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Ripening and Storage of the 'Liberty' Apple[1]

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Abstract

Studies were conducted with 'Liberty' apples to assess changes during the harvest season as well as to determine optimal storage conditions. Generally, 'Liberty' fruit were smaller, firmer, redder, and sweeter than 'Empire' fruit harvested at similar periods. The internal ethylene concentrations of 'Liberty' fruit exceeded one ppm approximately two weeks prior to optimal harvest. The development of excessive levels of browncore in 'Liberty' fruit, both in refrigerated air and controlled atmosphere storage, suggested that 'Liberty' fruit must be stored at higher than 3.1C if extended storage is required. Further study must assess the timing of the development of browncore and the relationship of browncore development to temperatures higher than 3.1C.

Environmental and food safety concerns over the use of pesticides to maintain production of high quality apples have focused attention on reducing pesticide applications in the orchard. Significant breeding efforts have been underway for a number of years to develop apple cultivars with resistance to major diseases. One such cultivar, 'Liberty,' was developed at the New York State Agricultural Experiment Station in Geneva and released in 1978 (4). 'Liberty' is reported to be resistant to apple scab, cedar apple rust, fire blight, and powdery mildew. Because of its quality and the heightened concerns over pesticide use, New England growers have become very interested in 'Liberty' as a commercial cultivar. In fact, a recent survey (1) suggested that it would be the fifth most planted cultivar in New England through the first half of the 1990's. This level of planting is remarkable for a cultivar that was not planted at all in the first half of the 1980's.

Unfortunately, very little information is available about the horticultural characteristics of 'Liberty,' and very importantly, very little is known about the ripening and storability of the fruit. The objective of the work reported here was to obtain some baseline information on ripening and storage of 'Liberty' fruit.

Materials and Methods

Harvest-season Changes

For maturity studies in 1988-90, 'Liberty'/M.7A trees, planted in 1980 at the University of Massachusetts Horticultural Research Center (UMHRC), Belchertown, were used. Each year, five blocks were selected, including one to three trees depending on fruit set. 'Empire'/M.26 trees, planted in 1975 in a separate location at the UMHRC, were used as a standard cultivar for comparison. Each year, five 'Empire' blocks were selected, each including a single tree.

In 1988, 20-fruit samples were harvested from each block at weekly intervals from 20 Sept. to 11 Oct. Internal ethylene concentrations were measured using gas chromatography of a one-ml sample removed from the core of each fruit. For a 10-fruit sample from three of the five blocks, the percent surface red color of each fruit was assessed visually, fresh weight of fruit was determined, flesh firmness was measured with an Effegi Penetrometer (Effegi, Alfonsine, Italy)

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using 2 punctures per fruit, and soluble solids content was determined on a bulk sample from 10 apples using a hand refractometer, Five fruit were cut equatorially, dipped in an iodine-potassium iodide (I-KI) solution, and rated for starch loss. 'Liberty' starch loss patterns were compared to a 'McIntosh' chart developed by Priest and Lougheed (5), and the 'Empire' patterns were compared to an 'Empire' chart developed by Chu (3).

In 1989, five-fruit samples were harvested from each block at weekly intervals from 8 Sept. to 13 Oct., and internal ethylene concentrations were determined. From 15 Sept. to 13 Oct. an additional 10-fruit sample was harvested for determining starch loss. Patterns developed by both cultivars were compared to an 'Empire' chart. On 22 Sept., 29 Sept., and 6 Oct. prior to assessment of starch loss, data on color, fresh weight, flesh firmness, and soluble solids content were collected as described above.

In 1990, samples were harvested at weekly intervals from 14 Sept. to 5 Oct. Sample size and fruit quality measurements were similar to those described for 1989; however, the quality of fruit color was also assessed using the U.S. Extra Fancy classification. 'Liberty' starch loss patterns were photographed and compared to the 'Liberty' chart developed by Autio (2).

Starch Chart

In 1990, 10-fruit samples were harvested at weekly intervals from 5 'Liberty' blocks from 4 Sept. to 5 Oct. Each fruit was cut equatorially, stained with I-KI solution, and photographed. A chart showing the progressive loss of starch was assembled.

Refrigerated Air Storage

For air storage studies, 'Liberty'/M.7A trees planted in 1980 at the UMHRC were partitioned into three blocks in 1988 and five blocks in 1989. Blocks consisted of one to three trees depending on fruit set. 'Empire'/M.26 trees, planted in 1975 in a separate location at the UMHRC, were used as a standard cultivar for comparison. Three 'Empire' blocks in 1988 and five 'Empire' blocks in 1989 were selected, each including a single tree.

