Attributes

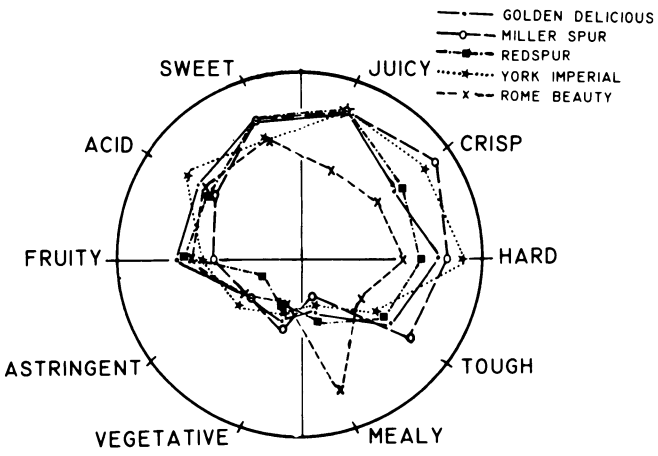

Fig. 2. Plot of sensory scores of 5 apple cultivars harvested at optimum maturity and held 7 days at 18°C. Sensory scores ranged from 0 (not detectable) to 7 (strong). The score is 0 at the center of the circle and increases outward to 5.5 at the boundary of the circle.

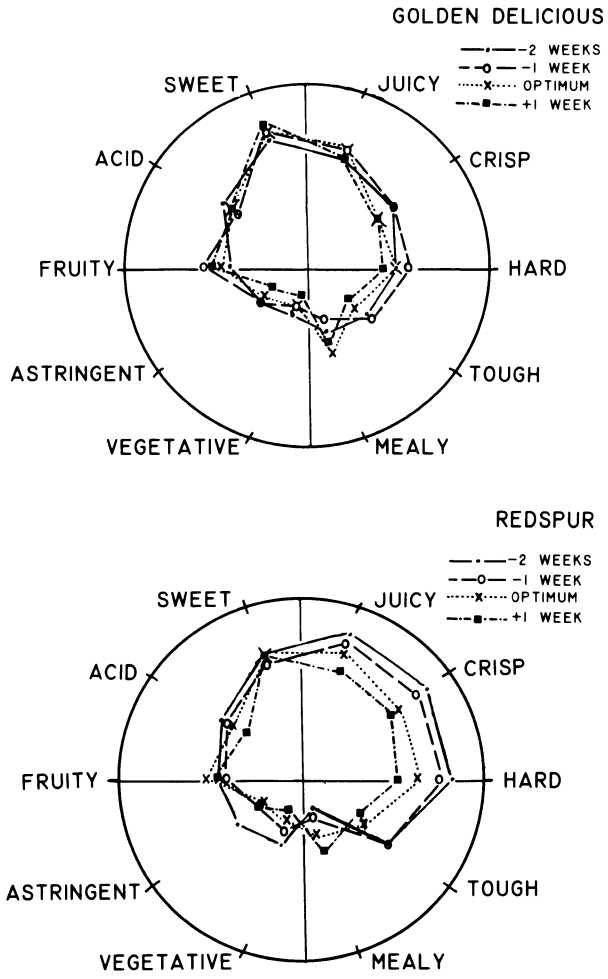

Fig. 3. Plot of average sensory scores of 'Golden Delicious' and 'Redspur' apples harvested 2 weeks and 1 week before optimum, at optimum, and 1 week after optimum time. Each point is an average of scores over 3 storage periods. Sensory scores ranged from 0 (not detectable) to 7 (strong). The score is 0 at the center of the circle and increases outward to 5.5 at the boundary of the circle.

were arranged around the circle on the basis of their characteristics and desirability: those placed on the right side are associated with texture and those on the left side are associated with flavor. The 6 attributes on top are associated with desirable features and those on the bottom of a circle are associated with undesirable features.

The patterns at optimum harvest were oval shaped with a flat base for all cultivars except 'Rome' (Fig. 2). Patterns for 'Rome' were also oval shaped, but had a protrusion at the base due to high scores for mealiness. The scores were similar among the 6 attributes placed at the top of the circle for 'Golden' and 'Redspur', and were higher for the 3 attributes on the right than for the 3 on the left of the circle for 'Miller' and 'York' (Fig. 2). This difference of the 2 groups is indicated by the oval favoring one side of the circle. The oval pattern of 'Rome' was skewed to the left because of disproportionately lower scores for juciness, crispness, hardness, and toughness. Scores for the individual attributes differed among cultivars, which can be seen by the slight differences in the oval pattern.

