# Analysis of the Volatile Constituents of Baked, "Jewel" Sweet Potatoes

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The volatile organic compounds of baked, "Jewel" sweet potatoes were trapped on porous polymer precolumns and analyzed by capillary column gas chromatography/mass spectrometry. Thirty compounds were identified: methanol, ethanol, acetone, diethyl ether, dichloromethane, 2,3-butanedione (diacetyl), 3-methylpentane, hexane, tetrahydrofuran, methylcyclopentane, 2,3-pentanedione, methylbenzene (toluene), 2-methyltetrahydrofuran-3-one, furfuraldehyde, dimethylbenzene (xylene), isobutyronitrile, 2-pyrone, heptanal, 2-furyl methyl ketone, benzaldehyde, 5-methyl-2-furaldehyde, trimethylbenzene (mesitylene), octanal, 2-pentylfuran, phenylacetaldehyde, nonanal, linalool, decanal, β-ionone, and 4-(2,2,3,3-tetramethylbutyl)phenol.

One of the major characteristics of sweet potato flavor is sweetness, which is due to the presence of sucrose and maltose (Stone, 1890; Hasselbring and Hawkins, 1915; Sinoda et al., 1931). In addition, sweet potatoes emit a delightful aroma while cooking, indicating that the volatile constituents contribute to the total flavor. There are marked differences in flavor due to cultivar (Constantin et al., 1966; Lanier and Sistrunk, 1979); there are also changes in flavor factors other than sweetness which are associated with curing and storage (Hamann et al., 1980). To date, no attempt to identify the volatile components of sweet potatoes has been reported.

This report describes the analysis of the volatile organic constituents of baked, "Jewel" cultivar sweet potatoes.

## MATERIALS AND METHODS

**Sweet Potatoes.** "Jewel" sweet potatoes were grown at the North Carolina Agricultural Research Service Central Crops Research Station near Clayton, NC. Standard cultural practices were used (Covington et al., 1976), and the roots were cured and stored at 13 °F (Kushman and Wright, 1969) until shipped to Brigham Young University, Provo, UT. As the roots were received, they were examined for defects caused by shipping. Healthy roots were stored at 13 °C until used, and damaged roots were discarded.

Selected roots were baked in an electric convection oven at 190 °C for 90 min. The edible portion was scooped out of the peel, mixed with a fork, and stored at 2–4 °C until analyzed.

**Concentration of Volatiles.** Volatiles were concentrated by collection on porous polymer (Tenax GC) precolumns by methods previously described (Novotny et al., 1974a,b; Lee et al., 1979). A 40-g sample of homogenized baked sweet potato parenchyma was heated at 90 °C in a 1-L, water-jacketed sampling jar, and dry helium, 100 mL/min, swept the sample volatiles onto a Tenax cartridge (20 mg of Tenax GC contained in a 3 mm i.d. × 65 mm glass tube) held at 25 °C. The cartridge was stored in a screw-cap, Teflon-lined centrifuge tube at −10 °C until analyzed by gas chromatography.

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Table I. Components of Sweet Potato Volatiles Identified by Mass Spectroscopy

| peak no.[a] | compd | retention time, min |
|---|---|---|
| 1 | methanol | 5.6[b] |
| 2 | ethanol | 5.8[b] |
| | acetone | 5.9[b] |
| | diethyl ether | 6.1[b] |
| 3 | dichloromethane | 6.6 |
| 4 | 2,3-butanedione (diacetyl) | 7.2[b] |
| 5 | 3-methylpentane | 7.7 |
| 6 | hexane | 8.3[b] |
| 7 | tetrahydrofuran | 8.6 |
| | methylcyclopentane | 8.9 |
| 8 | 2,3-pentanedione | 10.0 |
| 9 | methylbenzene (toluene) | 13.3[b] |
| 10 | 2-methyltetrahydrofuran-3-one | 14.7 |
| 11 | furfuraldehyde | 15.6[b] |
| 12 | dimethylbenzene (xylene) | 18.1[b] |
| | isobutyronitrile | 18.3 |
| | 2-pyrone | 18.6 |
| 13 | heptanal | 19.7[b] |
| 14 | 2-furyl methyl ketone | 20.0 |
| 15 | benzaldehyde | 22.4[b] |
| 16 | 5-methyl-2-furaldehyde | 22.8 |
| 17 | trimethylbenzene (mesitylene) | 26.3 |
| 18 | octanal | 26.6 |
| 19 | 2-pentylfuran | 27.6 |
| 20 | phenylacetaldehyde | 30.0[b] |
| 21 | nonanal | 33.8 |
| 22 | linalool | 34.7 |
| 23 | decanal | 41.0 |
| 24 | β-ionone | 44.7[b] |
| 25 | 4-(2,2,3,3-tetramethylbutyl)phenol | 55.5 |

[a] Peak numbers refer to Figure 1. [b] Retention times and mass spectra were verified with standard reference compounds.

