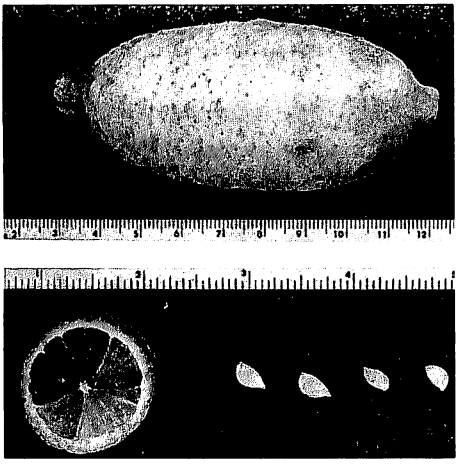


Figure 4. Top—Fruit of F_1 hybrid. Bottom—Cross section of fruit and seeds. Scale—top, centimeters; bottom, inches.

Perhaps the most interesting and a potentially valuable attribute for citrus breeding is the very short reproductive cycle inherited from *M. papuana*. Long juvenility periods, generally pervasive in *Citrus* and most of its relatives, are an important component of the long time period between origination and completion of validation testing that every selection must undergo. Although it is not possible to eliminate the need for or the time required for validation testing of selections, a genetic trait source for a short seed-to-seed cycle could significantly reduce the juvenility component of the complete breeding-selection cycle.

Literature Cited

1. Barrett, H. C. 1985. Hybridization of *Citrus* and related genera. Fruit Var. J. 39(2):11-16.

Fruit Varieties Journal 44(3):117-123 1990

Evaluation of Ripening and Fruit Quality of 'Gala' and 'McIntosh' Apples at Harvest and Following Air Storage

DUANE W. GREENE AND WESLEY R. AUTIO[1]

Abstract

The high quality of 'Gala' was confirmed in this investigation. Taste panelists preferred 'Gala' over 'McIntosh' regardless of harvest date or length of storage. 'Gala' was firmer, developed higher soluble solids, and had lower titratable acidity than 'McIntosh' but red color and color intensity developed later than 'McIntosh.' The time of ripening of 'Gala,' relative to 'McIntosh,' was not definitively established because of the uncharacteristic pattern of ethylene evolution displayed by 'Gala.' The rapid rise in ethylene evolution that characterize many apple fruit entering the climacteric did not occur with 'Gala.' Rather, the internal ethylene level rose to 1.5 to 2.5 ppm early in September and remained there for over 4 weeks, after which, it started to rise slowly to over 10 ppm by mid-October. 'Gala' lost more weight in storage than 'McIntosh,' but the weight loss was reduced considerably by storage in plastic-lined bags.

Introduction

'Gala' is an apple cultivar that was introduced in 1962 by Dr. Donald McKenzie from a cross made between 'Kidd's Orange Pippin' and 'Golden Delicious' (7). Fruit is round conic with a red blush over a very distinctive golden-yellow ground color. It is a crisp, sweet, and aromatic apple with firm, yellow flesh (1, 2, 7). Fruit size may be medium to small but large fruit are possible if tree vigor is

[1]Department of Plant and Soil Sciences, University of Massachusetts, Amherst, MA 01003. Paper No. 2946 Massachusetts Agricultural Experiment Station, University of Massachusetts at Amherst.

maintained and proper chemical thinning is done (12). There appears to be broad consumer acceptance of 'Gala' since it is being planted extensively in the United States, England, France, and Brazil, as well as in New Zealand where it originated (7, 8). 'Gala' is a relatively easy apple to grow, since it has moderate vigor, produces adequate branches, and rarely requires limb spreading (12). It is very precocious and produces heavy, annual crops if properly thinned (2, 5, 8). 'Gala' had one of the highest early yields and one of the highest yield efficiencies of the 12 cultivars tested in a planting of early season apples (4). 'Gala' appears destined to become a very popular apple cultivar based upon current observations (9, 11). However, there are no published reports on its quality, ripening characteristics, or storage potential.

This investigation was undertaken to assess fruit quality at harvest, and fruit quality and consumer acceptance following storage of 'Gala' compared to 'McIntosh,' a cultivar that is grown extensively and appears to ripen at a similar time.

Materials and Methods

Fruit used in this investigation were collected in 1988 from Kidd's D-8 'Gala'/M.26 planted in 1978 and 'Roger's McIntosh'/M.26 planted in 1976 at the University of Massachusetts Horticultural Research Center in Belchertown, Mass. Trees were located in the same orchard, separated by about 100 meters. Only the 'McIntosh' trees received 750 ppm of daminozide on July 18, 1989.