In 1988, 20 apples were harvested from each block at weekly intervals beginning on 20 Sept. and ending on 11 Oct. Flesh firmness was measured on 10 apples. The remaining apples were kept at 0C in a commercial storage in Shoreham, VT until 14 Dec., after which flesh firmness was again assessed on 10 apples.

In 1989, 60 apples were harvested from each block on 22 Sept., 29 Sept., and 6 Oct. Flesh firmness was measured on a 10-apple sample at harvest and after storage. Each sample was kept at 0C in the UMHRC storage for 117 days, regardless of harvest date. The fruit were kept at 20C for 14 days, after which the incidences of bitter pit, decay, senescent breakdown, and browncore were assessed.

Controlled Atmosphere Storage

Controlled atmosphere studies were conducted utilizing the same blocks as described for the air storage studies, except an additional replication was included from a commercial orchard in Vermont in 1988.

Sixty fruit were harvested from each block on 27 Sept. 1988 and partitioned randomly into two groups. Flesh firmness was measured at harvest on 10 apples. Fruit were transported to a commercial storage in Shoreham, VT. One group from each block was kept at 0C, 3% O_2, and 2% CO_2 ("hard CA"), and the second group was kept at 3.3C, 3% O_2, and 5% CO_2 ("soft CA"). After 5 and 6.5 months, flesh firmness was measured on 10 apples.

A 120-fruit sample was harvested from each block on 29 Sept. 1989 and partitioned randomly into two groups. Flesh firmness was measured at har-

vest on 10 apples. All fruit were kept at the UMHRC storage. One group from each block was kept under "hard CA" conditions (0C, 2.7% O_2, <2% CO_2), and the second group was kept under "soft CA" conditions (3.1C, 3% O_2, 5% CO_2). After five months, fruit were kept for two weeks at 0C under ambient atmospheric conditions, after which flesh firmness was measured on 10 apples. Remaining fruit were maintained at 20C for eight days, and assessed for incidences of bitter pit, decay, senescent breakdown, and browncore.

Data Analysis

All data were analyzed using the Generalized Least Squares procedure of the SAS statistical analysis program (SAS Institute, Inc., Cary, NC). In general, means were separated by F test. Firmness was covaried with fruit weight, and firmness after storage was covaried with fruit weight and firmness at harvest. Means presented are least-squares means adjusted for the covariates.

Table 1. Flesh firmness of 'Liberty' and 'Empire' fruit harvested at weekly intervals from 20 Sept. to 11 Oct. and kept at 0C until 14 Dec. 1988.

Cultivar	Harvest date	Flesh firmness (N)
Liberty	20 Sept.	69.5
	27 Sept.	76.4
	4 Oct.	75.0
	11 Oct.	73.4
Empire	20 Sept.	62.1
	27 Sept.	67.3
	4 Oct.	66.7
	11 Oct.	67.0
Significance		
Cultivar		ns
Harvest date		*
Cultivar x Date		ns
Fruit weight		ns
Firmness at harvest		ns

*, ns: Significant at p = 0.05 or nonsignificant, respectively.

Table 2. Flesh firmness of 'Liberty' and 'Empire' fruit kept for 5 or 6.5 months under soft CA (3.3C, 3% O_2, 5% CO_2) or hard CA (0C, 3% O_2, <2% CO_2) storage conditions. Fruit were harvested on 27 Sept. 1988.

		Flesh firmness (N)	
Cultivar	Storage	5 months	6.5 months
Liberty	Soft	66.3	64.4
	Hard	63.2	56.6
Empire	Soft	69.3	65.2
	Hard	61.5	56.9
Significance			
Cultivar		ns	
Length of storage		**	
Type of storage		***	
Cultivar x Length		ns	
Cultivar x Type		ns	
Length x Type		ns	
Cultivar x Length x Type		ns	
Fruit weight		ns	
Firmness at harvest		ns	

***, **, ns: Significant at p = 0.001, p = 0.01, or nonsignificant, respectively.

Results and Discussion

Harvest-season Changes

Figures 1 through 3 depict change of fruit quality and ripening of 'Liberty' and 'Empire' during the harvest season. Generally, 'Liberty' fruit were smaller than 'Empire' fruit, although this difference may be due to crop load differences. 'Liberty' fruit were firmer during the harvest season than 'Empire,' even after fruit weight effects were removed. In most years, soluble solids content of 'Liberty' fruit was higher than that of 'Empire,' and 'Liberty' fruit generally were more highly colored than 'Empire.'

