12. Lapins, K. O. 1974. Spur-type growth habit in 60 apple progenies. J. Amer. Soc. Hort. Sci. 99:568-572.
13. Lapins, K. O. 1976. Inheritance of compact growth type in apple. J. Amer. Soc. Hort. Sci. 101:133-135.
14. Lee, J. M. and N. E. Looney. 1977a. Branching habit and apical dominance of compact and normal apple seedlings as influenced by TIBA and GA3. J. Amer. Soc. Hort. Sci. 102:619-622.
15. Lee, J. M. and N. E. Looney. 1977b. Abscisic acid levels and genetic compaction in apple seedlings. Can. J. Plant. Sci. 57:81-85.
16. Looney, N. E. and W. D. Lane. 1984. Spur-type growth mutants of McIntosh apple: A review of their genetics, physiology and field performance. Acta Hort. 146:31-46.
17. Looney, N. E., J. S. Taylor, and R. P. Pharis. 1988. Relationship of endogenous gibberellin and cytokinin levels in shoot tips to apical form in four strains of 'McIntosh' apple. J. Amer. Soc. Hort. Sci. 113:395-398.
18. Oberle, G. D. 1965. The occurrence of spur-type trees in seedling apple populations. Fruit V2r. Hort. Dig. 19:43-46.
19. Olien, W. O. 1986. 'Chick-A-Dee McIntosh': A new spur-type strain. Fruit Var. J. 40:34.
20. Phinney, B. O. 1957. Growth response of single gene dwarf mutants in maize to gibberellic acid. Proc. Nat. Acad. Sci. 42:185-189.
21. Proctor, J. T. A. 1990. The 'McIntosh' apple. Fruit Var. J. 44:50-53.
22. Robitaille, H. A. and R. F. Carlson. 1971. Response of dwarfed apple trees to stem injections of gibberellic and abscisic acids. HortScience 6:639-640.
23. Robitaille, H. A. and R. F. Carlson. 1976. Gibberellin and abscisic acid-like substances and the regulation of apple shoot extension. J. Amer. Soc. Hort. Sci. 101:388-392.
24. Sachs, T. and K. V. Thimann. 1964. Release of lateral buds from apical dominance. Nature 201:939-940.
25. Sachs, T. and K. V. Thimann. 1967. The role of auxins and cytokinin in the release of buds from dominance. Amer. J. Bot. 54:136-144.
26. Thimann, K. V. 1937. On the nature of inhibitions caused by auxin. Amer. J. Bot. 24:407-412.
27. Tobutt, K. R. 1985. Breeding columnar apples at East Malling. Acta Hort. 159:63-68.
28. Tobutt, K. R. 1986. Breeding of apples and pears—Columnar apples. Annu. Rpt. E. Malling Res. Sta. for 1985. p. 61.
29. Trajkovski, V. 1986. Breeding work with apple, cherry and plum with aims for dwarfing and productivity. Compact Fruit Tree 19:138-143.
30. Vanderhoef, L. N. and R. R. Dute. 1981. Auxin regulated wall loosening and sustained growth in elongation. Plant Physiol. 67:164-169.
31. Yadava, U. L. and D. F. Dayton. 1972. The relation of endogenous abscisic acid to the dwarfing capability of East Malling rootstocks. J. Amer. Soc. Hort. Sci. 97:701-705.
32. Zagaja, S. W. and M. Faust. 1983. Population analysis of vigor and growth pattern of apple seedlings with short internode parentage. J. Amer. Soc. Hort. Sci. 108:939-944.

