Effect of Feathery Mottle Virus Infection on Sweet Potato Sensory Properties

W. M. WALTER JR. and J. W. MOYER

ABSTRACT

Four sets of sweet potato clones obtained by meristem tip culture were used to investigate the effect of feathery mottle virus (FMV) infection on the appearance, sensory quality and chemical composition of the storage roots. This study, encompassing four generations, indicated that FMV infection had a slight effect on carbohydrate metabolism but no effect on the polyphenoloxidase-phenol system. Flavor and texture profile analyses indicated that for one clone, FMV-infected roots were more desirable when baked than healthy roots. Considering the study as a whole, FMV infection did not appear to adversely affect sweet potato sensory properties. Clones produced from the same parent by meristem tip culture might have different compositional and sensory properties.

INTRODUCTION

SWEET POTATO VIRUS DISEASES (SVD) have been reported in many parts of the world (Terry, 1982) and have in some instances been shown to affect yields (Hahn, 1979) and chemical composition (Chung et al., 1981). The names given to SVD are indicative of the symptoms produced on the foliage, in the roots, or on general plant morphology, and as a result, the identity of many of these diseases is not well established.

In the United States, most commercially grown sweet potatoes are infected with feathery mottle virus (FMV). The virus name describes the major observed symptom which is an irregular chlorotic lesion associated with the leaf veins of the plant foliage. Although selected strains cause symptoms in roots of certain cultivars, it is not known what effect the virus infection has on yields and quality as a result of altering normal metabolism in symptomless roots.

With improvement in methods to eliminate viral infection and to index (monitor) plants for viral infection (Ebenshade and Moyer, 1982), it has become possible to obtain sufficient plant material to measure the effect of FMV on sweet potato quality. This study was conducted to determine the effect of FMV on the biochemical and chemical composition of sweet potato roots and to relate these changes to root sensory properties.

MATERIALS & METHODS

Sweet potatoes

Four sets of healthy and virus-infected clones obtained from a common parent ('Jewel') by a meristem tip culture procedure (Moyer and Collins, 1982) were field-grown using recommended horticultural practices for North Carolina. Each clone originated from a different meristem. The virus-infected clones were obtained by graft-inoculating rooted cuttings of each healthy clone with FMV-injected scions of *Ipomoea setosa*. The original clones were determined to be healthy or virus-infected by repeated graft-indexing to *I. setosa*. Sprouts were transplanted in June and were harvested in October, approximately 120 days after transplanting. This study was conducted for four generations of plants, beginning in 1981 and ending with the 1984 crop. In 1983 insufficient sprouts were produced due to poor bedding conditions and, thus, the third generation was not included. After harvest, the roots were cured for 1 wk at 30°C and 85% relative humidity (RH) followed by storage at 13°C and 85% RH for 60 days.

Author Walter is affiliated with the U. S. Dept. of Agriculture, Agricultural Research Service, and North Carolina Agricultural Research Service, Dept. of Food Science, North Carolina State University, Raleigh, NC 27695–7624. Author Moyer is affiliated with the Dept. of Plant Pathology, North Carolina State Univ. Raleigh, NC 27695–7616.

Compositional analyses

After storage, each clone was divided into two lots. One lot was analyzed immediately; the second lot was baked prior to sensory evaluation and compositional analysis. Roots which were baked were prepared by thoroughly washing the periderm with water followed by air drying. The skin was pierced several times with a fork and the roots wrapped individually in aluminum foil. The roots were put on a tray and placed in a preheated, gas-fired convection oven set at 195–200°C. The roots were baked at that temperature for 90 min. After removal from the oven, the baked roots were cooled. The interior flesh was removed and passed through a collander (2 mm hole diameter). The collandered material was used for subsequent analyses and sensory evaluation. Moisture and alcohol-insoluble solids were measured on both raw and baked tissues (Walter, 1987). For those roots which were not baked, the peel was removed, the roots were quartered along the long axis, and a representative portion of the tissue was grated. The grated material served as the analytical samples.

Sugars. Ten-gram samples of tissue were blended with 50 mL 95% ethanol and 8 mL H_2O for 1 min. The mixture was quantitatively transferred to a 100 mL volumetric flask and held for 1 wk at room temperature. Individual sugars were measured on derivitized samples using gas chromatography (Walter and Hoover, 1984). The sugar content of both raw and baked material was measured.