Experiment 1. Ten fruit were collected randomly from 3 'Gala' and 3 'McIntosh' trees at weekly intervals starting on August 24 and continuing through October 19. Fruit collection was made from interior and exterior fruit in all quadrants of the tree. Internal gas sample were taken from each fruit and the concentration of ethylene was determined as previously described (3). All fruit were weighed, the surface area with red color estimated to the nearest 10%, and the red color judged to be typical or atypical of the cultivar. Flesh firmness was determined with an Efegi penetrometer by making 2 punctures at the interface between red and green/yellow areas. Soluble solids concentration was determined using a hand refractometer on a composite sample of the juice collected during the firmness test. Two 1.5 cm slices were taken from opposite sides of each fruit, placed in plastic bags, and frozen at -20°C. Frozen fruit samples were thawed over night, then a 20 ml juice sample was collected after extraction using a juicer (Acme Juicerator). Titratable acidity was determined by titrating the juice to pH 8.1 with 0.1 N NaOH.

Experiment 2. Eighty fruit per tree were harvested from all quadrants of 3 'Gala' and 3 'McIntosh' trees on Sept. 15, Sept. 22, and Sept. 29. On each date fruit were separated into 8 uniform groups of 10 apples each. Four of the groups were placed in paper bags and 4 were placed in similar paper bags that were lined with plastic. Three paper bags of 10 apples and 3 plastic-lined bags of 10 apples were placed in air storage at 0°C. Fruit in the fourth remaining bag, either lined or not lined with plastic, were evaluated at harvest for flesh firmness, red color, soluble solids, and titratable acidity as described in Experiment 1. A group of apples from each harvest date that was stored in a paper bag or in a plastic lined paper bag was removed from storage on Oct. 25, Nov. 22, and Dec. 14, and flesh firmness, soluble solids, and titratable acidity was determined. Fruit were then peeled, sliced, and subjected to a taste

panel evaluation of between 24 and 32 individuals. Each taste panelist was asked on each date to evaluate crispness, sweetness, acidity, and overall rank of fruit from each of the 3 harvest dates using a descriptive scoring test (6).

Experiment 3. On Sept. 23 a bulk sample of 'Gala' and one of 'McIntosh' were harvested. Eight uniform samples of approximately 3000 g each were selected for each cultivar. Four of the samples for each cultivar were placed in paper bags and 4 were placed in plastic-lined paper bags. All samples were weighed then placed in air storage at 0°C. Bags were weighed every 2 weeks until Feb. 28, 1989. Fruit were examined at each weighing date to determine if any shriveling had occurred.

Statistical analysis. All data were subjected to analysis of variance. Since the two cultivars were spatially separated, the replications existed within cultivars, making replication a nested effect. Where multiple harvests were taken, the design was considered a split-plot over time.

Results

When the initial harvest was made on August 24, 'McIntosh' had more red color than 'Gala' (Fig. 1A). Both cultivars continued to develop red color on successive harvest dates. Although 'Gala' appeared to reach the maximum red color of 80% in early October, 'McIntosh' continued to develop red color to the last harvest on October 19 when nearly 100% of the fruit surface was judged to be red. The U. S. Extra Fancy grade was defined for both cultivars as requiring 50% or more red color, typical for the cultivar (although an official color requirement has not yet been specifically established for 'Gala.' There was a significant cultivar X harvest date interaction (Fig 1B). 'McIntosh' developed typical red color earlier and reached nearly 100% U. S. Extra Fancy before 'Gala.' However, by September 28, fruit from both cultivars were nearly 100% U. S. Extra Fancy.

'Gala' fruit were consistently firmer on all harvest dates (Fig. 1C). There was a highly significant cultivar X harvest date interaction. Flesh firmness of 'Gala' dropped more rapidly on successive harvest dates than 'McIntosh' so that by the middle of October differences in flesh firmness were considerably less than on the earlier harvest dates.

