Influence of Apple Green Crinkle Disease on the Quality of Granny Smith Apples

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ABSTRACT

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Granny Smith apples infected with green crinkle (AGC), a graft-transmissible disease presumed but unproven to be incited by a virus, were 22% smaller than healthy apples. Fresh, infected Granny Smith apples were darker green with lower moisture content than uninfected apples. After 4 mo of cold storage, 30% of the infected apples deteriorated with an unidentified blossom end rot and became commercially unacceptable. Applesauce yield was significantly reduced when produced from infected apples. Increased drip loss in sauce and cook loss for sliced and frozen apple slices occurred. Decreased shear values occurred in infected apple slices, and the color of processed, infected fruit was a more pronounced yellow.

Additional key words: *Malus domestica*, postharvest

Commercial production of the Granny Smith apple cultivar is relatively new in the United States. In Washington State, Granny Smith has become an important cultivar, so that by 1982 it accounted for 1% of apple shipments from Washington (10). To date, little information is available concerning the future potential of Granny Smith, but interest in this cultivar has become widespread. The crop size for this cultivar already surpasses all but two of the older cultivars, Red Delicious and Golden Delicious. Information concerning production and storage of Granny Smith is extensive and covers many specific topics (2–5,7–9).

Diseases of apples, particularly those caused by viruses, can be serious problems in the production of Granny Smith (2). Apple green crinkle disease, caused by a graft-transmissible agent (AGC) presumed to be a virus, is one frequent serious pathogen of Granny Smith that occurs in many strains that vary in virulence from very mild to severe. As many as 10% of the trees grown in Tasmania are infected (5). Although the number of infected trees in the United States has not been accurately determined, the disease is common among the trees in earlier commercial plantings. More recent plantings of trees produced under good nursery improvement programs are free of AGC. Research has indicated that some virus diseases may influence fruit quality (3), but little information (5) is available concerning the influence of AGC on fruit quality, and none is available for Granny Smith or other cultivars planted in the United States. Accordingly, this study was initiated to determine in part the influence of AGC on the fresh and processed quality of Granny Smith apples.

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MATERIALS AND METHODS

This study was done over a 3-yr period using Granny Smith apple trees grown in the vicinity of the Washington State University Irrigated Agriculture Research and Extension Center, Prosser, WA. The test orchard was 9 yr old and comprised two sources of trees. Individual virus indexing of all trees determined that trees from both sources were totally infected with the common latent viruses apple chlorotic leaf spot, apple stem grooving, and apple stem pitting. However, the trees from one source were infected additionally with AGC, which provided the only detectable virus-pathogen difference. This strain of AGC appeared mild and produced neither "cat-faced" fruit nor foliage symptoms, although cat-faced fruit may have been removed early in the season during crop thinning. Fruit symptoms were evident in the spring, but they gradually became less pronounced by harvest. All trees had received identical cultural practices. Tree sampling consisted of 12 single-tree plots, six of which were AGC-infected and six of which were not.

Immediately after harvest, flesh color, firmness, soluble solids, pH, and titratable acidity were determined for 10 fruits from each tree. A box of fruit from each tree was then refrigerated at 1 C, removed at various intervals (0, 2, 4, and 6 mo), and evaluated. At the end of the storage period, flavonoids, nonflavonoids, total phenols, and total browning were determined on the fresh stored fruit. Fruit for processing were removed from storage after 6 mo and processed into sauce and canned and frozen slices.

Apples for sauce were sliced and immediately cooked for 5 min at 93.5 C. The cooled apple slices were then processed into sauce with a Langsenkamps pulper-finisher with a 1.25-cm screen. Water (25% by weight) was added to all lots, and the soluble solids were adjusted to 16° brix with dry sucrose. The sauce was heated to 83 C and poured hot into 303 × 406 cans. Sauce yield was determined by weight difference before and after each unit operation. The sealed cans were processed for 10 min at 98 C and cooled rapidly. Apples for slices were peeled, sliced, and blanched at 93.5 C for 5 min. Cook loss was determined by weight difference after each unit operation. A weighed amount of fruit was placed into 303 × 406 cans or 1.5-mil polyethylene bags. The canned slices were covered with 20% sucrose syrup, sealed, processed for 10 min at 98 C, and rapidly cooled. The bagged slices were placed in a blast freezer operating at −20 C. The canned and frozen products were stored for 30 days before evaluation.

Color of whole apples was determined with an Agtron Model E-5W reflectance spectrophotometer. The color of applesauce and apple slices was determined with an Agtron Model 300A reflectance spectrophotometer using the blue mode. A Food Technology Corporation Texture Test System equipped with a PT 1 penetration test set and a 1.1-cm probe was used to measure firmness of the whole apples. A CE-1 universal cell was used to measure the shear values for the sliced product. Shear values are reported as the amount of force required to shear 100 g of sliced product. Soluble solids were determined with a digital refractometer. A glass electrode pH meter with an expanded scale was used to determine pH. Titratable acidity was determined by titrating to an end point of pH 8.2 with 0.1 N NaOH and expressed as percent malic acid. Consistency of the applesauce was measured on a USDA flow sheet by prescribed procedures (12). Free liquor (weep) was determined by allowing 100 g of sauce to drip through one layer of cheesecloth for 30 min. Drip for frozen apple slices was measured after slices had been allowed to thaw at ambient temperature for 12 hr. Moisture and drained weight were determined by official methods (1).

