CAROTENE DISTRIBUTION IN THE SWEET POTATO

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Russell M. Ampey
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This is to certify that the

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"Carotene Distribution In The Sweet Potato."

presented by

Russell M. Ampey

has been accepted towards fulfillment
of the requirements for

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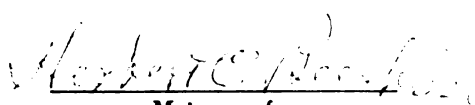

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By

Russell M. Ampey

AN ABSTRACT

Submitted to the School for Advanced Graduate Study
of Michigan State University of Agriculture and
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Department of Botany and Plant Pathology

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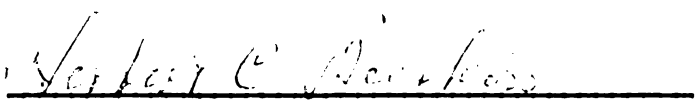
Approved 

Russell M. Ampey

ABSTRACT

CAROTENE DISTRIBUTION IN THE SWEET POTATO

The data presented indicate that three sweet potato varieties contained different amounts of carotene. The Queen Mary variety had the highest concentration, the Porto Rico Unit I less, and the Porto Rico variety the lowest concentration.

Carotene is not uniformly distributed throughout the root. The stem-end of the root contained more carotene than the center region and the center region had more than the root-end. Transverse carotene concentration differences were also indicated with the core usually containing more carotene than peelings. Whereas longitudinal difference in the carotene distribution appeared to be characteristic, the transverse differences may alternate from year to year.

It appeared that carotene synthesis continued for some time in the sweet potato root after harvest. During storage, the carotene tends to become more uniformly distributed throughout the root. The ratio of the carotene contained in the root-end compared to that contained in the stem-end increased during storage.

The peelings of sweet potatoes contained considerable carotene. Discarding this region of the root results in a substantial loss of pro-vitamin A.

The data indicate that the Queen Mary and the Porto Rico sweet potatoes were superior to the Unit I variety in the retention of carotene during storage.

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INTRODUCTION AND LITERATURE REVIEW

The sweet potato (Ipomoea Batatas, Lam.) is the most important horticultural crop in the South where it ranks first among the vegetable crops in total acreage, value of production, and value of sales. Montgomery (26) reported that 11,000,000 bushels of sweet potatoes were grown in Louisiana in 1950 with a value of approximately 11,000,000 dollars. The southern market shows preference for "yams"* while the northern market shows preference for sweet potatoes. The sweet potato is an important food item because of several factors, chief among which are its high content of total carbohydrates, carotene (pro-vitamin A), and of ascorbic acid (vitamin C). Jacobs (13) in listing the nutritive values of sweet potatoes showed them to contain 125 calories, carotene equal to 7,700 I. U. of vitamin A and 22 mg. of ascorbic acid per 100 grams.

The caroteen contained in the sweet potato is not evenly distributed throughout the root. Thus Speirs, Cochran, Peterson, Sherwood, and Weaver (32) first reported on the distribution of carotene within the "Unit I Porto Rico" sweet potato variety. They found that there was a progressive increase in carotene content from the root-end through the center to the stem-end of the root. Ezell and Wilcox (5) also found regional differences in the carotene content of the "Porto Rico" variety of sweet potato. They found that the stem-end may contain

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*"Yam" refers here to the sweet potato Ipomoea Batatas, Lam. not the true yam Dioscorea Batatas, Decne. The southern commercial market refers to I. Batatas as "yam" if, when cooked, it is moist and sweet rather than dry and not sweet; the latter is refered to as sweet potato. The northern commercial market, generally, makes no such distinction.

two to three times as much carotene as the root-end of the same specimen.

There is considerable confusion in the literature regarding the effect of storage on the carotene content of sweet potatoes. Thus MacLeod, Armstrong, Heap, and Talbert (18), MacLeod and Utley (19), Anderson (1), and others, reported increases in carotene content in sweet potatoes during storage. Mitchell and Lease (25), and Speirs, Cochran, Peterson, Sherwood, and Weaver (32), and others, however, found no such increases.

Changes in the distribution of the carotene within sweet potatoes during storage have so far not been reported.

This investigation was designed principally to study the changes in the distribution of carotene during storage in the root of three common sweet potato varieties, the Queen Mary, the Porto Rico Unit I, and the Porto Rico.