Fruit Varieties Journal 46(2):87-92 1992

Postharvest Quality of 'Virginia Gold' Apple Fruit

Osler C. Kamath, Mosbah M. Kushad[1,2] and John A. Barden[1]

Abstract

'Virginia Gold' (*Malus domestica* Borkh.) is cross between 'Golden Delicious' and 'Yellow Newtown' (Albamarle Pippin). 'Virginia Gold' fruit matures approximately 160 days from full bloom and, unlike 'Golden Delicious' fruit, it is not susceptible to russett except in the stem cavity. At maturity, soluble solids concentration (SS) is lower, while flesh firmness and starch index are similar to 'Golden Delicious.' In addition, titratable acidity (TA) and TA/SS ratio are higher in 'Virginia Gold' than in 'Golden Delicious.' 'Virginia Gold' fruit stored in a commercial controlled atmosphere storage were firmer than fruit held at regular cold storage, and the fruit did not shrivel even when stored for up to 8 months without polyethylene box liners.

'Virginia Gold' fruit is susceptible to soft scald (ribbon scald) when stored at low temperature. In 1988 and in 1990, 37% and 46% of the fruit developed soft scald when stored at -1.1°C, respectively. Soft scald was eliminated by storing the fruit at 2.2°C or by controlled atmosphere storage and was significantly reduced by dipping the fruit postharvest in a combination of diphenylamine and ethoxyquin.

[1]Assistant professor and professor, respectively, Department of Horticulture, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061-0327.
[2]To whom correspondence should be addressed.

Introduction

'Virginia Gold' is a cross between 'Golden Delicious' and 'Yellow Newtown' ('Albamarle Pippin') developed by Dr. G. D. Oberle and officially released in 1973 by the Virginia Polytechnic Institute, and State University Agricultural Experiment Station. Several growers in Virginia and West Virginia are interested in this cultivar for its desirable and distinct characteristics.

The tree of 'Virginia Gold' is moderately vigorous with a tendency toward alternate bearing unless properly thinned. Its pollen is viable and has produced good fruit set on other cultivars. In Blacksburg, Virginia the fruit matures uniformly at about the same time as 'Rome Beauty' or about 155-160 days from full bloom. Furthermore, fruit drop at maturity in this cultivar is not a serious problem.

Fruit color is bright golden-yellow with a finish that is superior to 'Golden Delicious' because russetting is seldom a problem except in the stem cavity. Compared to 'Golden Delicious,' the fruit skin is very waxy and the fruit does not shrivel as easily. The fruit diameter is approximately 1-3 cm larger than 'Golden Delicious' and the flavor resembles 'Yellow Newtown' with a suggestion of 'Golden Delicious' aroma. To date there has been no evaluation of the postharvest quality of this cultivar.

'Virginia Gold' is susceptible to soft scald. Soft scald is also called ribbon scald or deep scald (6) is distinctly different from superficial scald. It is identified by a sharp, ribbon-like brown discoloration of the skin; the exact cause of the disorder is not known. It is more severe in overmature fruit and in fruit that are placed in cold storage when their respiratory rate is high (6). Soft scald develops very rapidly during the first 3 months in storage, especially when the fruit are not cooled immediately. Our objective in this study was to evaluate the maturity and storage characteristics of 'Virginia Gold' fruit.

Materials and Methods

Six twelve-year old 'Virginia Gold' trees located at the Virginia Polytechnic Institute and State University farm in Blackburg, VA were selected for this study. The trees were grafted on MM.111 rootstock and spaced at 5.4 x 6 m. 'Virginia Gold' fruit maturity was compared to fruit harvested from six fifteen-year old 'Sundale Spur Golden Delicious' on MM.111 growing at the same location. Pest control and thinning were applied according to a commercial spray program developed by the Virginia and West Virginia Cooperative Extension Services.