Phenolics. Weighed tissue samples (ca. 10g) were homogenized with 95% ethanol, diluted to a final volume of 100 mL (80% ethanol) and allowed to equilibrate. A 4 mL aliquot was removed and evaporated to dryness under a stream of nitrogen followed by evacuation at ca. 1 mm Hg vacuum until constant weight was attained. The sample was removed and 1 mL ethanol containing 40 μg of coumarin (internal standard) was added. The mixture was sonicated, allowed to stand for 1 hr and filtered through a 0.2 μm filter. From 4–7 μL were injected into an HPLC for each analysis. The HPLC system was similar to that described earlier (Walter and Giesbrecht, 1982) except a Waters model 660 solvent programmer replaced the two-chambered gradient maker. The gradient program began with 16% methanol in 0.033 M phosphate buffer (pH 3.3) and ended with 40% methanol in the same buffer. Curve 6 on the programmer was used; the gradient change occurred during the first 15 min of the 27-min run. Phenols were detected at 334 nm with a Varian Varichrome variable wavelength detector. Quantitation was accomplished by electronic integration of peak areas.

Polyphenoloxidase and darkening. Polyphenyloxidase (PPO) activities and darkening values were measured as previously described (Walter and Purcell, 1980). Phenolics, PPO activity and darkening values were measured on raw sweet potatoes only.

Sensory analysis

Flavor and texture profiles were established by a panel trained in both flavor (Cairncross and Sjostrom, 1950) and texture (Civille and Szczesniak, 1973) profiling. The panel consisted of 6 or 7 individuals for each session. Scores for flavor and texture notes were based on a descriptive intensity scale that was converted to a 1 to 14 numerical scale for statistical analyses. A score of 1 = not detectable and a score of 14 = extremely intense. A single lot of canned sweet potatoes was used as the standard for treatment comparisons for both years.

Table 1—Composition of healthy and virus-infected sweet potato clones (raw)[a,b]

Clone	% Moisture[c]	% Alcohol-insoluble solids[c]	Polyphenol-oxidase activity[d]	Chloro-genic acid[e]	Isochloro-genic acid[e]	% Total sugars[c]	% Fructose	% Glucose[c]	% Sucrose[c]	% Darken-ing[f]
J-49										
Infected	74.74	17.70	44.69	5.30	8.13	6.78	0.96	1.21	4.60	0.143
Healthy	74.86	18.32	55.59	4.45	6.46	6.93	1.05	1.31	4.57	0.169
N[g]	13	11	13	13	13	9	9	9	9	13
J-574										
Infected	74.64	17.41	56.67	6.31	10.31	7.07	1.07	1.37	4.63	0.203
Healthy	74.02	16.72	49.84	6.88	9.37	6.94	1.00	1.28	4.55	0.189
N[g]	13	11	13	13	13	9	9	9	9	13
J-88										
Infected	76.14	15.36	54.37	4.39	7.97	6.05	0.97	1.13	3.95	0.213
Healthy	75.05	17.30	47.88	5.27	9.31	5.58	0.95	1.07	3.56	0.212
N[g]	13	11	13	13	13	9	9	9	9	13
J-299										
Infected	74.95	16.69	37.44	4.57	6.65	5.65	0.98	1.17	3.51	0.193
Healthy	74.55	17.01	44.87	4.36	7.35	5.45	1.11	1.32	3.60	0.233
N[g]	13	11	13	13	13	9	9	9	9	13

[a] Combined data for three generations.
[b] No statistically significant differences (P≤0.05) observed between infected and healthy samples from the same clone for each of the compositional parameters.
[c] % of fresh weight.
[d] Change in absorbance per min per g tissue at 450 nm.
[e] mg/100 g tissue.
[f] Absorbance of tissue homogenate at 420 nm.
[g] No. of observations.

Table 2—Composition of healthy and virus-infected sweet potato clones (baked)[a]

Clones	% Moisture	% Alcohol-insoluble solids	% Total sugars	% Fructose	% Glucose	% Sucrose	% Maltose
J-49							
Infected	71.89	9.58	15.19	1.07	1.29	3.86	8.96
Healthy	71.98	10.04	15.64	1.11	1.25	3.84	8.88
N[b]	9	9	9	9	9	9	9
J-574							
Infected	70.55	10.26	14.74	0.92	1.08	3.57	9.16
Healthy	71.66	9.94	15.42	1.04	1.33	3.94	9.19
N[b]	9	9	9	9	9	9	9
J-88							
Infected	73.54	7.88	13.54	1.11	1.21	3.78	7.25
Healthy	73.84	7.83	13.24	1.19	1.29	3.55	7.21
N[b]	9	9	9	9	9	9	9
J-299							
Infected	72.30	8.77	14.13	1.09*[c]	1.27**[c]	3.54	8.22
Healthy	71.44	8.73	15.71	1.28	1.48	3.97	8.98
N[b]	9	9	9	9	9	9	9

[a] All values in % of cooked weight (collandered material). Combined data for three generations.
[b] No. of observations.
[c] Means are different at P≤0.05 level (*) or P≤0.01 level (**).