**Gas Chromatography.** A "W" trap was formed with the first 20 cm of a glass capillary column, 80 m × 0.28 mm i.d., coated with SF-96 methylsilicone stationary phase. The column was installed in a Perkin-Elmer Model 3920 gas chromatograph with the injection port modified to accept the precolumn cartridges. The helium carrier gas was adjusted to a flow rate of 4 mL/min. With the column at 25 °C, the column trap was cooled with liquid nitrogen in a small Dewar flask. The precolumn was introduced into the injector port which was maintained at 250 °C. Volatiles were thermally desorbed from the precolumn and swept into the capillary trap for 10 min. The Dewar flask containing the liquid nitrogen was then removed from the trap and, after 4 min at 25 °C, the oven temperature was raised to 190 °C at 4 °C/min.

**Standards.** Samples of many compounds tentatively identified by mass spectrometry were obtained from var-

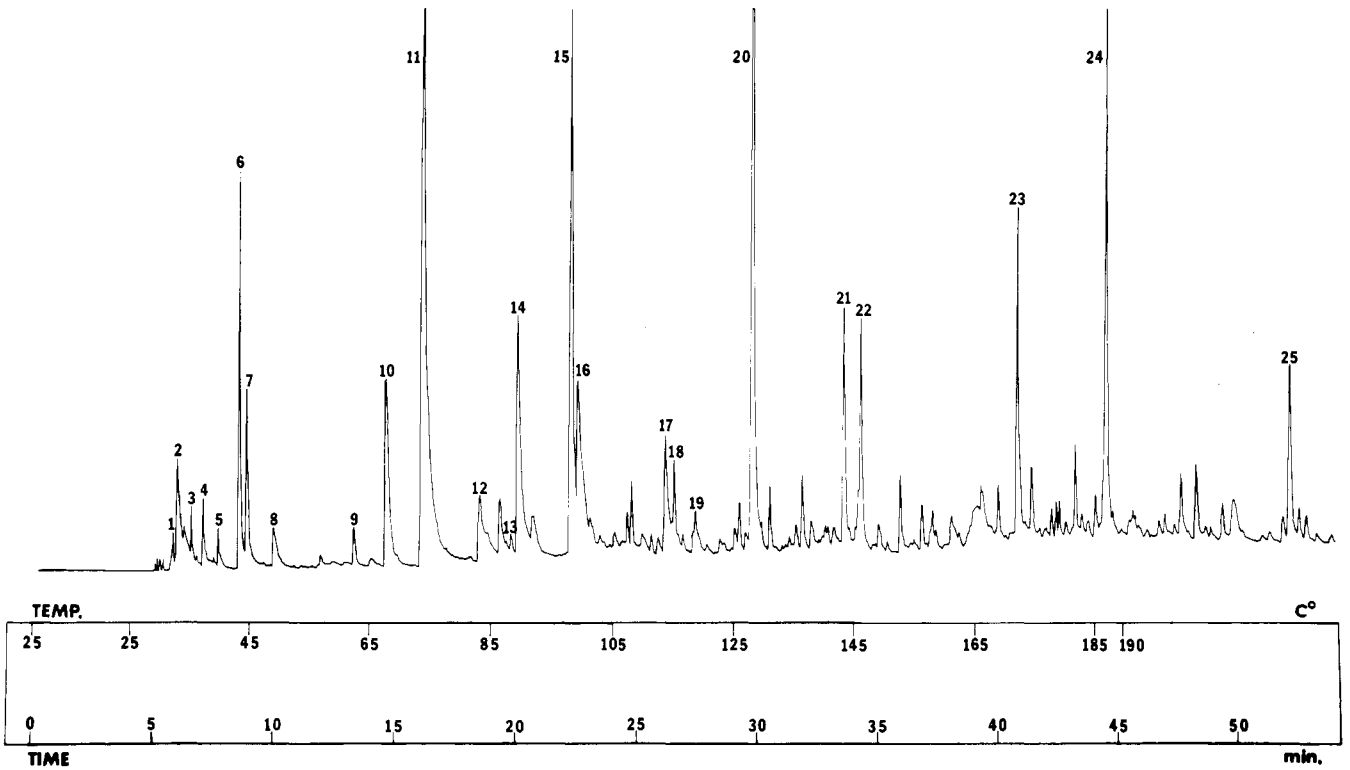


**Figure 1.** Typical chromatogram of the volatile fraction of baked, "Jewel" sweet potatoes. Conditions were as described in the text.

ious commercial sources and used as standards to verify retention and mass spectral data. These compounds are indicated in Table I. The remaining compounds were identified by comparing their mass spectra with published spectra (Stenhagen et al., 1974).

**Mass Spectrometry.** Volatile components were identified by combined gas chromatography/mass spectrometry. The instrument used was a Hewlett-Packard Model 5982A gas chromatograph/mass spectrometer coupled to a 5934A data system. The same capillary column and conditions were used in this chromatographic system as were used in the Perkin-Elmer 3920. The electron impact ionization energy was 70 eV, and the scan rate was 80 amu/s.

## RESULTS AND DISCUSSION

Figure 1 is a chromatogram of the volatiles from baked, "Jewel" sweet potatoes. The numbered peaks are identified in Table I. Many peaks in the chromatogram were not identified because the mass spectral fragmentation patterns could not be easily solved. Further work is being done in this area.