Fruit maturity. In 1988 and 1990 'Virginia Gold' fruit were harvested on 9 October and 10 October and 'Golden Delicious' were harvested on 22 September and 24 September, respectively at mid-morning. A sample of 10 uniform fruit were collected from the outer canopy of each tree per cultivar and brought to the laboratory for immediate testing. Flesh firmness was measured on a pared fruit surface (two measurements per fruit) with an Effigi penetrometer fitted with an 11.1 mm plunger. Soluble solids concentration (SS) was determined with a hand refractometer (Atago N-1). Titratable acidity (TA) was determined by titrating a 10 ml juice sample with a 0.1 N NaOH to pH 8.1 and expressed as mg of malic acid-equivalent per ml of juice. The SS and TA were determined on a pooled juice sample from the 10 fruit per tree. Starch level was evaluated according to the Ontario scale for 'Golden Delicious' (8). The distal-half of each fruit was dipped in an iodine solution for 15 seconds and rated on a 1 to 9 index in which the starch concentration is inversely proportional to the index number. Ethylene production rate was determined by placing a 5 fruit subsample from each tree in a sealed 4-

liter glass jar for 1 h. A 1 ml air sample was withdrawn from each jar and injected into a Hitachi[R] gas chromatograph fitted with an activated alumina column and flame ionization detector.

Effect of storage type and scald inhibitors on 'Virginia Gold' fruit quality. Two 50-fruit samples were harvested from each of six 'Virginia Gold' trees on 9 October, 1988. One sample was stored at 0°C; the other sample was stored in commercial CA storage. The CA room was maintained at 2.5% O_2, 2% CO_2, and 0°C. Relative humidity in both the regular and the CA rooms was maintained at approximately 90%. Following 150 d in storage, one half of each sample was evaluated for firmness, SS, ethylene, and TA. Similar measurements were made on the remaining fruit from each sample after 7 days at room temperature. Fruit kept at room temperature was also evaluated from soft scald, superficial scald, breakdown, and bitter pit.

For the scald inhibition study, two samples of 50 'Virginia Gold' fruits were harvested on 9 October, 1988 from each of the same six trees described above. One sample per tree was dipped for 20 seconds in a mixture of 2 g/l diphenylamine (DPA) and 2.7 g/l 6-ethoxy-1, dihydro-2, 2, 4-trimethyl quinoline (ethoxyquin) (6) and the other sample was not treated. Apple samples were stored in 0°C air storage for 150 d and were then evaluated for superficial scald, soft scald, breakdown, and bitter pit.

Effect of storage temperature on soft scald development. In 1990 a study was conducted to determine the effect of storage temperature on soft scald development. Four samples of 80-fruit per tree were harvested on 10 October. Fruit were stored in wooden crates at either -1.1, 0, 1.1, or 2.2°C fruit-core temperature for 145 days. Fruit-core temperature was monitored in each room by inserting a fruit thermometer into the flesh of a single fruit to a depth of about 2 cm. Storage temperatures were adjusted twice each day as needed. Following storage fruit were evaluated for soft scald, superficial scald, firmness, and SS as described previously. Data were analyzed by ANOVA, Duncans multiple range test, LDS, and/or regression. Percentages data were transformed by arcsin square root prior to statistical analysis.

Results and Discussion

'Virginia Gold' fruit were harvested when the starch-iodine test reading was about 3.0 using the Ontario 'Golden Delicious' starch index of 1 to 9 (8). The number of days from full bloom to maturity in 1988 and 1990 were about 158 d and 162 d for 'Virginia Gold' and 151 and 153 for 'Golden Delicious,' respectively. At harvest 'Virginia Gold' and 'Golden Delicious' fruit firmness were very similar at approximately 70 N (Table 1). The most noticeable differences in maturity parameters between 'Virginia Gold' and 'Golden Delicious' were in SS and TA. 'Virginia Gold' fruit had higher

Table 1. Comparison of 'Virginia Gold' and 'Golden Delicious' apple fruit maturity parameters.[z]

Cultivar	Harvest date	Firmness (N)	SS (%)	TA (mg malate/ml juice)	Starch index
'Virginia Gold'	Oct. 9, 1988	70.0 a	11.3 b	6.9 a	3.2 a
'Golden Delicious'	Sept. 15, 1988	71.2 a	12.5 a	5.1 b	3.9 a
'Virginia Gold'	Oct. 10, 1990	68.9 a	11.9 b	6.7 a	3.4 a
'Golden Delicious'	Sept. 17, 1990	69.8 a	13.8 a	5.3 b	3.2 a

[z]Mean separation within year by LSD test, $P = 0.05$.
SS = Soluble Solids, TA = Titratable Acidity. Starch index is based on a scale of 1-9 in which starch concentration is inversely proportioned to the starch index.

