Technical Papers

The Ratio of Carotene to Carotenoid Pigments in Sweet-potato Varieties

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The sweet potato has long been recognized as a valuable source of carbohydrates in the human diet. More recently its importance as a source of carotene (provitamin A) has been stressed. Sweet potatoes vary greatly in depth of yellow or salmon color, not only between varieties but also within a variety. Depth of color within a variety has been used as a criterion of excellence in the selection of improved strains of some of the standard varieties. If the yellow color of the sweet potato is due to carotene alone, it is readily evident that varieties with deep-colored flesh are much more valuable as a source of provitamin A than are those with lightly-colored flesh. If other carotenoids are also present, then the relative amounts of carotene and other pigments are a matter of interest. This study was made to determine what portion of the yellow pigment in different sweet-potato varieties is carotene.

Matlack (*5*) studied the yellow pigments of the Porto Rico variety. After phasic separation of the extracted pigments, attempts to isolate crystalline xanthophylls from the alcoholic phase proved unsuccessful, but other tests indicated the presence of violaxanthin. Chromatographic adsorption of the recrystallized pigments of the epiphase on a Tswett column of calcium hydroxide gave four colored bands, only the lower band yielding sufficient material for isolation of crystals. He identified these crystals as β-carotene. From these results he concluded that the latter was the predominant pigment of the sweet potato, with a small amount of xanthophylls, one of which was violaxanthin. He gave no data, however, as to what percentage of the total yellow pigments was β-carotene. Lease (*4*) states that the yellow pigment of Porto Rico sweet potatoes is almost entirely β-carotene, and Villere, *et al.* (*6*) working with the same variety, also state that it is the principal carotenoid pigment of sweet potatoes. Other workers have reported carotene as the principal yellow pigment of sweet potatoes. However, little if any quantitative data have been reported as to the relative amounts of various yellow pigments in different varieties of sweet potatoes.

In the work reported here each sample analyzed consisted of 20 grams of a composite of half of each of three to six unpeeled potatoes split lengthwise, ground in a food chopper, and mixed thoroughly before sampling. The Wall and Kelley method (*7*) was used in extracting the pigments and determining the carotene. The aqueous-alcohol fraction contained little, if any, pigments. The ether extract was a clear yellow. The total ether-soluble pigments was determined photoelectrically from the petroleum ether extract before chromatographing, and the carotene after chromatographing. Both were read at a wave length of 460 mμ, and the concentrations calculated from the same concentration curve, prepared from 90 per cent β- and 10 per cent α-carotene.

The mean concentrations of total pigments, carotene, and the carotene/total-yellow-pigment ratio for several varieties of sweet potatoes are given in Table 1. It is readily evident that yellow pigments other than carotene are present in these sweet-potato varieties. A limited number of analyses made on several intervarietal hybrid selections being grown at the Plant Industry Station at Beltsville, Maryland, showed that they too contained other yellow pigments. The ratio of carotene to total yellow pigments varies with different varieties, and the greater the concentration of total pigments, the higher the carotene/total-pigment ratio. In general, this relationship holds true not only within a variety but also within individual roots, as shown in Table 2, in which are presented results for individual roots and portions of roots ana-

TABLE 1

THE CAROTENE AND TOTAL PIGMENTS OF DIFFERENT VARIETIES OF SWEET POTATOES

Variety	No. of samples	Total pigments mg./100 grams* Means ± s $\bar{x}$	Carotene mg./100 grams* Means ± s $\bar{x}$	Ratio $\frac{\text{carotene}}{\text{Total pigments}} \times 100$ Means ± s $\bar{x}$
Maryland Golden ..	42	5.84 ± .086	5.18 ± .083	88.64 ± .46
Porto Rico	48	4.37 ± .066	3.58 ± .068	81.76 ± .70
Nancy Hall	38	1.81 ± .036	1.09 ± .038	60.01 ± 1.40
Vineland Bush ...	49	0.73 ± .018	0.24 ± .010	32.04 ± .84
Southern Queen ..	41	0.47 ± .066	0.13 ± .004	28.29 ± .45
Triumph ..	19	0.40 ± .006	*	*

* Fresh weight basis.
Approximately one-fourth of the pigments at harvest was carotene, but the carotene fraction had disappeared by early December. Samples taken from storage in late May contained a small amount of carotene.