EXPERIMENTAL METHODS AND MATERIALS

"Carotene" as used here includes all fat soluble pigments in the sweet potato of which the predominant pigment is beta-carotene according to Lease (17), Matlack (20), and Villere, Heinzelman, Pominski, and Wakeham (35). Thus Ezell and Wilcox (5) found for the Porto Rico sweet potato that beta-carotene was 82 percent of the total carotenoids. Miller, Melampy, Mikell, and Hernandez (24) found from 93 to 99 percent beta-carotene of the total carotenoids in the Unit I Porto Rico variety and from 94 to 100 percent beta-carotene of the carotenoids in the Queen Mary sweet potato.

Sources of materials. The sweet potatoes used for this study were secured from the Louisiana State Experiment Station, Baton Rouge, Louisiana and Henry Wells' farm in East Baton Rouge Parish, Louisiana. In the present study only varieties commonly grown and available on the open market were used. No attempt was made to secure "genetically pure lines".

Storage. All sweet potatoes used in this study had already been cured seven days at a temperature of 80 to 85°F and a relative humidity of 80 percent. Kimbrough (16) reported that healing of wounds resulting from harvest to be the most important feature in curing. The sweet potatoes were stored in open crates in a room ambient (60 - 70°F) room temperature until analyzed for carotene.

Speirs, Cochran, Peterson, Sherwood, and Weaver (32) and Ezell and Wilcox (7) found that the moisture content of sweet potatoes remains relatively constant during storage. These authors reported that small

losses in weight that may occur during storage are usually due to loss in dry matter and not of water. Speirs et al. (33) in a study covering six southern states showed that the Unit I Porto Rico contained 69.8 percent water at harvest, 69.2 percent after curing and 69.5 percent after four months of storage; the Queen Mary percentages were 73.7, 72.8, and 73.1 respectively. Since the moisture content of sweet potatoes remains relatively constant during storage the amounts of carotene reported in this paper are based upon the fresh weight. Many investigators follow this procedure.

Analytical methods and procedure. A one gram sample of fresh root material was found to provide a suitable amount of carotene for readings on the photoelectric colorimeter employed. Samples were taken from the stem-end approximately one inch from the scar tissue, the center of the root, and approximately one inch from the scar tissue at the root-end. Thin transverse sections were used to make up these one gram samples. When peelings were to be analyzed they were obtained from the center section of the root as were the core samples.

Carotene was extracted from the samples by the Moore and Ely (27) method with minor modifications. One gram of fresh sweet potato tissue was macerated in a Waring Blendor with 25-50 milliliters of commercial acetone for four minutes, washed down with more acetone and macerated for one minute longer. These washings were necessary because of considerable foaming. The macerated tissue was filtered through a Buchner funnel. Although the residue was colorless upon filtration it was rinsed further to insure complete removal of carotene.

The filtrate was transferred to a separatory funnel and 50 milliliters of petroleum ether (c. p. grade) were added and thoroughly mixed by gentle spinning and turning. Distilled water was added to transfer the carotene from the acetone to the petroleum ether. The supernatant petroleum ether solution was washed several times with water to insure the removal of the acetone and it was dried by filtering through anhydrous sodium sulfate. The solution was brought to a volume of 100 milliliters by the washings which came through the sodium sulfate.

The amounts of carotene in the petroleum ether solution were determined by the use of photoelectric filter photometry (Cenco-Sheard-Sanford Photelometer) in which a blue Number 554 Corning glass light filter of standard thickness was employed. The amounts of carotene present in the samples were determined by the use of a calibration graph prepared by using known concentrations of a pure solution of a mixture of 90 percent beta-carotene and 10 percent alpha-carotene in petroleum ether.

EXPERIMENTAL RESULTS

1. Distribution of the Carotene Within the Sweet Potato Root

A. Stem-end, middle, and root-end regions

Samples from the stem-end, the middle, the root-end, the peelings, and the core areas of sweet potato roots were analyzed for carotene content. The average amounts of carotene contained in the stem-end, the middle, and the root-end and standard deviations are summarized in Table I and graphically presented in Figure 1.