Informal taste evaluations suggested that the appropriate first date of harvest for these two cultivars was similar, 30 Sept., approximately one week before 'Delicious'; however, measurement of internal ethylene concentrations showed that 'Liberty' is a peculiar cultivar, in that internal ethylene levels exceeded one ppm (the normal level associated with the initiation of ripen-

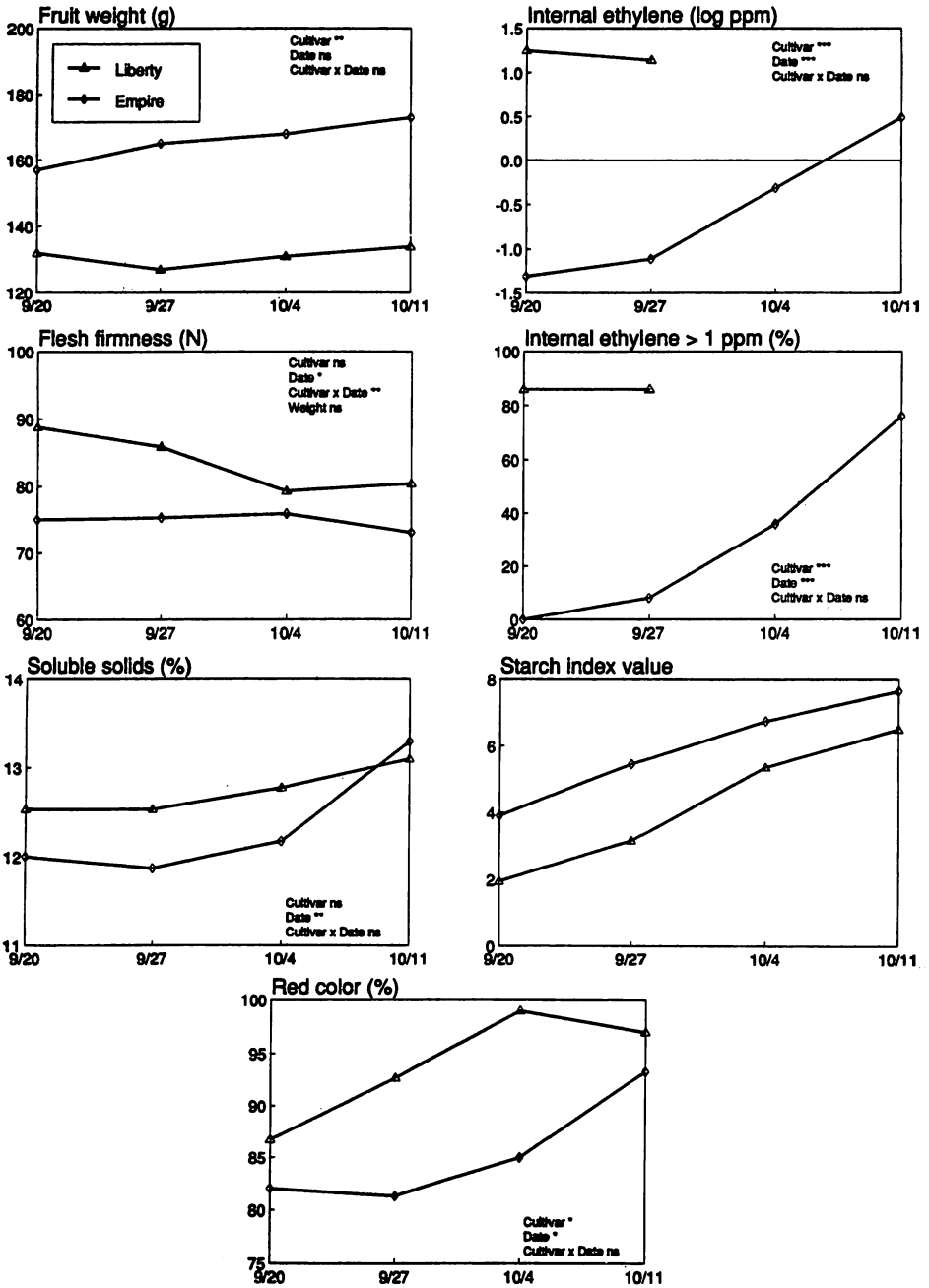

Figure 1. Weight, flesh firmness, percent red color, internal ethylene concentration, percent with internal ethylene concentration, percent with internal ethylene concentration > 1 ppm, soluble solids content, and starch index value of 'Liberty' and 'Empire' fruit throughout the 1988 harvest season.