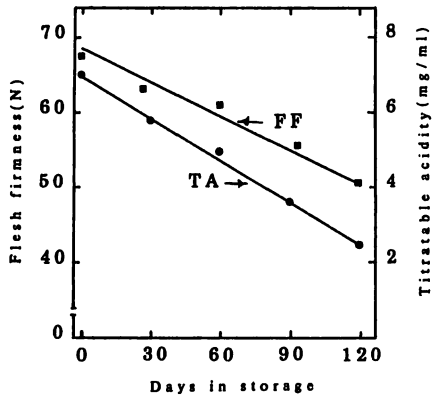

Figure 1. Regression of fruit firmness (FF) and titratable acidity (TA) of 'Virginia Gold' apple on days in storage. Regression equations are: for FF, Y = 68.5 - 0.15X and R^2 = 0.80°° for TA, Y = 7.0 - 0.03X and R^2 = 0.79°°. Data points are the means of 10 fruit per sampling date. Regression equations and R^2 values were calculated from the data within each mean.

TA and lower SS than 'Golden Delicious.' The TA to SS ratio for 'Virginia Gold' in 1988 and 1990 were 0.56 to 0.58, respectively, while 'Golden Delicious' had ratios of 0.41 and 0.38. The fruit of 'Virginia Gold' tasted slightly tarter and less sweet than 'Golden Delicious' fruit. There was no cultivar by harvest date interaction for all the maturity parameters tested, which suggests that maturity was similar in both seasons.

Fruit firmness declined with days in cold storage (-1.1°C) at a linear rate (R^2 = 0.80, Fig. 1). The softening rate of 'Virginia Gold' fruit in storage was approximately 0.15 N/day, which was considerably less than 'Golden Delicious' fruit, which softened at a rate of 0.27 N/day (data not included). After 150 d storage 'Virginia Gold' fruit were firmer when stored in CA than when stored at -1.1°C air storage (Table 2). The difference in firmness between CA and air stored fruit was even greater after the fruit were held at room temperature for 7 days (Table 2).

Unlike 'Golden Delicious' fruit which are commercially stored in polyethylene box liners to reduce shriveling, 'Virginia Gold' fruit shriveled little even when stored for up to 8 months; this is possibly due to the presence of a heavy wax layer on the skin surface of the fruit.

TA declined from 6.9 at harvest to 2.5 mg malate/ml juice after 4 months in regular cold storage (Fig. 1). The decline was linear with R^2 = 0.79 (Fig. 1). Liu and Samelson (5) showed a similar decline in TA during storage of 'McIntosh' apples. A positive correlation (R^2 = 0.74) was observed between TA and fruit firmness (data not shown).

Similar to 'Golden Delicious' (2), soluble solids in 'Virginia Gold' fruit remained relatively unchanged during cold storage and was not affected by storage type (Table 2). Ethylene was not detectable before harvest and during the first 12 days after harvest (data not shown). The lack of rise in ethylene synthesis immediately after

Table 2. Effect of controlled atmosphere storage on postharvest quality in 'Virginia Gold' fruit.

Storage type[y]	Firmness (N)	SS (%)	TA (mg malate/ml juice)	Ethylene (ul/kg/h)
Air storage (0°C)	50.0 b[z]	11.3 a	3.6 a	39 b
CA	57.6 a	11.3 a	3.7 a	44 b
Air storage + 7 DRT	46.0 c	11.0 a	2.6 b	193 a
CA + 7 DRT	54.5 ab	11.2 a	3.0 b	199 a

[z]Mean separation within column by Duncan's multiple range test, P = 0.05.
[y]Fruit were stored for 150 days. 7 DRT = fruit held at room temperature for 7 days prior to measurements.
SS = Soluble Solids, TA = Titratable Acidity.