Table 3—Composition of the second and fourth generations of healthy and virus-infected sweet potato clones (baked)[a]

Clone	Compositional component	Treatment	Mean
J-49	% Alcohol-insoluble solids	Infected	9.54
		Healthy	10.25
J-574	% Sucrose	Infected	3.45
		Healthy	4.14
J-299	% Fructose	Infected	1.12
		Healthy	1.37
	% Glucose	Infected	1.23
		Healthy	1.53

[a] Within each clone and compositional component, means for healthy and infected are different at P≤0.05.

The number of flavor and texture profile descriptive notes developed by Hamann et al. (1980) were reduced to eliminate interdependent notes (Syarief et al., 1985a, b). Flavor notes were: (1) sweet basic—sweet perceived on the taste buds of the tongue; (2) starch—resembling the typical flavor of white potato, an awareness of potato starch; (3) caramel—cooked sugar flavor. In addition, the panels detected an off-flavor note in some clones which was described as cold damage. The texture notes were: (1) first bite moistness—degree to which sample feels moist in mouth; (2) mastication gumminess—amount of energy required to disintegrate the sample for swallowing; (3) residual ease of swallow—effort required to swallow sample.

Sensory evaluations were performed from 10:00 a.m. to 11:00 a.m. At each session, the panelists evaluated four coded samples. Each set of four samples consisted of two clones, one clone of each set was virus-infected, and the other was healthy. Individual scores and the consensus score for each character note were subjected to statistical analysis.

Statistical analysis

The SAS PROC TTEST procedure (SAS, 1982) was performed to determine the significance between infected and healthy tissue. Significant differences were accepted at the 5% level of probability.

RESULTS & DISCUSSION

Compositional analyses

Comparison of the composition of healthy and virus-infected, raw sweet potatoes gave no indication that the infection had affected any of the parameters measured over the four generations in this study (Table 1). The parameters selected for analysis represent aspects of sweet potato quality. The moisture content, alcohol-insoluble solids and sugar content have an impact on the sensory properties, sweetness and mouthfeel. The PPO, chlorogenic acid, isochlorogenic acid and degree of darkening influence the visual appeal of sweet

Table 4—Flavor and texture scores for healthy and virus-infected, baked sweet potato clones[a,b]

Clone	Flavor notes			Texture notes			
	Sweet basic	Starch	Caramel	First-bite moistness	Mastication gumminess	Ease of swallow	Cold hurt
J-49							
Infected	6.40**	2.00	4.2**	9.07	5.93*	11.40**	1.00**
Healthy	4.73	2.33	3.0	8.53	7.33	10.20	2.14
N	15	15	15	15	15	15	14
J-574							
Infected	5.73*	2.33	4.00**	8.07	7.73	9.53	2.08**
Healthy	4.40	2.47	2.67	8.27	7.47	10.07	1.00
N	15	15	15	15	15	15	13
J-88							
Infected	5.14	2.29	3.00	8.50	7.71	10.57	1.57
Healthy	4.28	2.43	2.57	8.43	7.00	10.92	1.64
N	14	14	14	14	14	14	14
J-299							
Infected	5.07	2.57	2.71	7.86**	7.29*	10.50*	1.71
Healthy	5.07	2.79	3.07	6.50	8.93	9.29	1.36
N	14	14	14	14	14	14	14

[a] Data for two generations.
[b] Means for healthy and infected are different; * at P≤0.05; ** at P≤0.01.

Table 5—Compositional data for raw sweet potato clones[a]

Clone	Dry matter[b]	Alcohol-insoluble solids[b]	PPO[c]	Chlorogenic acid[d]	Isochlorogenic acid[d]	Darkening[e]	Fructose[b]	Glucose[b]	Sucrose[b]	Total sugar[b]
J-49	25.20^{A}	18.01^{A}	50.14^{A}	4.87^{B}	7.29^{B}	0.156^{B}	1.01^{A}	1.26^{AB}	4.59^{A}	6.85^{A}
J-574	25.67^{A}	17.06^{AB}	53.25^{A}	6.59^{A}	9.84^{A}	0.196^{AB}	1.03^{A}	1.33^{A}	4.59^{A}	6.95^{A}
J-88	24.41^{B}	16.34^{B}	51.12^{A}	4.84^{B}	8.64^{AB}	0.213^{A}	0.96^{A}	1.10^{B}	3.75^{B}	5.81^{B}
J-299	25.26^{A}	16.85^{B}	41.15^{B}	4.47^{B}	7.00^{B}	0.213^{A}	1.04^{A}	1.26^{AB}	3.55^{B}	5.85^{B}

[a] Clones produced from a common parent (cv. 'Jewel') by meristem tip culture. Means in the same column with the same superscript are not different (P≤0.05).
[b] Percent of raw weight.
[c] Change in absorbance per min per g tissue at 450 nm.
[d] mg/100 g of tissue.
[e] Absorbance of tissue homogenate at 420 nm.