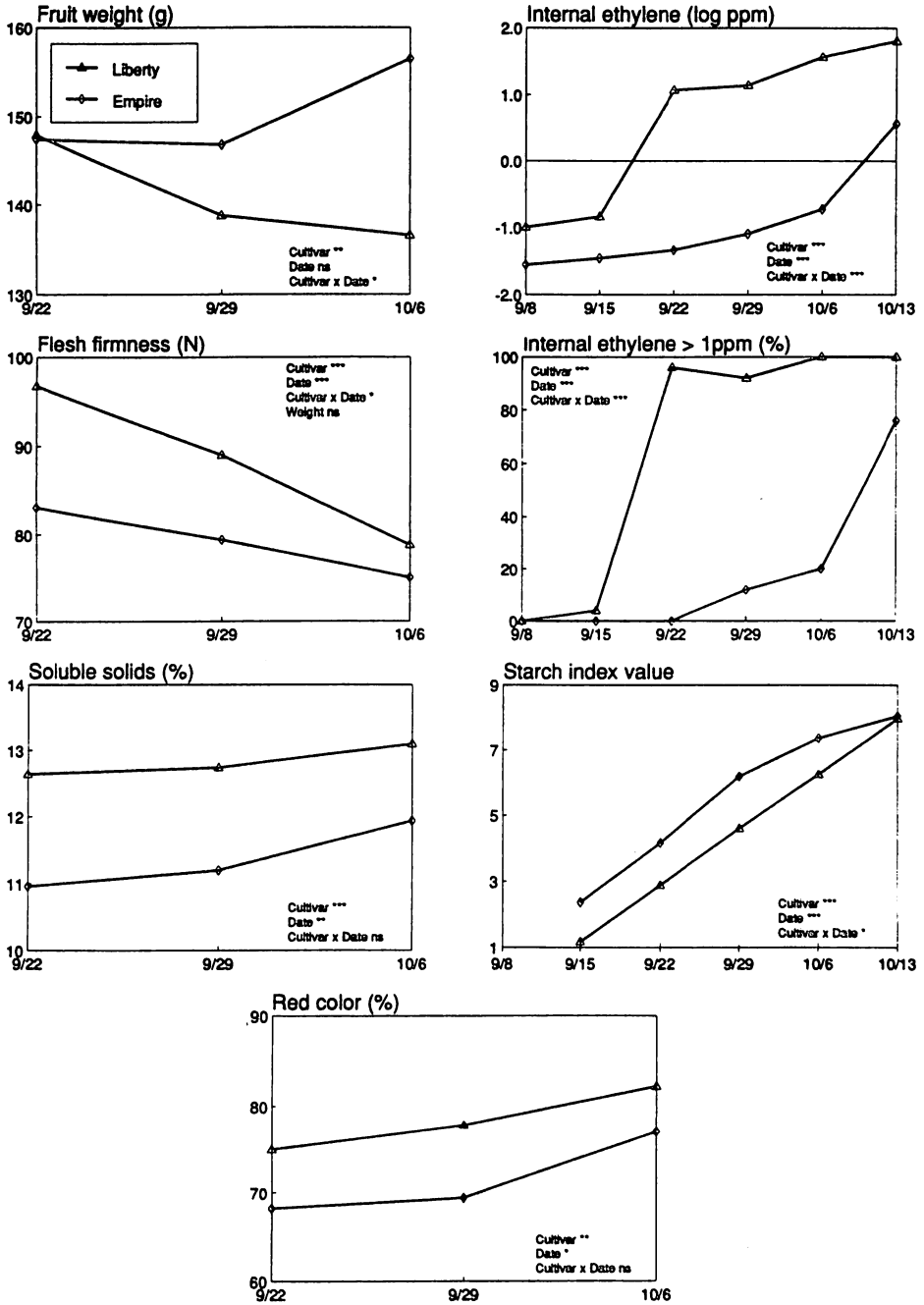

Figure 2. Weight, flesh firmness, percent red color, internal ethylene concentration, percent with internal ethylene concentration > 1 ppm, soluble solids content, and starch index value of 'Liberty' and 'Empire' fruit throughout the 1989 harvest season.