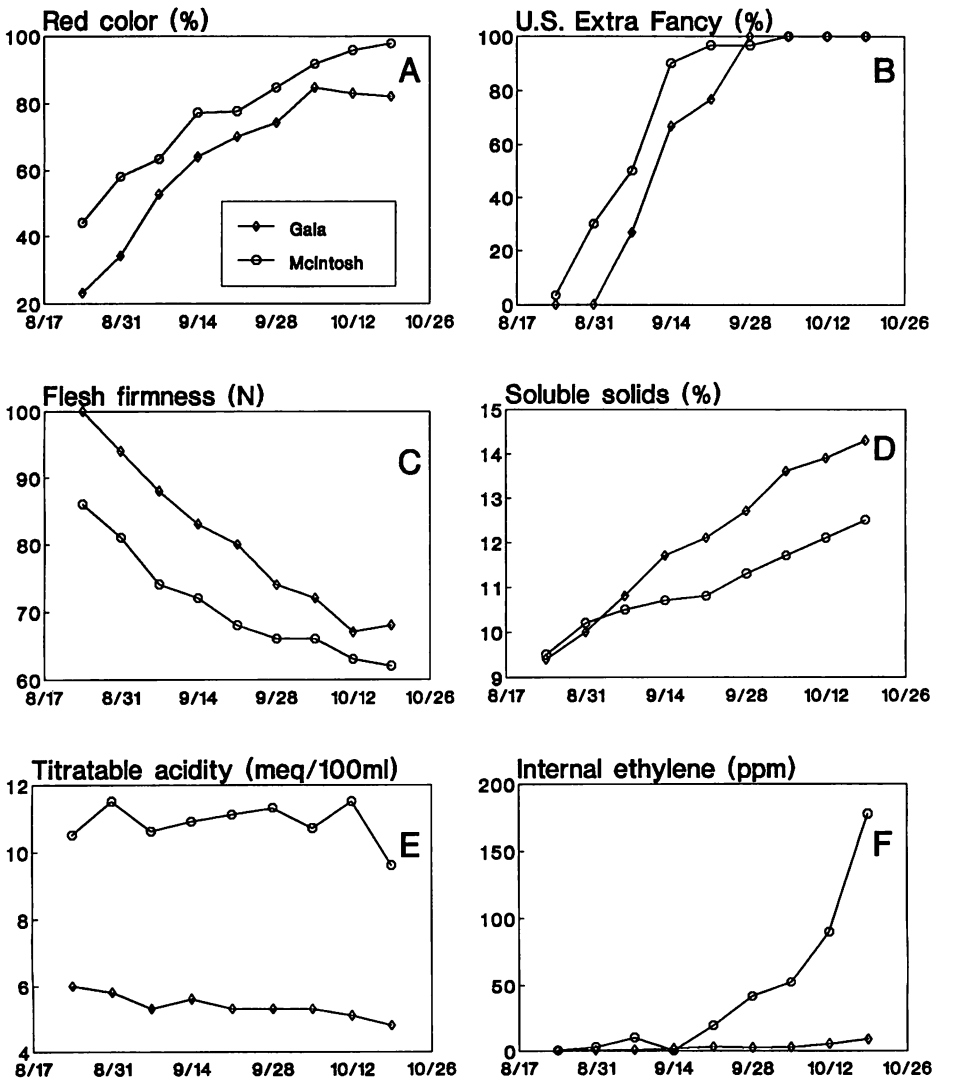
Initially soluble solids content was similar for both cultivars (Fig. 1D). There was a highly significant cultivar X harvest date interaction. The soluble solids content of 'Gala' increased more rapidly and rose to a higher level than that of 'McIntosh' On the final harvest date 'Gala' had 2% higher soluble solids than 'McIntosh.'

Titratable acidity of 'McIntosh' was nearly twice as high as that of 'Gala' on all harvest dates (Fig. 1E). Acid content of fruit decline slightly but not significantly for both cultivars over the 8-week sampling period.

Fruit weight of 'Gala' was greater than that of 'McIntosh' on all harvest dates (data not shown). Fruit weight increased with successive harvest dates.

Fruit internal ethylene concentrations remained very low in all fruit on all early sampling dates through Sept. 14 when increasing numbers of 'McIntosh' fruit began producing progressively larger amounts of ethylene (Fig. 1F). After Sept. 14, 'Gala' fruit produced ethylene but considerably less ethylene than that of 'McIntosh.'

With progressive harvest dates, soluble solids increased, flesh firmness decreased, and titratable acidity remained unchanged for both cultivars (Table 1). 'Gala' fruit were firmer, had higher soluble solids, and had lower titratable acidity than 'McIntosh' on all harvest dates and after all stor-



Figures 1A-F. Changes in fruit quality parameters and characteristics of 'Gala' and 'McIntosh' prior to, during, and after the normal harvest period: August 24 through October 19. Experiment 1.

Fig. 1A. Red color.
Fig. 1B. U.S. Extra Fancy.
Fig. 1C. Flesh firmness.
Fig. 1D. Soluble solids.
Fig. 1E. Titratable acidity.
Fig. 1F. Internal ethylene.

age periods. Flesh firmness dropped rapidly after harvest but the rate of loss slowed considerably in storage. There was a significant cultivar X storage length interaction for titratable acidity. Acidity of 'McIntosh' declined more rapidly than acidity of 'Gala' in storage. Soluble solids concentrations of fruit in storage were erratic and inconsistent.