TABLE I

AVERAGE CAROTENE CONTENT AND STANDARD DEVIATIONS FOR STEM-END, MIDDLE, AND ROOT-END OF QUEEN MARY, PORTO RICO UNIT I, AND PORTO RICO SWEET POTATOES

	Micrograms carotene per gram, fresh weight					
Variety	Stem-end	SD	Middle	SD	Root-end	SD
Queen Mary	268	± 39	167	± 19	121	± 10
Porto Rico Unit I '45	234	± 32	125	± 10	77	± 7
Porto Rico Unit I '47	177	± 7	140	± 5	102	± 4
Porto Rico	175	± 12	128	± 10	81	± 11

On examining the data in Table I it is seen that the averages of the carotene content for the various sections differ for the varieties studied. The average carotene content for the stem-end was much larger than for the other regions.

The average carotene content of the stem-end region was considerably larger for the Queen Mary and the Unit I 1945 than for the Porto Rico or the Unit I 1947 sweet potatoes. That there was considerable

variability in the carotene content of the three varieties can be seen by examining the standard deviations.

The difference in carotene content between the regions of the sweet potato root was tested statistically. Table II shows an analysis of variance of the carotene content of the stem-end, the middle, and the root-end of the Queen Mary variety of sweet potatoes.

TABLE II

ANALYSIS OF CAROTENE DATA FOR REGIONS OF QUEEN MARY SWEET POTATO

Source of Variations	D.F.	S.S.	M.Sq.	F.
Total	19	135,944		
Between Regions Average	2	71,716	35,858	9.49**
Within Regions or Error	17	64,228	3,778	

**Significant at the one percent level.

On testing the averages pertaining to the sections by a Studentized Range Table it was found that the average of the carotene measurements in the stem-end was significantly larger than the averages of the carotene measurements in the root-end and also larger than the averages of the middle section. There was not a significant difference between the average pertaining to the middle and the root-end. This was true for the Porto Rico Unit I 1945 crop also.

By a similar analysis it was found that the averages of the carotene contents in all three regions of the Porto Rico variety were significantly different. This was also found to be true for the Porto Rico Unit I 1947 crop.

The present study corroborates the work of Speirs, Cochran, Peterson, and Weaver (32) and Ezell and Wilcox (5) who showed that the

carotene in the Unit I Porto Rico and the Porto Rico sweet potatoes was not uniformly distributed throughout the root. In addition, the present study showed that the Queen Mary also had similar regional differences and that each region was consistently higher in carotene content than those of the Porto Rico Unit I and the Porto Rico varieties.

The data of Speirs et al. (32) show that the Porto Rico Unit I stem-end contained 128 ug/gm, the center section 118 ug/gm, and the root-end section 108 ug/gm of carotene. The data of Ezell and Wilcox (5) show that these values for the Porto Rico variety were stem-end 45, center 31, and root-end 19 ug/gm.

Table III shows the ratio of carotene contained in the several regions of the sweet potato root based on a weighted average computed by combining values for the stem-end, the middle, and the root-end regions. These ratios are graphically presented in Figure 2.

TABLE III

CAROTENE CONTENT AND RATIOS FOR STEM-END, MIDDLE, AND ROOT-END BASED ON THE AVERAGE FOR THE ROOT

	Micrograms carotene per gram, fresh weight							
Variety	Whole Root		Stem-end		Middle		Root-end	
	Av.	Ratio	Av.	Ratio	Av.	Ratio	Av.	Ratio
Queen Mary	181	1.00	268	1.48	167	0.92	121	0.67
Unit I '45	144	1.00	234	1.63	125	0.87	69	0.48
Unit I '47	135	1.00	177	1.31	140	1.04	87	0.64
Porto Rico	128	1.00	175	1.37	128	1.00	81	0.63

If the data of Speirs et al. (32) were similarly treated the ratios for the Unit I Porto Rico sweet potato were: stem-end section 1.10, the center section 1.02, and the root-end section 0.88. The data of Ezell

and Wilcox (5) showed the following for the Porto Rico variety: stem-end 1.36, the center 0.95, and the root-end 0.69.

Thus Speirs et al. (32) found that the middle region of the Unit I sweet potato carotene content was 90 percent of that in the stem-end and that the root-end content was 79 percent of the stem-end content. These percentages for the present study (the average values for the two crops) were lower, being approximately 71 percent for the middle region and 38 percent for the root-end. The percentages for the Porto Rico variety found by Ezell and Wilcox (5) and those for the present study for these regions are quite similar. The percentages as determined by Ezell and Wilcox (5) were middle region 70 percent of the stem-end concentration and the root-end 43 percent. The data of the present study show the middle region concentration to be 70 percent of the stem-end concentration and the root-end to be 46 percent. These percentages for the Queen Mary variety were 62 and 45 respectively.