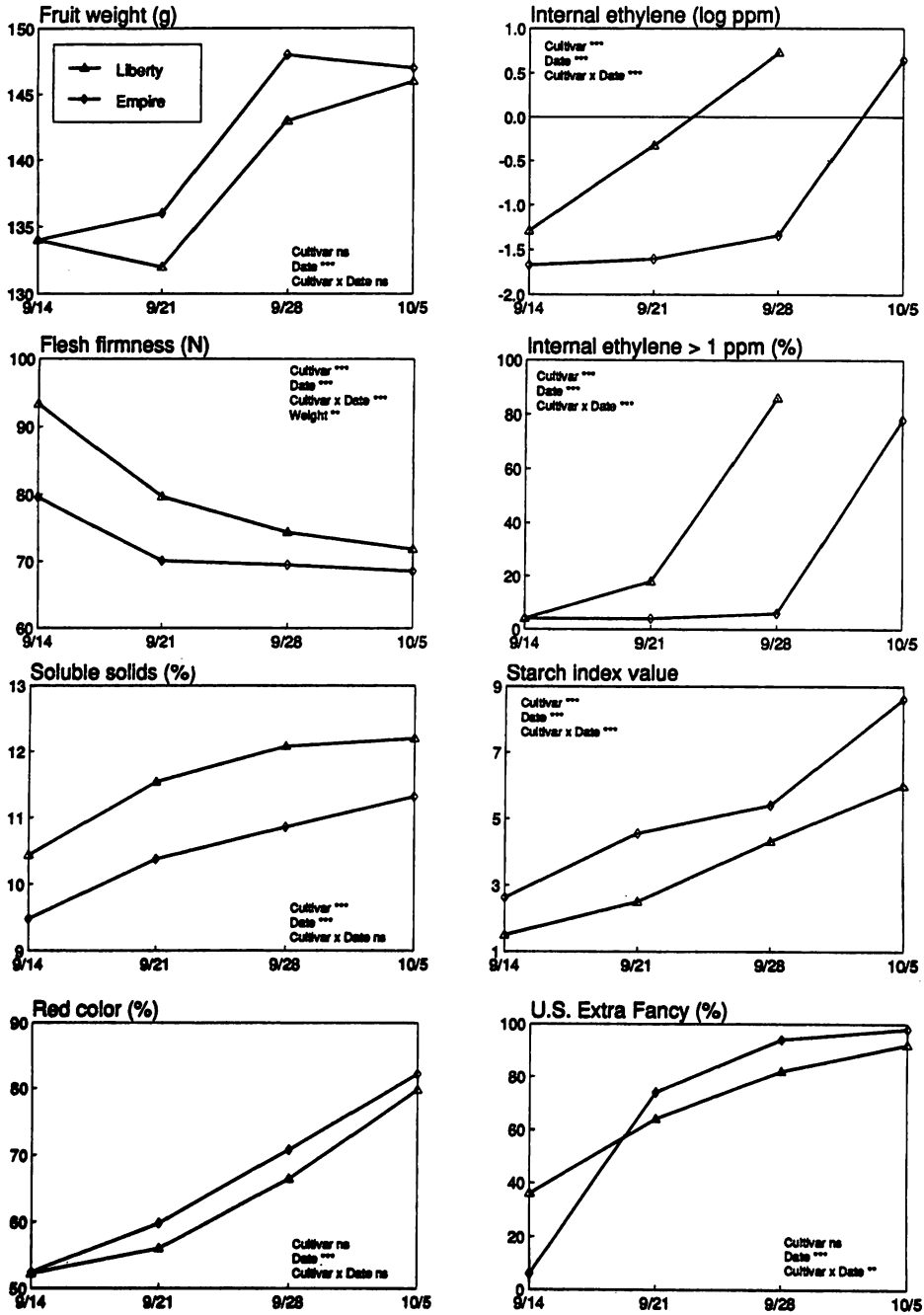

Figure 3. Weight, flesh firmness, percent red color, percent U. S. Extra Fancy, internal ethylene concentration, percent with internal ethylene concentration > 1 ppm, soluble solids content, and starch index value of 'Liberty' and 'Empire' fruit throughout the 1990 harvest season.

ing) as much as two weeks prior to the apparent optimal first date of harvest. It is unlikely that 'Liberty' fruit should be harvested three weeks prior to 'Delicious.' This situation makes accurate assessment of fruit ripening very difficult, since internal ethylene measurement is normally the most accurate technique. Alternatively, the starch-iodine test may be helpful in assessing maturity.