Table 6—Compositional data for baked sweet potato clones[a,b,c]

Clone	Dry matter	Alcohol-insoluble solids	Fructose	Glucose	Sucrose	Maltose	Total sugar
J-49	28.06^{B}	9.81^{A}	1.09^{A}	1.27^{B}	3.85^{A}	8.92^{A}	15.13^{A}
J-574	28.90^{B}	10.09^{A}	0.98^{B}	1.20^{B}	3.75^{A}	9.18^{A}	15.11^{A}
J-88	26.31^{A}	7.85^{C}	1.15^{A}	1.25^{B}	3.76^{A}	7.23^{B}	13.39^{B}
J-299	28.13^{B}	8.75^{B}	1.18^{A}	1.38^{A}	3.67^{A}	8.60^{A}	14.83^{A}
LSD[d]	1.02	0.43	0.10	0.10	0.30	0.85	1.03

[a] Percent of baked weight.
[b] Clones produced from a single parent ('Jewel') by meristem tip culture.
[c] Means in the same column with the same superscript are not different (P≤0.05).
[d] Least significant difference (P≤0.05).

potatoes. These parameters are related to the phenolic-PPO system which causes a brown discoloration of the flesh. The enzyme (PPO) and the substrates (chlorogenic acid and its isomers) have been implicated in discoloration of various fruits and vegetables (Walter and Purcell, 1980; Weaver and Charley, 1974; Mondy et al., 1967).

Since it is possible that the viral infections worsen with each succeeding generation, the composition within clones for the last two generations was separated and statistically analyzed. The only statistically significant difference was observed for PPO activity in clone J-299. For PPO the infected clone had a PPO activity of 20.6 units, while the healthy clone had an activity of 35.4 units (P≤0.01). Thus, the infected clone appeared to be less susceptible to enzymatic discoloration due to PPO than did the healthy clone.

When a sweet potato is baked, endogenous amylolytic enzymes hydrolyze the starch into sugars (mainly maltose) and thus cause a sweet taste and the mouthfeel sensation to become softer and smoother than the uncooked root. If viral infection interfered with the starch hydrolysis, quality would be impaired. The data showed this did not occur. The only statistically significant differences for three generations between healthy and virus-infected clones were in fructose and glucose concentrations (Table 2). For both sugars the healthy tissue had a slightly high concentration than the infected tissue. However, the differences were so slight as to be nondetectable sensorially. Analysis of data from the second and fourth generations showed that three of the clones had statistically different amounts of several of the components. In cultivar J-49 the healthy tissue contained more alcohol-insoluble solids, while in clones J-574 and J-299 healthy tissue had higher levels of sucrose and fructose plus glucose, respectively (Table 3). This indicated that the virus infection might have had some effect on the carbohydrate metabolism.

Sensory analysis

In the United States, the preferred sweet potato has a deep orange color, tastes sweet and has a smooth, creamy consis-

tency when masticated. This smooth, creamy texture is commonly referred to as "moistness." In a comparison of two treatments such as were used in this study, the following would be a desirable change. For flavor notes, the preferred sweet potato would have a higher sweet basic score, a lower starch score and a higher caramel score. For texture notes, the preferred sample would have a higher first-bite moistness score, a lower mastication gumminess score and a higher ease of swallow score.

The data indicate (Table 4) that for cultivars J-49 and J-574, the infected roots have more desirable flavor notes, sweet basic and caramel. The starch flavor note scores were not different. Among the texture note scores for J-49, infected roots had a higher ease of swallow score than did healthy roots and a lower mastication gumminess score. All of these scores are consistent, with J-49 infected being more desirable sensorially than J-49 healthy. The only other clone showing different scores for texture notes was J-299. Again, infected clone scores were consistent with a higher quality baked root than healthy clone scores. Healthy and infected texture note scores for clone J-574 were not different. For the remaining clone, J-88, no differences were detected in either flavor or texture note scores between healthy and infected roots.