Table IV shows the averages of the carotene content of the whole sweet potato and their standard deviations, together with the averages of the ratios of the carotene content of the middle region to the carotene content of the stem-end and their standard deviations. The table also shows the averages of the ratios of the determinations of the carotene content in the root-end to the stem-end and their standard deviations. These ratios are graphically presented in Figure 3.

On examining Table IV it is evident that there is considerable variation in the distribution of the carotene in the three different sweet potatoes used. For this table a weighted average was not used as in Table III. The ratio of the middle region to the stem-end was larger than the ratio root-end to stem-end for all varieties. The

ratios ranged from about 90 percent larger for the Unit I 1945 for the middle region to the stem-end than the root-end to the stem-end to about 45 percent larger for the same ratios for the Queen Mary variety.

TABLE IV

AVERAGE CAROTENE CONTENT AND RATIOS OF THE CAROTENE CONTENT FOR MIDDLE TO STEM-END AND ROOT-END TO STEM-END

Variety	Whole Potato Av.(ug/gm)	SD	M/S.e.Ratio	SD	R.e./S.e.Ratio	SD	No. Items
Queen Mary	197	± 24	0.77	± 0.06	0.53	± 0.11	6
Unit I '45	143	± 15	0.65	± 0.07	0.34	± 0.04	19
Unit I '47	134	± 4	0.81	± 0.02	0.52	± 0.03	76
Porto Rico	125	± 11	0.76	± 0.07	0.48	± 0.06	12

B. Peelings and Core

The sweet potato is usually peeled when used for human consumption. The amounts of carotene lost by this practice may be of interest. The literature revealed no information on the carotene content of sweet potato peelings. There are, however, reports for the outer and inner regions of the carrot root. Thus in 1940 Werner (37) reported higher carotene concentrations in the phloem of carrots than in the xylem. Harper and Zscheile (12) also reported that the phloem contained more carotene than the inner region of the carrot.

Since the carrot shows these differences in the carotene content near the surface and within the root it was thought that possibly there were similar differences in the sweet potato root. A transverse slice about one-half inch thick was cut from the center region of the sweet potato root. This disk was peeled approximately as a house wife would

peel the root for human consumption. Peelings were analyzed for carotene as were also the part remaining - here called the core.

Table V shows the carotene content of peelings and core regions of sweet potatoes and their standard deviations. The table also shows the ratio of peelings to core carotene concentration and the standard deviations. Figure 4 shows graphically the carotene content of peelings and core.

TABLE V

AVERAGE CAROTENE CONTENT OF PEELINGS AND CORE AND PEELINGS TO CORE RATIO

	Micrograms carotene per gram, fresh weight					
Variety	Peelings Av.	SD	Core Av.	SD	Ratio Peelings/core	SD
Queen Mary	187	± 15	208	± 21	0.90	± 0.05
Unit I '45	144	± 21	137	± 16	1.05	± 0.35
Unit I '47	119	± 7	146	± 8	0.82	± 0.18
Porto Rico	113	± 5	135	± 15	0.84	± 0.13

It will be noted that the core region of the three varieties contained more carotene than the peelings except the 1945 crop of the Porto Rico Unit I. There was considerable variability in the carotene content as can be seen by examining the standard deviations. The core region contained about 22 percent more carotene than peelings in the Unit I 1947 sweet potato and 5 percent less for the same variety in 1945. The differences between the carotene content of the peelings and the core regions were significantly different for the Unit I 1947 crop, however, they were not significantly different for the other varieties.

2. Carotene Content of the Whole Root

Relatively dilute solutions are required when photoelectric filter photometry is employed to determine carotene concentrations. Either whole sweet potato roots may be run through a food mill and small portions of the pulp be used for samples or the data from the regions of the root might be combined to represent the carotene concentration per unit weight. The latter procedure may result in shorter exposure to the elements and less decomposition prior to extraction of the pigment. Thus in the present study the data for the stem-end, the middle, and the root-end samples were combined and used as "the root average" carotene content.

Table VI shows the average carotene content for the three varieties of sweet potatoes and their standard deviations. The data are graphically presented in Figure 5.