'Gala' was preferred to 'McIntosh' in taste tests over all harvest dates. Taste panelists consistently rated 'Gala' crisper, sweeter, and less acid. The later the harvest date the more the fruit were preferred by taste panelists. The longer fruit were kept in storage the less taste panelists liked them, although rank dropped most dramatically on the last 2 evaluation dates.

Fruit stored in plastic-lined paper bags lost considerably less weight than those stored in paper bags (Fig. 2). There was a cultivar X plastic/paper X date interaction. 'Gala' stored in paper bags lost more weight in storage than 'McIntosh' and they lost it more rapidly. If fruit were placed in plastic-lined paper bags fruit of both 'McIntosh' and 'Gala' lost a comparable amount of weight. Fruit shriveling was noted only with 'Gala,' beginning in December (data not shown).

Discussion

'Gala' is a very promising new cultivar that appears to be a viable alternative for growers who wish to replace 'McIntosh' or to plant a cultivar that has broad customer appeal. There was

Table 1. Effect of time of harvest, length of storage period on fruit quality and taste panel evaluation of 'Gala' and 'McIntosh' apples.

Treatment	Flesh firmness (N)	Soluble solids (%)	Titratable acidity (meq/100 ml)	Taste panel evaluation			
				Crispness	Sweetness	Acidity	Rank
Harvest date							
Sept. 15	61.9	10.8	6.4	5.6	5.5	6.2	5.6
Sept. 22	57.8	11.0	6.3	5.5	5.7	6.0	5.7
Sept. 29	57.4	11.6	6.5	6.0	6.1	6.3	6.2
Significance[z, y]	l°°q°°	l°°q°°	NS	l°°q°°	l°°	NS	l°°
Evaluation date							
Harvest	71.6	11.1	7.9				
Oct. 25	58.7	11.3	6.5	6.5	6.7	6.6	6.9
Nov. 22	53.2	11.1	6.1	5.3	5.4	5.9	5.3
Dec. 14	52.6	11.0	5.1	5.2	5.2	6.1	5.2
Significance	l°°q°°	l°°q°°c°	l°°°	l°°q°°	l°°q°°	l°°q°	l°°q°°
Cultivar							
Gala	67.0	11.7	4.3	7.4	6.5	4.9	6.6
McIntosh	51.1	10.6	8.5	4.4	5.0	7.5	5.0
Significance	°°	°	°	°°	°°	°°	°°
Storage							
Paper	59.2	11.2	6.4	5.7	5.7	6.1	5.7
Plastic	58.9	11.1	6.4	5.6	5.8	6.2	5.9
Significance	NS	°°	NS	NS	NS	NS	NS

[z] °, °°, °°°, NS—Main effects within columns significant at the 5%, 1%, 0.1% levels or nonsignificant.
[y] l, q—Signifies that the response is linear or quadratic, respectively.

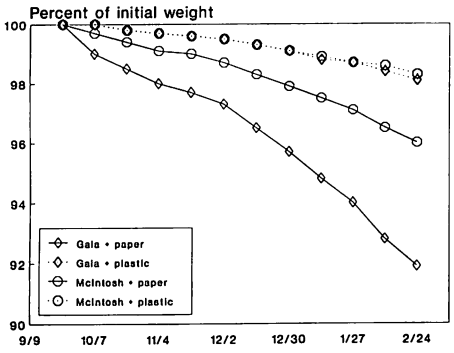


Figure 2. Weight loss of 'Gala' and 'McIntosh' in air at 0°C in either paper bags or plastic-lined paper bags. Experiment 3.

a strong preference for 'Gala' by taste panelists after storage.

Red color development frequently is used as the primary factor determining when an apple is picked since a minimum of the apple surface must have typical red color to meet U.S. specified standard grades. Red color developed on 'McIntosh' earlier and ultimately on a larger percent of the fruit surface than it did on 'Gala' Just prior to the first harvest date (9/15) 90% 'McIntosh' and 65% 'Gala' were classified as U. S. Extra Fancy and could have been harvested while taste panelists preferred fruit harvested over 2 weeks later. It appears that red color development may be a poor indicator for determining the appropriate time for the harvest of 'Gala.' Morgan et al. (9) reported that ground color rather than red color was the most reliable indicator of maturity of 'Gala.' There are several red coloring strains of 'Gala' available (10). With reduced nonred areas on these strains, it may be more difficult to determine visually the appropriate time to harvest 'Gala' for best quality and storage potential.