The size and shape of oval patterns changed with harvest dates as shown for 'Golden' and 'Redspur' (Fig. 3). The plots represent harvest scores averaged over storage periods. The scores of juciness, crispness and hardness generally decreased with harvest, which resulted in reduction of the oval area in the top-right of the circle, as shown for 'Redspur'. Scores of sweetness, acidity and fruitiness changed slightly with harvest, but the changes were not consistent among attributes or cultivars. The significance of the changes with harvest differed with attribute and cultivar (Table 2).

Scores of astringency and vegetativeness generally decreased with maturity and all changes except those of astringency in 'Rome' and 'York' and vegetativeness of 'York' were significant. Scores for toughness generally decreased and mealiness generally increased with harvest period and the amount of change differed with cultivar. Changes in mealiness of 'Rome' were not significant, but initial scores were considerably greater than those of other cultivars and remained greater even at the last harvest (Table 2).

Changes in pattern with storage differed with cultivars, as shown by the storage scores averaged over harvest periods (Table 2), which are plotted for 'Miller' and 'Rome' (Fig. 4). Patterns of 'Golden' and 'Rome' changed the most as shown for 'Rome' (Fig. 4). Changes in 'Golden' and 'Rome' apples were due to sharp increases in mealiness and sharp decreases in all other attributes except sweetness, during the first 2.5-months storage. The patterns became smaller with storage due to the decreasing scores of most attributes as shown for 'Miller' (Fig. 4).

Discussion

The sensory attributes of apple cultivars were characterized by the profile technique and the general characteristics of a cultivar were noted by the pattern of the plotted data. These patterns indicate that these apple cultivars could be separated into at least 3 characteristic classes. The first class would contain cultivars, such as 'York', that have strong features for attributes located at the top of the circle, which consisted of fruitiness, acidity, sweetness, juiciness, crispness and hardness. The second class would contain cultivars, such as 'Redspur', that have stronger features for juiciness, crispness, and hardiness than for fruitiness, acidity, and sweetness. The last class, as shown for 'Rome', would have a definite feature for mealiness and moderate intensities for attributes in the top of the

Table 2. Average intensity scores for 10 attributes of 5 apple cultivars harvested before, at, and after optimum harvest date and stored for various periods at 0°C.