In 1988, a 'McIntosh' starch chart was used to assess starch loss from 'Liberty.' The beginning of optimal harvest was when the starch index level reached 3-3.5. In 1989, because of a better match of the pattern, an 'Empire' chart was used for 'Liberty' fruit. Optimal harvest was when the starch index value reached 4.5. In 1990, a chart specific to 'Liberty' was developed (Figure 4). This chart was roughly calibrated with informal taste evaluations, and under Massachusetts conditions, harvest of 'Liberty' fruit should begin when the starch index value reaches 4.5.

Refrigerated Air Storage

In 1988, fruit were kept for approximately 2.5 months at 0C, and only flesh firmness was determined after storage (Table 1). 'Liberty' and 'Empire' fruit were not significantly different; however, there were differences among the four harvest dates. Fruit collected on 27 Sept., 4 Oct., and 11 Oct. softened to a lesser degree than fruit collected on 20 Sept. In 1989, fruit were kept for nearly four months at 0C, after which firmness and the incidences of storage disorders were assessed. After accounting for fruit size and firmness at harvest, 'Liberty' fruit softened less than 'Empire' fruit, and the latest harvest softened more than earliest harvest. Decay, bitter pit, and senescent breakdown were more prevalent in 'Empire' fruit than 'Liberty' fruit. Browncore, on the other hand, was much more of a problem with 'Liberty' than 'Empire.' Browncore developed in 70-90% of 'Liberty' fruit after four months at 0C and 14 days at 20C.

Table 3. Flesh firmness and the incidence of storage disorders of 'Liberty' and 'Empire' fruit (harvested September 29, 1989) stored under "soft CA" (3% O_2, 5% CO_2, 3.1C) or "hard CA" (2.7% O_2, < 2% CO_2, 0C) conditions for 5.5 months.

	Flesh firmness (N)[z]			Superficial scald (%)			Senescent breakdown (%)		
Cultivar	Soft CA	Hard CA	Mean	Soft CA	Hard CA	Mean	Soft CA	Hard CA	Mean
Liberty	43.9	45.2	44.6	5.0	6.0	5.5	0.0	14.1	7.0
			ns			ns	ns	**	**
Empire	46.2	49.3	47.8	3.5	0.0	1.7	1.0	0.0	0.5
Mean	45.1*	47.3		4.3 ns	3.0		0.5**	7.1	

	Bitter pit (%)			Decay (%)			Browncore (%)		
	Soft CA	Hard CA	Mean	Soft CA	Hard CA	Mean	Soft CA	Hard CA	Mean
Liberty	3.0	0.0	1.5	7.8	20.1	14.0	70.2	51.5	61.3
	**	ns	**			ns			***
Empire	23.1	0.5	11.9	13.0	20.1	16.6	5.6	0.0	2.8
Mean	13.1**	0.2		10.4 ns	20.1		40.5 ns	26.7	

[z]Firmness data were covaried with fruit size and firmness at harvest; however, each was nonsignificant. Statistical separation is presented for the means of cultivar and CA treatment. Where the interaction of cultivar and CA treatment was significant, statistical separation is presented for the cultivar means within each CA treatment.

***, **, *, ns: P = 0.001, P = 0.01, P = 0.05, and nonsignificant, respectively.

Considering firmness, bitter pit, decay, and senescent breakdown, 'Liberty' fruit had superior storage quality to that of 'Empire' fruit; however, the incidence of browncore must be seen as a significant detractor. Browncore is a sign of chilling sensitivity (6), and the high incidence of browncore in 'Liberty' suggests that it is a very chilling-sensitive cultivar and cannot be kept at 0C for extended periods of time. In future studies, the timing of the development of browncore will be determined.

Controlled Atmosphere Storage

To maximize the length of the marketing period, many growers store apples for extended periods under controlled atmospheric conditions. The two types of storage used most commonly in New England are "hard CA" (0C, ~3% O_2, and < 2% CO_2) and "soft CA" (3.3C, 3% O_2, and 5% CO_2). Generally, cultivars that are chilling sensitive are kept in soft CA, and those that are chilling resistant are kept in hard CA. To determine the best storage conditions for 'Liberty,' fruit from the