Total browning of the stored apples was measured by noting the decrease of reflectance in the yellow mode on an Agtron Model 500A reflectance spectrophotometer calibrated with 00 and 90 disks immediately after blending a portion of apple tissue. Agtron readings after a 10-min interval were used as an indication of total browning. Nonflavonoids, flavonoids, and total phenols were determined by previously used methods (6,11). A randomized block design was used for data analysis.

RESULTS

Fresh Granny Smith apples infected with AGC weighed 22% less, were darker green in skin color, were softer, and contained relatively more moisture than uninfected apples (Table 1). Soluble solids, pH, and titratable acidity of fresh Granny Smith apples were not altered by AGC.

As storage time progressed from 0 to 6 mo, skin color of the AGC-infected apples became about 10% lighter green. Firmness decreased, but even though the decrease in firmness was significant, AGC-infected apples maintained an acceptable level of firmness for good commercial quality. Thirty percent of the infected apples were judged commercially unacceptable after only 4 mo of cold storage because of an unidentified, black, blossom end rot. This indicates an importantly reduced storage life for fruit infected with AGC. Soluble solids and pH increased and titratable acidity decreased during the storage period. This increase in the soluble solids/titratable acidity ratio generally enhances consumer acceptance by reducing the tart flavor found in Granny Smith apples before storage.

Apples with AGC showed a marked increase in nonflavonoids, flavonoids, and total phenols (Table 2). The increase in these compounds has a distinct influence on the color of the fresh and processed product.

Infected Granny Smith apples produced 11% less applesauce than uninfected apples (Table 3). In addition, sauce from apples infected with AGC had increased drip loss, a more pronounced yellow color (a lower Agtron 300A blue value), and lower moisture. USDA flow rate was not affected by AGC.

Cook loss during the production of canned and frozen apple slices was substantially greater (21%) for apples infected with AGC (Table 4). Increases in drained weight of canned apple slices occurred regardless of AGC, but canned slices from infected apples gained less (8%) than those from uninfected apples. A greater drip loss (21.3%) occurred from frozen apple slices produced from infected apples, and shear values (firmness) were reduced for apple slices. This reduction in firmness occurred in both canned and frozen slices produced from infected apples. A more pronounced yellow color occurred for both canned and frozen apple slices produced from infected apples.

Table 1. Quality attributes of Granny Smith apples as influenced by apple green crinkle disease

Apples	Fresh weight (g)	Color[y]	Firmness (newtons)	Soluble solids (%)	H_2O (%)	pH	Titratable acidity (% malic)
Healthy	176.1*[z]	43.5*	81.8*	12.4 NS	84.9*	3.41 NS	0.494 NS
Diseased	137.2	42.6	38.2	12.2	85.5	3.43	0.498

[y] Percent green measured by Agtron Model E-5W reflectance spectrophotometer.
[z] * = Mean separation within treatments in a column according to Duncan's multiple range test (significant at $P = 0.05$).

Table 2. Influence of apple green crinkle disease on total browning, nonflavonoids, flavonoids, and total phenols in Granny Smith apples

Apples	Total browning[y] after 10 min	Nonflavonoids	Flavonoids	Total phenols
Healthy	24.6*[z]	42.4*	15.8*	58.2*
Diseased	28.3	47.8	29.6	74.4

[y] Total browning measured by Agtron Model 500A reflectance spectrophotometer using yellow mode.
[z] * = Mean separation within treatments in a column according to Duncan's multiple range test (significant at $P = 0.05$).

Table 3. Quality attributes of canned applesauce produced from Granny Smith apples as influenced by apple green crinkle disease

Apples	Sauce yield (%)	USDA flow (cm)	Drip 30 min (ml)	Color[y]	H_2O (%)
Healthy	49.7*[z]	4.6 NS	17.4*	57.9*	80.8*
Diseased	44.7	4.6	18.7	46.7	80.4

[y] Percent blue measured by Agtron Model 300A reflectance spectrophotometer using blue mode.
[z] * = Mean separation within treatments in a column according to Duncan's multiple range test (significant at $P = 0.05$).

Table 4. Quality attributes of canned and frozen apple slices produced from Granny Smith apples as influenced by apple green crinkle

		Canned			Frozen		
Apples	Cook loss (%)	Drained weight gained	Shear (newtons)	Color[y]	Drip loss (%)	Shear (newtons)	Color[y]
Healthy	26.0*[z]	13.8*	69.5*	30.7*	137.0*	75.9*	45.7*
Diseased	32.8	12.7	52.8	25.9	174.0	67.7	30.8

[y] Percent blue measured by Agtron Model 300A reflectance spectrophotometer using blue mode.
[z] * = Mean separation within treatments in a column according to Duncan's multiple range test (significant at $P = 0.05$).

DISCUSSION

Infection with the causal agent of AGC apparently changes the quality of the fresh and processed product and reduces the weight of Granny Smith apples. Fresh Granny Smith apples infected with the causal agent of AGC are darker green with somewhat lower moisture content, a combination that could enhance market acceptance, but infected apples do not store well. After a short storage period, some apples begin to deteriorate with an unidentified, black, blossom end rot, although Granny Smith reportedly stores soundly for long periods. Applesauce yield from infected apples is definitely reduced, and quality was reduced by increased drip loss. However, the sauce from these infected apples had a more pronounced yellow color, which would increase consumer acceptance. Cook losses for apples were much higher when AGC-infected apples were used. Decreased shear values (firmness) occurred when infected apples were used, but the more intense yellow color was more desirable for sliced apples from AGC-infected fruit.

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