Attribute	Cultivar	Average scores over storage periods: Time from optimum harvest date −2 wk	−1 wk	0 wk	1 wk	Average scores over harvest dates: Length of storage 0 mo.	2.5 mo.	5.0 mo.
Juiciness	Golden Delicious[z]	3.5	3.7	3.7	3.6	4.5	3.4	3.1
	Miller Spur[zy]	4.0	3.6	4.0	3.6	4.0	3.9	3.6
	Redspur[zy]	4.6	4.2	4.0	3.4	4.3	3.6	4.1
	Rome Beauty[z]	2.5	2.4	2.1	2.3	3.2	1.8	1.9
	York Imperial[z]	--	4.3	4.4	4.1	4.2	4.6	4.0
Crispness	Golden Delicious[zy]	3.1	3.1	2.6	2.6	4.2	2.1	2.4
	Miller Spur[zy]	4.5	4.3	4.3	3.8	4.6	4.2	3.9
	Redspur[zy]	4.7	4.2	3.6	3.3	4.0	3.6	4.3
	Rome Beauty[z]	2.6	2.6	2.3	2.4	3.4	1.9	2.3
	York Imperial[zy]	--	4.8	4.8	4.3	4.8	5.0	4.1
Hardness	Golden Delicious[zy]	2.7	3.1	2.7	2.3	3.9	1.9	2.4
	Miller Spur[zy]	4.4	4.0	4.2	3.7	4.5	3.9	3.7
	Redspur[zy]	4.5	4.1	3.5	2.8	3.8	3.4	4.0
	Rome Beauty[z]	2.9	2.9	2.5	2.6	3.6	2.1	2.6
	York Imperial[zy]	--	4.9	4.7	4.2	4.9	4.6	4.3
Toughness	Golden Delicious[zy]	2.3	2.4	1.8	1.6	3.4	1.2	1.6
	Miller Spur[zy]	3.8	2.9	3.3	2.8	3.6	3.1	2.8
	Redspur[zy]	3.2	3.2	2.3	1.9	2.9	2.3	2.8
	Rome Beauty[zy]	1.9	1.9	1.5	1.4	2.3	1.3	1.5
	York Imperial	--	3.2	3.1	3.0	3.3	3.2	2.9
Mealiness	Golden Delicious[zy]	2.0	1.7	2.6	2.5	1.2	2.9	2.4
	Miller Spur[zy]	0.6	1.0	1.3	1.9	1.0	1.2	1.4
	Redspur[zy]	0.8	1.1	1.7	2.3	1.8	1.6	1.0
	Rome Beauty[z]	3.8	3.9	4.0	4.0	2.7	4.7	4.1
	York Imperial	--	0.8	1.1	1.0	0.7	1.0	1.1
Vegetative	Golden Delicious[y]	1.5	1.3	1.1	1.0	1.9	1.1	0.7
	Miller Spur[zy]	1.9	1.6	1.7	1.3	2.1	1.3	1.5
	Redspur[zy]	2.0	1.7	1.4	1.3	1.7	1.4	1.6
	Rome Beauty[zy]	1.4	1.1	1.0	1.0	1.6	0.9	0.9
	York Imperial[z]	--	1.1	1.2	1.0	1.6	1.0	0.8
Astringency	Golden Delicious[zy]	1.8	1.7	1.6	1.2	2.1	1.4	1.1
	Miller Spur[zy]	2.4	2.3	2.0	1.9	2.5	1.9	1.9
	Redspur[zy]	2.4	1.7	1.4	1.6	1.6	1.6	2.0
	Rome Beauty[y]	1.2	1.2	1.4	1.2	1.5	1.0	1.0
	York Imperial[y]	--	2.3	2.1	1.9	2.7	1.9	1.7
Fruitiness	Golden Delicious[zy]	2.5	3.2	2.7	3.0	3.5	2.8	2.4
	Miller Spur[zy]	2.2	2.5	2.9	3.2	2.7	2.9	2.5
	Redspur[zy]	2.5	2.4	2.9	2.5	3.2	2.2	2.3
	Rome Beauty[y]	2.2	2.0	2.4	2.2	3.0	1.8	1.9
	York Imperial[y]	--	2.7	2.4	2.3	3.0	2.2	2.3
Acidity	Golden Delicious[zy]	3.2	2.7	2.8	2.8	3.6	2.7	2.5
	Miller Spur	3.2	3.0	2.9	2.9	3.2	3.0	2.8
	Redspur[zy]	3.0	2.8	2.6	2.2	2.8	2.4	2.8
	Rome Beauty[zy]	3.1	3.1	2.7	3.0	3.6	2.7	2.7
	York Imperial[zy]	--	4.2	4.0	3.6	4.3	3.8	3.6
Sweetness	Golden Delicious[z]	4.0	4.2	4.2	4.5	4.3	4.2	4.3
	Miller Spur[zy]	3.9	3.9	4.1	4.3	3.8	4.4	3.9
	Redspur[z]	3.9	3.8	4.0	4.0	4.2	3.9	3.9
	Rome Beauty	3.5	3.4	3.5	3.5	3.6	3.4	3.5
	York Imperial	--	4.0	3.8	3.8	3.9	3.9	3.8

Scale for sensory scores: 0 = not detectable, 7 = strong.

[z]Changes during harvest time were significant at the 5% level as determined by regression analysis of variance.

[y]Changes during storage were significant at the 5% level as determined by regression analysis of variance.