TABLE VI

AVERAGE CAROTENE CONTENT OF QUEEN MARY, PORTO RICO UNIT I, AND PORTO RICO SWEET POTATOES

Variety	Micrograms carotene per gram, fresh weight	SD
Queen Mary	197	± 24
Porto Rico Unit I 1945	143	± 15
Porto Rico Unit I 1947	134	± 4
Porto Rico	135	± 11

It will be noted that the Queen Mary sweet potato contained larger amounts of carotene than the other varieties. This sweet potato variety was developed through breeding by the Louisiana State Experiment Station. The Porto Rico variety is an old variety and still favored by

many producers. The Unit I was developed by selection from the older variety and is the standard commercial variety.

These sweet potato varieties have been used in many sweet potato investigations. Ezell and Wilcox (5) found only 44 ug/gm carotene for the Porto Rico and Speirs et al. (32) found 38 ug/gm for the same variety. The latter investigators also reported 132 ug/gm for the Queen Mary and 80 ug/gm for the Unit I variety. Miller et al. (24) reported 185 ug/gm beta-carotene for the Queen Mary and 127 ug/gm for the Unit I, whereas, Fieger et al. (8) listed 73 ug/gm for the Queen Mary and 34 ug/gm for the Porto Rico Unit I.

The amounts of carotene reported in the present study were practically the same as those reported by Miller et al. (24) but were higher than those reported by Speirs et al. (32), Ezell and Wilcox (5), and Fieger et al. (8). In the present study the amounts of carotene are used only as a basis to evaluate the distribution of carotene within the root and changes of carotene content in the regions of the sweet potato root during storage.

3. Variations in Carotene Content for Crops of Two Years

Since the Porto Rico Unit I sweet potato is the most popular variety in commercial use crops of two different years were analyzed to determine if the distribution of carotene was similar. Table VII shows the comparison of Porto Rico Unit I sweet potatoes harvested in 1945 and 1947 and the comparison is graphically presented in Figure 6.

It will be noted that although the total carotene was different for the two crops the concentration of the carotene in both crops was highest in the stem-end, intermediate in the middle and lowest in the

root-end. The transverse distribution of the carotene for these two crops, on the contrary, was not similar.

The carotene content varied from about 32 percent more in the stem-end region of the 1945 crop to only 2 percent more in the root-end. The middle region of the 1945 crop had about 12 percent less carotene than the 1947 crop and the core region about 7 percent less.

TABLE VII

COMPARISON OF THE 1945 AND 1947 CROPS OF PORTO RICO UNIT I SWEET POTATOES

	Micrograms carotene per gram, fresh weight											
Year	Whole Root		Stem-end		Middle		Root-end		Peelings		Core	
	Av.	SD	Av.	SD	Av.	SD	Av.	SD	Av.	SD	Av.	SD
1945	143	± 15	234	± 32	125	± 16	89	± 7	144	± 21	137	± 16
1947	134	± 4	177	± 7	140	± 5	87	± 4	119	± 7	146	± 8

Table VIII shows an analysis of variance of the carotene content data for the stem-end of the Porto Rico Unit I 1945 and 1947 crops.

TABLE VIII

ANALYSIS OF VARIANCE OF THE CAROTENE CONTENT OF PORTO RICO UNIT I FOR 1945 AND 1947 PERTAINING TO STEM-END DATA

Source of Variation	D.F.	S.S.	M.Sq.	F.
Total	99	734,775		
Between Years	1	51,897	51,897	7.4**
Within Years	98	682,878	6,968	

** Significant at the 1 percent level.

The F-value in Table VIII indicated that the average of the carotene content of the stem-end for 1945 was significantly larger than

that for 1947 which shows, as far as these measurements are concerned, that the carotene content can vary from year to year. This may be related to the difference in total rainfall during the growing seasons of 1945 and 1947; the former had 16.52 inches, whereas the latter had only 13.23 inches. This variation of 3.29 inches of rain may have contributed to this difference in carotene distribution. The month of July may have been especially critical since the normal precipitation for July is 6.84 but in 1945 there were 5.03 inches of rainfall and in 1947 there were only 0.94 of an inch of rainfall.*

A statistical analysis indicated that the average of the carotene content of the middle section for 1945 is significantly less than that for 1947. This analysis is shown in Table IX.

TABLE IX

ANALYSIS OF VARIANCE OF THE PORTO RICO UNIT I 1945 AND 1947 CAROTENE PERTAINING TO MIDDLE SECTIONS

Source of Variation	D.F.	S.S.	M.Sq.	F.
Total	98	190,059		
Between Years	1	22,609	22,609	13**
Within Years	97	167,450	1,726	

**Significant at 1 percent level.

4. Changes in Carotene Distribution During Storage

Although there are many references in the literature dealing with the effect of storage on the carotene content of sweet potatoes there are no reports on changes in the distribution of carotene in the root during storage.