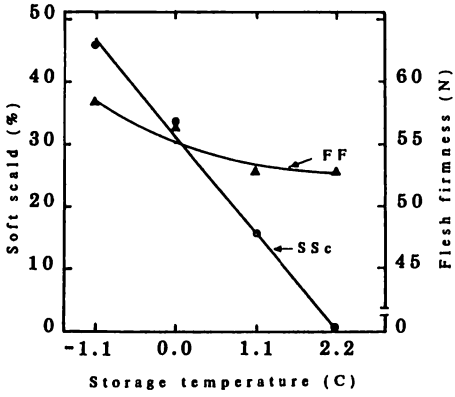

Figure 2. Regression of percent soft scald (SSc) and flesh firmness (FF) of 'Virginia Gold' apple on storage temperature. Regression equations are: for SSc, Y = 0.31 - 0.14X and R^2 = 0.80 and for FF, Y = 55.6 - 2.3X + 0.4X² and R^2 = 0.24. Data points are the means at each storage temperature. Percent SSc transformed by the arcsin square root prior to regression analysis. Regression and R^2 were calculated from data within each mean.**

harvest agrees with recent data on 'Granny Smith' (3). Ethylene production started to increase 30 days after harvest and reached its climacteric peak after 90 days in storage. A noticeable increase in ethylene production occurred several days following the onset of starch breakdown and a decline fruit firmness. These results are in agreement with the findings of Blankenship and Unrath (1), who suggested that ethylene production rate cannot be used as an indicator of maturity in certain apple cultivars.

In 1988, 37% of the fruit developed soft scald after 120 d storage at -1.1°C. There are some suggestions that soft scald is a disorder related to chilling-injury (6, 9); however, to our knowledge there had been no data published to support this suggestion. To determine the effect of storage temperature on soft scald, in 1990 mature 'Virginia Gold' fruit were stored at fruit-core temperatures of -1.1, 0, 1.1, and 2.2°C. Soft scald declined linearly with the increase in storage temperature (R^2 = 0.80, Fig. 2). Fruit held for 120 days at -1.1°C had 45% soft scald while fruit held at 2.2°C had 0% soft scald. The severity of soft scald was enhanced in the flesh but not in the skin when the fruit was kept at room temperature for 7 days. Fruit firmness declined with an increasing storage temperature in a quadratic manner (R^2 = 0.24, Fig. 2). Likewise, fruit stored at 2.2°C had a slight but not significant increase in rots (data not shown).

Soft scald was eliminated by storing the fruit in controlled atmosphere storage and was reduced by dipping the fruit in a commercial formulation of diphenylamine and ethoxyquin (Table 3). Porritt and Meheriuk (6) reported that the disorder can be prevented by subjecting the fruit to 20-30% CO_2 for 2 days during the beginning of storage. Warming the fruit to 38-42°C for 8-12 h before cold storage was also reported to reduce soft scald (6). From this and other it appears that soft scald is a chilling injury related disorder.

'Virginia Gold' is also susceptible to superficial scald, which is characterized by a brown discoloration of the hypodermal cells during storage; its causes and remedies have been the subject of a recent review (4). The

Table 3. Effect of scald inhibitors and controlled atmosphere storage (CA) on percent incidence of physiological disorders in 'Virginia Gold'.[z,y]

Treatment	Soft scald	Superficial scald	Bitter pit	Internal breakdown
	%			
Untreated Control	37 a[x]	0.0 a	2 a	0 a
DPA + ethoxyquin	9 b	0.4 a	1 a	0 a
CA	0 c	0.0 a	2 a	0 a

[z]Data transformed by arcsin square root prior to statistical analysis. Pretransformation values are shown.
[y]Fruit were stored for 150 days and evaluated after 7 days at room temperature.
[x]Mean separation within column by Duncan's multiple range test, P = 0.05.