The off-flavor detected (cold hurt) by the panel was found both years in infected roots from clone J-574, indicating that under some environmental conditions the virus might cause an off-flavor in this clone. In clone J-49, the off-flavor was noted in healthy roots for 1 year only and, thus, was probably due to an environmental effect only. Although detected in the remaining clones, there was no statistically significant difference in scores between healthy and virus infected tissues.

The data obtained in this study indicated that feathery mottle virus infection might cause subtle changes in the metabolic pathway affecting carbohydrates. There was no evidence to indicate that the phenol-PPO system was affected by virus infection. Sensory studies suggested that for one clone, J-49, infected roots were more desirable than healthy roots. Considering the study as a whole, FMV infection did not appear to adversely affect sweet potato quality.

Although this virus has little effect on the sensory qualities of the clones of 'Jewel' sweet potato, the observed between-clone variability for compositional and sensory properties (Tables 5 and 6) is consistent with variation in flesh and skin color observed between meristem tip culture-derived clones of 'Jewel' (Moyer and Collins, 1983). Thus, it might be necessary to evaluate cultivars following meristem tip culture to select clones for propagation with properties equal to or better than the original clone and to avoid inadvertent selection of a less desirable clone.

REFERENCES

Cairncross, S. E. and Sjostrom, S. B. 1950. Flavor profiles—a new approach to flavor problems. Food Technol. 4: 308.

Chung, M. L., Lias, C-S., and Li, L. 1981. Effect of virus infection on the yield and quality of sweet potatoes. Plant Prot. Bull. (Taiwan, R.O.C.) 23: 137.

Civille, G. V. and Czczesniak, A. S. 1973. Guidelines for training a texture profile panel. J. Text. Stud. 4: 204.

Ebenshade, P. R. and Moyer, J. W. 1982. An indexing system for sweet potato feathery mottle virus in sweet potato using the enzyme-linked immunosorbent assay. Plant Disease 66: 911.

Hahn, S. K. 1979. Effects of viruses (SPVD) on growth and yield of sweet potatoes. Exp. Agric. 15: 253.

Hamann, D. D., Miller, N. C., and Purcell, A. E. 1980. Effects of curing on the flavor and texture of baked sweet potatoes. J. Food Sci. 45: 992.

Mondy, N. I., Owens-Mobley, E., and Gedde-Dahl, S. B. 1967. Influence of potassium fertilizer on enzymatic activity, phenolic content, and discoloration of potatoes. J. Food Sci. 32: 378.

Moyer, J. W. and Collins, W. W. 1982. Meristem tip culture of sweet potatoes. HortSci. 17: 157.

Moyer, J. W. and Collins, W. W. 1983. 'Scarlet' sweet potato. HortSci. 18: 111.

SAS. 1982. "SAS User's Guide: Statistics." SAS Institute, Inc., Cary, NC.

Syarief, H., Hamann, D. D., Giesbrecht, F. G., and Young, C. T. 1985a. Interdependency and underlying dimensions of sensory textural characteristics of selected foods. J. Text. Stud. 16: 29.

Syarief, H., Hamann, D. D., Giesbrecht, F. G., Young, C. T., and Monroe, R. J. 1985b. Interdependency and underlying dimensions of sensory flavor characteristics of selected foods. J. Food Sci. 50: 631.

Terry, E. R. 1982. Sweet potato (*Ipomoea batatas*) virus diseases and their control. In "Sweet Potato. Proceedings of the First International Symposium." R. L. Villareal and T. D. Griggs (Ed.), p. 161. Asian Vegetable Research and Development Center, Shanhua, Tainan, Taiwan, China.

Walter, W. M. Jr. 1987. The effect of curing on sensory properties and carbohydrate composition of baked sweet potatoes. J. Food Sci. In Press.

Walter, W. M., Jr. and Giesbrecht, F. G. 1982. Effect of lye peeling conditions on phenolic destruction, starch hydrolysis and carotene loss in sweet potatoes. J. Food Sci. 47: 810.

Walter, W. M. Jr. and Hoover, M. W. 1984. Effect of pre-processing storage conditions on the composition, microstructure and acceptance of sweet potato patties. J. Food Sci. 49: 1258.

Walter, W. M., Jr. and Purcell, A. E. 1980. Effect of substrate levels and polyphenol oxidase activity on darkening in sweet potatoes. J. Agric. Food Chem. 28: 941.

Weaver, C. and Charley, H. 1974. Enzymatic browning of ripe bananas. J. Food Sci. 39: 1200.

Ms received 1/30/87; revised 4/27/87; accepted 4/27/87.

Paper no. 10754 of the Journal Series of the North Carolina Agricultural Research Service, Raleigh, NC 27695-7601.