Samples of the Queen Mary, the Porto Rico, and the Porto Rico Unit I sweet potatoes were analyzed for carotene content from November of 1946 through July of 1948. The storage time for each crop was divided into two periods, an early storage period of approximately four months duration (October to January), and a later storage period running beyond January. The Queen Mary variety was stored approximately seven months, the Unit I 1947 crop for ten months, the Unit I 1945 crop for thirteen months, and the Porto Rico for approximately sixteen months.

The results of these analyses are shown in Table X and are graphically presented in Figures 7, 8, 9, and 10.

TABLE X

THE CAROTENE CONTENT OF THREE SWEET POTATO VARIETIES DURING TWO STORAGE PERIODS

Storage	Micrograms carotene per gram, fresh weight									
	Whole Root	SD	Stem-End	SD	Middle	SD	Root-End	SD	RE/SE Ratio	SD
					QUEEN MARY					
To January	186	± 38	290	± 80	168	± 40	100	± 10	.34	± .16
After Jan.	208	± 35	245	± 26	167	± 28	142	± 12	.58	± .11
					PORTO RICO					
To January	130	± 26	200	± 33	125	± 30	65	± 15	.33	± .02
After Jan.	137	± 14	170	± 17	129	± 12	84	± 12	.49	± .07
					PORTO RICO UNIT I 1945					
To January	161	± 55	274	±103	160	± 46	83	± 12	.30	± .03
After Jan.	140	± 16	233	± 38	119	± 13	66	± 17	.28	± .04
					PORTO RICO UNIT I 1947					
To January	148	± 7	200	± 11	154	± 7	90	± 5	.45	± .05
After Jan.	121	± 4	154	± 5	124	± 4	84	± 5	.55	± .04

A. Changes in Carotene Content per Unit Fresh Weight During Storage

The data for the combined carotene content for the stem-end, middle, and root-end (whole root) show that the Queen Mary and the Porto Rico sweet potatoes had more carotene per unit of fresh weight after prolonged storage. Although the data showed certain trends these averages were not statistically significant. The Unit I sweet potatoes had less carotene per unit of fresh weight after prolonged storage. The differences were statistically significant for the 1947 crop but were not significant for the 1945 crop. The lack of statistical signigicance in many cases simply reflects the great variation in the samples taken.

A disturbing factor in analyses of this sort is the fact that there are changes in the moisture and in the dry weight content of sweet potatoes during storage. Scott and Matthews (31) studied the loss of weight of sweet potatoes during curing and storage. They found for the Porto Rico sweet potato a weight loss of 1.7 percent during curing, 5.8 percent weight loss for two months of storage, 7.7 percent after four months, and 10.4 percent after six months of storage. Their mean values for sixteen sweet potato varieties were 2.1 percent weight loss during curing, 6.7 percent after two months of storage, 9.3 percent after four months, and 13.5 percent after six months of storage. On this basis, the Queen Mary may have lost about 16 percent of its original weight during seven months of storage, Porto Rico about 26 percent during sixteen months, Unit I 1945 about 25 percent during thirteen months, and the Unit I 1947 about 22 percent during the ten months of storage.

Table XI shows an estimate of "correction" in absolute carotene content due to losses in moisture and dry weight during storage for

the combined stem-end, middle, and root-end data (whole root) for the three varieties of sweet potatoes.

TABLE XI

ESTIMATE OF "CORRECTION" IN ABSOLUTE CAROTENE CONTENT DUE TO LOSSES IN MOISTURE AND DRY WEIGHT DURING STORAGE AS PUBLISHED BY SCOTT AND MATTHEWS (31)

	ug/gm carotene content on fresh weight basis				
	Before Storage	After Storage			
Variety		Uncorrected for losses in moisture and dry wt.		Corrected for losses in moisture and dry wt.	
		To Jan.	After Jan.	To Jan.	After Jan.
Queen Mary	113	186	208	169	175
Porto Rico	130	130	137	120	101
Unit I'45	125	161	140	147	105
Unit I'47	142	148	121	135	94

It must be recognized that this loss of weight due to moisture loss and/or loss of dry matter may affect the relative carotene concentration and if there were different losses between regions of the sweet potato root this would affect the relative carotene concentration in these regions. These facts undoubtedly have contributed to the lack of agreement among investigators. It must be kept in mind that the data presented in the present paper are based upon the carotene content of sweet potatoes bought by the pound in the market regardless of weight changes due to either moisture or dry weight losses.