disorder is effectively controlled by dipping the susceptible cultivars in a mixture of DPA and ethoxyquin (7). However 'Golden Delicious,' one of the parents of 'Virginia Gold,' develops bluish coloration of the skin when treated with DPA; therefore only ethoxyquin is recommended commercially on 'Golden Delicious' to control scald (6). In this study, treatment of 'Virginia Gold' fruit with a combination of DPA and ethoxyquin did not cause any visible skin injury. Furthermore, percent superficial scald, bitter pit, and internal breakdown were very low in 'Virginia Gold' immediately after storage (data not shown) and after 150 days cold storage plus 7 days at room temperature (Table 3).

In conclusion, 'Virginia Gold' is an attractive 'Golden Delicious' like apple cultivar. It is resistant to russetting and its skin finish and storage performance are superior to 'Golden Delicious.' The fruit does not shrivel in storage as easily as 'Golden Delicious' and therefore does not require polyethylene box liner to reduce moisture loss. Soft scald can be a serious problem in 'Virginia Gold' fruit, especially when they are stored at below 0°C. Storing the fruit under CA, at temperatures above 0°C, and treatment with scald inhibitors can effectively reduce this disorder.

Literature Cited

1. Blankenship, S. M. and C. R. Unrath. 1988. Internal ethylene levels and maturity of 'Delicious' and 'Golden Delicious' apple destined for prompt consumption. J. Amer. Soc. Hort. Sci. 113:88-91.
2. Couey, H. M. and K. L. Olsen. 1975. Storage response of 'Golden Delicious' apple after high-carbon dioxide treatment. J. Amer. Soc. Hort. Sci. 100:148-150.
3. Drake, S. R., F. E. Larson, and S. S. Higgins. 1991. Quality and storage of 'Granny Smith' and 'Greenspur' apples on seedling, M.26, and MM.111 rootstocks. J. Amer. Soc. Hort. Sci. 115:261-264.
4. Ingle, M. and M. C. D'souza. 1989. Physiology and control of superficial scald of apple: A review. HortScience 24:28-31.
5. Liu, F. W. and D. Samelson. 1986. Rates of change in firmness, acidity, and ethylene production of 'McIntosh' apples in simulated low-ethylene CA storage. J. Amer. Soc. Hort. Sci. 111:404-408.
6. Porritt, S. W. and M. Meheriuk. 1982. Postharvest disorders of apple and pears. Ag. Canada Pub. 1737/E pp. 51-52.
7. Porritt, S. W. and M. Meheriuk. 1968. Application of chemicals for control of apple scald. Can. J. Plant Sci. 48:495-500.
8. Priest, K. L. and E. C. Lougheed. 1981. Evaluating apple maturity using the starch-iodine test. Ontario ministry of Agriculture and Food AGDEX 211/59.
9. Smock, R. M. and G. D. Blanpied. 1969. The storage of apples. Cornell Ext. Bull. 440.

Rapid Production of O.3 Rootstock

Cuttings derived from tissue-cultured O.3 rootstock rooted well (94%) and the rooting effect persisted in cutting stem tissue cultured rootstocks grown for 1 year in the field. The growth rate of tissue cultured rootstocks exceeded that of cuttings and growth rate of both types was increased by added P and N to the nutrient solution. Trees on tissue-cultured rootstocks had more branches than those on cutting-derived rootstocks and the higher level of N. From Hogue and Neilsen. 1991. *HortScience* 26:1416-1419.

Erratum

In the paper by Esmaeil Fallahi in *Fruit Varieties Journal* 46(1):44-48 in Table 2 on page 47 the leaf mineral nutrient concentration for rootstock SWI should be as follows:

Rootstock[y]	N (%)	K (%)	Ca (%)	Mg (%)	Zn (ppm)	Cu (ppm)	Mn (ppm)	Fe (ppm)
SWI	2.23 efg	1.61 a	6.17 a	.414 de	20.1 abc	13.1 abc	10.8 de	42.3 cd