The onset of the ethylene climacteric is the most reliable and widely-accepted indicator of the status of ripening of an apple. Ripening frequently is quantified by selecting a somewhat arbitrary internal ethylene concentration (0.5-1 ppm) as the beginning of the climacteric. The pattern and kinetics of ethylene evolution in 'McIntosh' is typical of many apple cultivars. Once the internal ethylene concentration of 'McIntosh' reaches 0.5 or 1 ppm, ethylene production increases dramatically. In contrast, ethylene evolution in 'Gala' is substantially different. Ethylene levels in 'Gala' fruit rose in early September to 1.5 to 2.5 ppm and remained there for several weeks. It was not until well past the normal harvest period for 'Gala' that average internal ethylene levels reached 10 ppm. However, once harvested, 'Gala' fruit exhibit a rapid rise in internal ethylene to a level similar to 'McIntosh' (data not shown). Therefore, 'Gala' has the capacity to produce increased levels of ethylene, but increased ethylene production by the fruit is considerably delayed on the tree.

Titratable acidity usually reaches a peak during apple development and then declines slowly toward harvest (13). The decline in titratable acidity prior to and following normal harvest was very slow in this investigation. Taste panelists could not distinguish differences in acid levels among the harvest dates spaced 7 days apart, and the lack of change in acid levels was confirmed by acid determination. Titratable acidity in 'Gala' was considerably lower than in 'McIntosh.' Acidity declined significantly for both cultivars in storage and this reduction was detected by taste panelists. The rate of decrease was greater in 'McIntosh' than with 'Gala,' although 'McIntosh' always had considerably higher acid levels.

'Golden Delicious,' one of the parents of 'Gala,' frequently are kept in storage in boxes lined with plastic. It

appears that 'Gala' will benefit similarly from storage in plastic since weight loss and shriveling can be reduced. In previous years shriveling was noted in October in the storage but not until December in this investigation. The summer of 1988 was the hottest on record in Massachusetts in 50 years. Perhaps fruit developed a thicker and less permeable wax layer under the stressful conditions, which helped reduce water loss.

There were no differences in measured parameters or taste panel evaluations between fruit stored in paper compared with those stored in plastic-lined paper bags.

This study is the first of several reporting the ripening and storage properties of 'Gala' fruit. Many areas require further investigation, such as further definition of the optimum harvest date, performance in controlled atmosphere storage, and the nature of the initiation of ethylene biosynthesis.

Literature Cited

1. Anderson, J. E. 1984. Gala — An apple variety worthy of trial. Fruit Notes 49(2):18.
2. Ballard, J. K. 1988. Gala. Pacific NW Fruit Tester's Assoc. Variety Profile Sheet, April 1989.
3. Bramlage, W. J., D. W. Greene, W. R. Autio, and J. M. McLaughlin. 1980. Effect of aminoethoxyvinylglycine on internal ethylene concentrations and storage of apples. J. Amer. Soc. Hort. Sci. 105:847-851.
4. Ferree, D. C., R. C. Funt, and C. K. Chandler. 1988. Comparison of early performance and fire blight susceptibility of 12 early season apple cultivars. Fruit Var. J. 42(1):24-28.
5. Greene, D. W. and W. R. Autio. 1986. Gala: A new cultivar for New England. Fruit Notes 51(1):12-14.
6. Heintz, C. M. and A. A. Kader. 1983. Procedures for the sensory evaluation of horticultural crops. HortScience 18:18-22.
7. McKenzie, D. W. 1984. Trends in apple varieties in New Zealand. Proc. Wash. State Hort. Soc. 80:161-166.
8. McKenzie, D. W. 1985. Apple selection in New Zealand is recounted. Goodfruit Grower 36(5):48-51.
9. Norton, R. 1988. The apple variety picture; new choices for growers. Goodfruit Grower 39(9):35-39.
10. Norton, R. A., R. L. Stebbins, W. D. Lane, and J. K. Ballard. 1989. The strains of Gala, Fuji, and Jonagold described. Goodfruit Grower 40(7):7.
11. Stebbins, R. 1988. New apple varieties. Goodfruit Grower 39(9):32-34.
12. Stebbins, R. L. 1987. Gala: A new Early-maturing apple variety. Pac. NW Expt. Pub. 319.
13. Ulrich, R. 1970. Organic acids, p. 89-118. In: A.C. Hulme (ed.), the biochemistry of fruits and their products. Vol. 1. Academic Press, New York. Figures IA-F.