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lyzed separately. These results show the wide variations that may occur within the Porto Rico variety and emphasize the need for care in the selection of propagating stock. No relationship between weight, length, or circumference of the root and the total pigments, carotene, or the carotene/total-pigment ratios was evident in this variety.

TABLE 2

THE CAROTENE AND TOTAL PIGMENTS OF INDIVIDUAL ROOTS OF PORTO RICO SWEET POTATOES

	Total pigments mg./100 grams	Carotene mg./100 grams	Ratio $\frac{\text{carotene}}{\text{Total pigments}} \times 100$
Individual roots	6.95	6.39	91.94
	6.32	5.52	87.34
	5.88	5.05	85.88
	5.66	4.75	83.92
	5.48	4.60	83.94
	4.94	4.13	83.60
	4.81	3.90	81.08
	4.77	3.99	83.64
	4.64	3.90	84.05
	4.47	3.85	86.13
	4.32	3.76	87.04
	4.32	3.65	84.49
	4.21	3.43	81.47
	4.17	3.49	83.69
	4.13	3.51	84.98
	4.13	3.34	80.87
	4.03	3.41	84.61
	3.97	3.26	82.11
	3.92	3.31	84.44
	3.91	3.13	80.05
	3.72	3.11	83.60
	3.70	3.03	81.89
	3.64	2.89	79.39
	3.25	2.56	78.77
	2.82	2.25	79.79
	2.78	2.01	72.30
	2.10	1.46	69.52
Portions of same root			
stem end	6.75	6.08	90.07
center	4.46	3.87	86.77
root end	3.44	2.36	68.60
stem end	5.54	4.59	82.85
center	3.98	3.38	84.92
root end	2.76	2.08	75.36
stem end	5.43	4.72	86.92
center	3.82	3.28	85.86
root end	2.97	2.30	77.44
stem end	3.15	2.39	75.87
center	2.26	1.66	73.45
root end	1.43	.76	53.15

The position of the other pigments on the chromatogram and the tenacity with which they were held indicate that they are different from those known to have provitamin A activity. Neo-β-carotene B or any other carotene of known provitamin A value would probably be carried down in the carotene fraction as here prepared.

Discussion. Kemmerer and Fraps (*2*) have reported that carotene prepared by the usual methods, including that reported here, may contain several fractions, some of which may have no biological activity. Their method calls for adsorption on a column of calcium hydroxide. While suitable for the separation of the various carotene isomers, it is not adapted to rapid routine analysis because of the time-consuming elutions involved.

Kemmerer, Fraps, and Meinke (*3*) have recently reported that the "crude-carotene" of raw sweet potatoes (variety not named) contained, besides β-carotene, neo-β-carotene B and "impurity A." They also found 2 per cent of neo-β-carotene U in one of the five baked samples tested and up to 27 per cent (average, 5 per cent) of this isomer in dehydrated sweet potatoes. No α-carotene was found in any of the samples. "Impurity A" has little if any biological value. Neo-β-carotene B has one-half that of β-carotene, and neo-β-carotene U was reported by Kemmerer and Fraps (*2*) as of no biological value, but Deuel, *et al.* (*1*) reported it as having 38 per cent of the value of β-carotene. According to Kemmerer, Fraps, and Meinke (*3*) the total biological activity of the "crude carotene" in the three samples of raw sweet potatoes tested was equivalent to 88 per cent β-carotene, and in the baked and in the dehydrated samples it was 76 per cent. Whether these figures are representative of all varieties is not known. Kemmerer and Fraps (*2*) reported earlier that both carotenoid X (neo-β-carotene U) and α-carotene were present in fresh sweet potatoes (variety not named) to the extent of 5.4 and 1.4 per cent, respectively, but in a later paper (*3*) reported neither to be present.

Summary. The fleshy roots of the sweet potato are shown to contain appreciable amounts of yellow pigments other than β-carotene. The carotene/total-pigment ratio varies among different varieties and within varieties. In the varieties tested, the carotene/total-pigment ratio increased with increase in intensity of yellow color. Triumph, a very light-colored variety, contained a small amount of carotene shortly after harvest, but this soon disappeared in storage.

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Amino Acid and Protein Deficiencies as Causes of Corneal Vascularization: A Preliminary Report[1]

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The appearance of vessels in the cornea of rats deficient in tryptophane and lysine was first described

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