Some of the compounds identified in sweet potato volatiles are similar to those isolated from heated glucose, e.g., furfuraldehyde and diacetyl (Walter and Fagerson, 1968). All of the compounds identified have been previously identified in the volatiles of other products, e.g., cooked vegetables (MacLeod and MacLeod, 1970), baked white potatoes (Buttery et al., 1973), roasted peanuts (Cobb and Johnson, 1973), and pressure-cooked pork liver (Mussinan and Walradt, 1974). Volatiles from all of the above sources contain large amounts of various pyrazines, none of which were identified in sweet potato volatiles.

Buttery et al. (1973) concluded that baked white potato contained less pyrazine than potato chips because the internal baking temperature did not exceed 100 °C. They postulated that the pyrazines which they did find in baked white potato may have migrated from the skins which had reached a higher temperature after they had dried. Temperatures of the sweet potatoes were probably similar to those of white potatoes, but nothing is known about the relative permeabilities of the nonedible subskin layers of sweet potatoes and those of white potatoes.

Much of the starch in "Jewel" sweet potatoes but not in white potatoes is converted to maltose during baking (Walter et al., 1975). The conversion of starch to maltose greatly increases the number of carbonyl groups in the sweet potato. Perhaps they contribute to the formation of furan and furan derivatives found in the sweet potato volatiles.

The relationship of the identified compounds to the aroma of baked sweet potatoes has not yet been established. There are differences in the aroma of different sweet potato cultivars (Constantin et al., 1966); thus, there may be differences in specific aroma precursors which have not yet been identified. The identification of such precursors may permit selection and marketing of sweet potatoes with consistently good flavor.

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# Effect of Substrate Levels and Polyphenol Oxidase Activity on Darkening in Sweet Potato Cultivars

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Homogenization of sweet potato in the presence of oxygen causes differing degrees of brown discoloration to occur, depending upon the cultivar. When browning occurs in processed sweet potato, it is a serious quality defect. In order to better understand browning, five sweet potato cultivars produced in two crop years were evaluated by relating browning to phenolic content, polyphenolase activity, and ascorbic acid levels. Browning was found to be significantly correlated only to phenolic content. Considerable within-year and year-to-year cultivar variation was observed in browning potential.

Although sweet potatoes do not discolor when cut or sliced as do certain fruits like peaches (Guadagni et al., 1949) or apples (Harel et al., 1966), they do darken or brown when heat processed (Scott et al., 1944). Scott et al. (1944) demonstrated that discoloration occurred when the outer portion of sweet potato roots was subjected to elevated temperatures not high enough to denature enzymes, but sufficient to disrupt cellular organization and, thus, cause polyphenol oxidase to react with "tannins". Since their report, the polyphenol oxidase (PPO; *o*-diphenol:$O_2$ oxidoreductase, EC 1.10.3.1) of sweet potato has been studied by several groups and shown to consist of soluble and particulate fractions specific for *o*-diphenols, especially chlorogenic acid and its isomers (Eiger and Dawson, 1949; Arthur and McLemore, 1956; Hyodo and Uritani, 1965).

Efforts to avoid processing-induced darkening have centered on producing cultivars with low discoloration potential. However, some research has been conducted on using pre-peel heating, longer lye-peeling time, and/or additives (Scott and Kattan, 1957; Twigg et al., 1974) to prevent darkening. In order to produce sweet potato cultivars of low discoloration potential, it has been suggested that plant breeding programs screen selections for PPO activity (Jones, 1972) and reject those selections which are high in the enzyme. High PPO activity is generally associated with sweet potatoes which darken during processing and, thus, are poorly accepted by consumers (Scott et al., 1944; Scott and Kattan, 1957).

Research on the enzymatic browning of many fruits and vegetables has shown that the potential for discoloration is related to phenolic levels, PPO activity, or a combination of both. In white potatoes (Mondy et al., 1967), peaches (Guadagni et al., 1949), and bananas (Weaver and Charley, 1974), the degree of darkening or browning is highly correlated with phenolic content but poorly related with PPO activity. Since the development of the PPO test for darkening potential (Scott and Kattan, 1957), very little data have been forthcoming concerning the relationship among PPO, substrate, and darkening potential. Walter et al. (1979) reported that, in the seven cultivars studied, the only phenolics present were chlorogenic acid and its isomers. These phenolics are effectively oxidized by sweet potato PPO. The purpose of our study was to determine the role native phenolics play in the enzymatic discoloration of sweet potato cultivars.

## MATERIALS AND METHODS

"Centennial", "Jewel", "Australian Canner", and "Pelican Processor" sweet potato cultivars were obtained at harvest from the North Carolina Agricultural Research Service, Central Crops Research Station at Clayton, NC. The roots were cured and stored as currently recommended (Covington et al., 1976). "Porto Rico 198", obtained from the Horticultural Crops Research Station at Clinton, NC, was handled in the same manner as the other cultivars.

The study was conducted on roots produced in 1977 and 1978. Ascorbic acid was measured on the 1977 crop only. Extent of browning, PPO activity, and phenol levels were measured for both crop years. The analyses for each

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