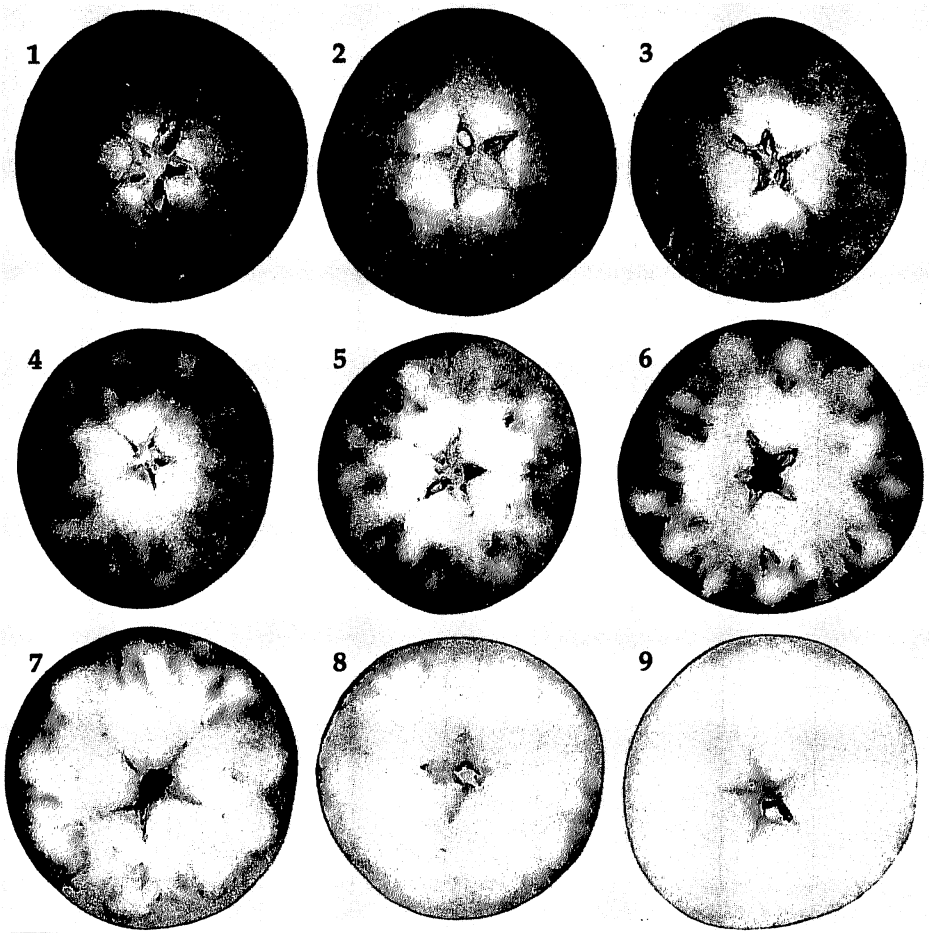

Figure 4. Starch-iodine chart developed to assess the loss of starch from 'Liberty' fruit (from Autio, 1991).

1988 harvest were kept in either hard or soft CA for 5 or 6.5 months. After storage, there was no difference in flesh firmness between 'Liberty' and 'Empire'; however, both cultivars softened less in soft CA than in hard CA. The 1989 harvest was kept under similar conditions to 1988 for 5.5 months. Less softening occurred during hard CA than soft CA storage. Significant amounts of senescent breakdown developed only in 'Liberty' fruit after hard CA storage. Significant amounts of bitter pit developed in 'Empire'