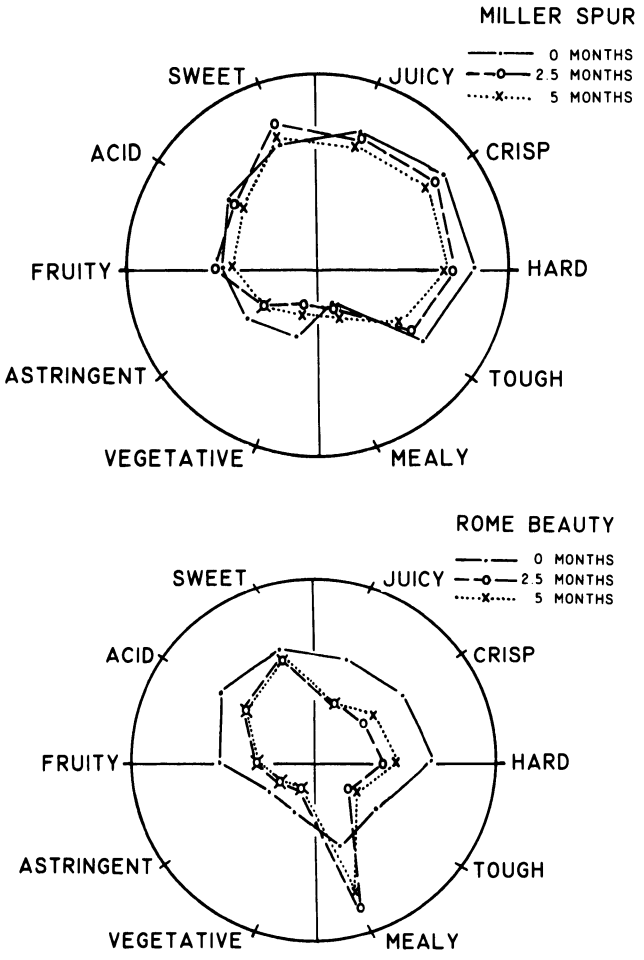

Fig. 4. Plot of average sensory scores of 'Miller Spur' and 'Rome Beauty' apples stored for 0, 2.5 and 5 months at 0°C. Each point is an average of scores over harvest dates. Sensory scores ranged from 0 (not detectable) to 7 (strong). The score is 0 at the center of the circle and increases outward to 5.5 at the boundary of the circle.

circle. Since patterns change with maturity of apple at harvest and length of storage, changes would be anticipated in the classification of cultivars.

The differences in the general quality characteristics of cultivars may be due, in part, to differences in the physiological age of cultivars at harvest. For example, the intensities and changes of intensities of 'Redspur' attributes indicate that these apples were in the early stage of maturation. These apples, at initial harvest, showed definite astringency and vegetativeness. The intensities of acidity, juiciness, hardness, and crispness were initially high and decreased with successive harvest dates. On the other hand, the intensities and inconsistent changes of 'Golden' attributes indicate that 'Goldens' were at the latter stage of maturation. Undoubtedly, other factors also contribute to the differences in characteristics among cultivars. This was noted by the intensity changes during storage of 'Miller' and 'Rome' apples. Intensities of 'Miller' attributes changed only moderately with storage, whereas, intensities of 'Rome' attributes decreased sharply during the first 2.5 months of storage. Such differences probably are due to differences in chemical composition and cellular structure. It would be interesting to examine the physiological age, metabolic and catabolic processes, and anatomy of these apple cultivars at harvest and determine the relationship of these factors to the sensory quality.

Literature Cited

1. Brennan, J. G., R. Jowitt, and A. M. A. Mohamed. 1977. Instrumental measurement of fruit texture: a study on apples. *Ann. Appl. Biol.* 87:121-127.
2. Gorin, M., J. W. Rudolphij, F. T. Heidema, and R. G. van der Vuurst de Vries. 1975. Metabolites in Golden Delicious apples as possible parameters of acceptability. *J. Sci. Food Agr.* 26:599-607.
3. Haller, M. H., J. M. Lutz, and E. D. Mallison. 1941. The relationship of firmness to ripeness of eastern-grown apples. *U.S. Dept. Agr. Circ.* 579.
4. Williams, A. A. and C. S. Carter. 1977. A language and procedure for the sensory assessment of Cox's Orange Pippin apples. *J. Sci. Food Agr.* 28:1090-1104.
5. Wright, R. C. and T. M. Whiteman. 1955. Some changes in eastern apples during storage. *U.S. Dept. Agr. Tech. Bul.* 1120.
6. Voho, K. and P. Varo. 1975. Chemical and organoleptic evaluation of some Finnish apple varieties. *J. Sci. Agr. Soc. Finland* 47:445-453.