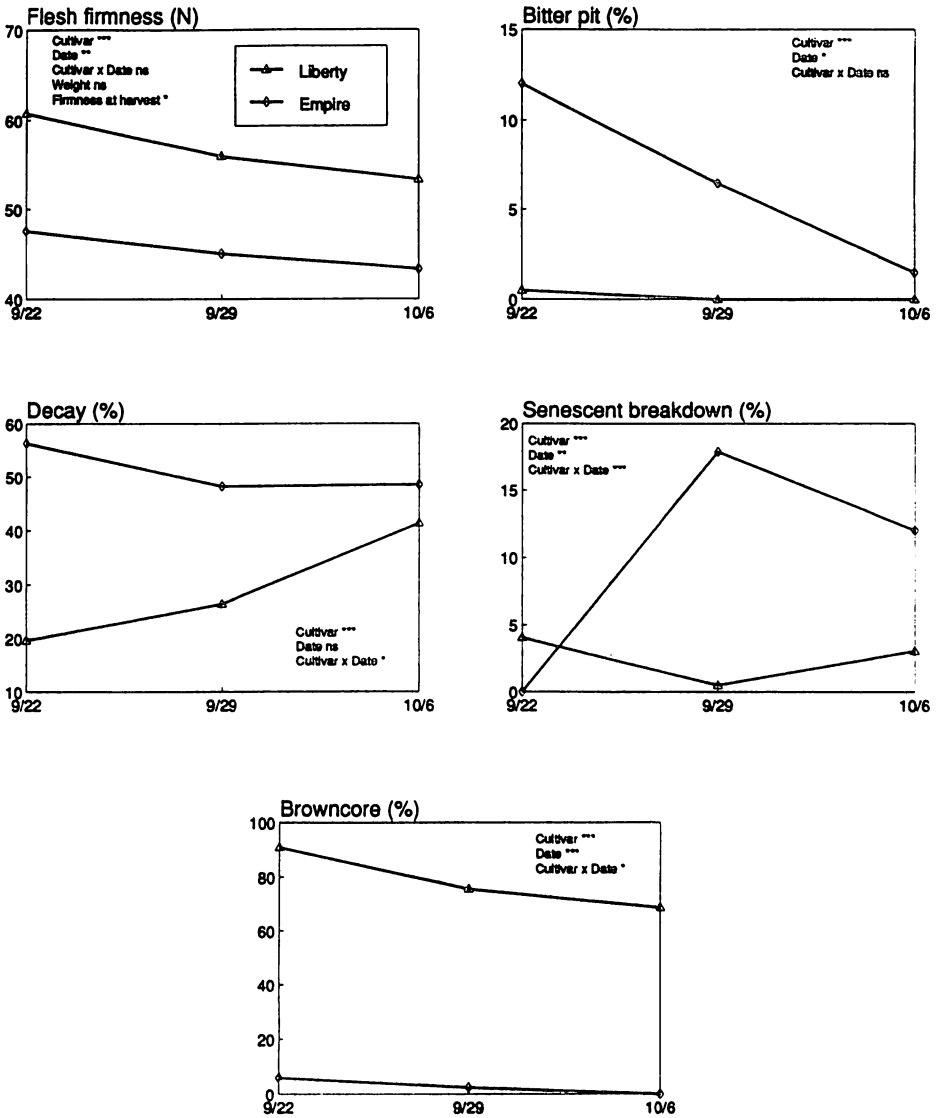

Figure 5. Flesh firmness and the incidence of storage disorders related to harvest date for 'Liberty' and 'Empire' apples in the 1989/90 storage season.

fruit only after soft CA storage, and significant amounts of browncore developed in 'Liberty' fruit in both types of CA storage.

It is clear from these results that 'Liberty' fruit will develop a great deal of browncore in standard controlled atmosphere storages. It was surprising to observe large amounts of browncore even in soft CA storage, where warmer temperature usually precludes the development of browncore. When a very chilling-sensitive cultivar is kept for extended periods, however, it may be necessary to utilize an even higher temperature than 3.1C or 3.3C. Further work must be conducted to determine a usable temperature for long-term storage of 'Liberty' fruit.

Conclusions

These studies have shown that 'Liberty' is an apple which ripens in late September at a time similar to 'Empire.' A starch-iodine test will be necessary to assess maturity accurately, since the fruit begins autocatalytic ethylene production well in advance of when they are ripe. 'Liberty' fruit store well, with the exception of a high sensitivity to chilling injury. This sensitivity may mean that 'Liberty' fruit will have to be stored at higher than normal temperatures if they are to be kept for extended periods of time.

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The 1988-91 Apple Variety Trial Report is Ready

Our 1988-91 summary report, which contains information about 87 apple varieties and advanced selections from breeding listed alphabetically, is now ready. Some of the varieties seen for the first time were: 'Chieftan,' 'Drakenstein,' 'Elan,' 'Florina,' 'Ginger Gold,' 'Katja,' 'Luvagold' and 'Jonagored.' Full-page profiles of the most promising varieties, based on up to 4 years results with taste panels on samples out of storage, plus extensive data on tree performance, are included.

The report also includes results of our comparisons of strains of 'Gala' and 'Jonagold,' of yellow apples which might compete with 'Golden Delicious,' and of September apples which might compete with 'Gala.' There are three charts which show the approximate maturity times of the more promising varieties. The relative maturity times of 'Granny Smith,' 'Braeburn,' and 'Fuji' for long storage are compared. The results of 12 taste panels conducted with the 1991 crop are reported. Post-storage shelf life of 'Braeburn,' 'Fuji' and Granny Smith' are compared.

The report may be purchased for $5 made payable to the Agricultural Research Foundation, and send to Bob Stebbins, Department of Horticulture, OSU, Corvallis, OR 97331.