B. Effect of Storage on the Longitudinal Distribution of Carotene

(1). Stem-end changes. All of the varieties and both crops of the Unit I had less carotene per unit of fresh weight in the stem-end after longer storage. The differences amounted to about 18 percent in the Queen Mary, 17 percent in the Porto Rico, 18 percent in the Unit I 1945, and about 30 percent in the 1947 crop of the Porto Rico Unit I. Due to the great variation between individual analyses these average differences were statistically significant only for the 1947 Unit I sweet potatoes. The differences for the Queen Mary and the 1947 Unit I appear to be larger than the differences which may be due to weight losses.

(2). Middle region changes. The middle region of all varieties had less carotene per unit of fresh weight after longer storage than after the short storage period except the Unit I 1945 crop. The changes in this region were less than those in the stem-end for the Queen Mary and the Porto Rico there being only a 1 percent difference and a 3 percent difference respectively. Unit I sweet potatoes, however, had larger differences in this region. The 1945 crop difference was about 34 percent per unit of fresh weight after the longer storage period and the 1947 crop difference was about 24 percent. These average differences also were statistically significant only for the 1947 Unit I. The differences for the Unit I sweet potatoes appear to be larger than the differences which may be due to weight losses.

(3). Root-end changes. The carotene content changes in the root-end were not consistent for all varieties. The Queen Mary and the Porto

Rico had a larger carotene content per unit of fresh weight in this region after prolonged storage than after the shorter period. The percentage difference was about 42 percent and 29 percent respectively. The Unit I, however, had a lower carotene content per unit of fresh weight in this region after prolonged storage. The differences were 26 percent for the 1945 crop and 7 percent for the 1947 crop. However, none of these differences were statistically significant. The fact that losses in carotene content in the Unit I sweet potatoes after prolonged storage were not significant suggests the effect of loss of dry matter during storage.

(4). Root-end/stem-end ratio. Table X also showed the root-end/stem-end carotene ratios and their standard deviations. This ratio was larger at the end of the second storage period for the Queen Mary, the Porto Rico, and the 1947 crop of the Unit I sweet potatoes. There was a very small decrease in this ratio for the 1945 Unit I variety. These ratios are graphically presented in Figure 11.

(5). General effect of storage on carotene distribution. It was found earlier in the present study that, in general, the data for the stem-end, middle, and root-end carotene content were significantly different. The effect of storage upon the longitudinal distribution of the carotene was tested statistically.

By the use of the analysis of variance it was found that the longitudinal regional distribution of the carotene was significantly different for both storage periods for all of the sweet potato varieties except the short period for the Queen Mary. On testing the differences between regions for the two storage periods it was found that

the Queen Mary regions were not significantly different for either storage periods. For the Porto Rico and the Unit I 1945 crop for the short storage period the regions were not significant but for the longer period they were significantly different. The Unit I 1947 regions were significantly different for both storage periods.

Tables XII through XV show an analysis of variance for the regions of the sweet potato varieties for the two storage periods.

TABLE XII

ANALYSIS OF CAROTENE DATA FOR STORAGE OF QUEEN MARY

Source of Variations	Short Period D.F.	S. S.	M.Sq.	F.	Long Period D.F.	S. S.	M.Sq.	F.
Total	8	104,377			8	27,850		
Between Reg.	2	27,478	13,739	1.1	2	17,044	8,522	4.7*
Within Reg.	6	76,899	12,800		6	10,806	1,801	

Not significant

*Significant at 5 percent level

TABLE XIII

ANALYSIS OF CAROTENE DATA FOR STORAGE OF PORTO RICO

Source of Variations	Short Period D.F.	S. S.	M.Sq.	F.	Long Period D.F.	S. S.	M.Sq.	F.
Total	5	22,503			29	79,915		
Between Reg.	2	18,141	9,071	6.2*	2	36,656	18,328	11.4**
Within Reg.	3	4,362	1,454		27	43,259	1,602	

*Significant at 5 percent level

**Significant at 1 percent level

TABLE XIV

ANALYSIS OF CAROTENE DATA FOR STORAGE OF PORTO RICO UNIT I 1945

Source of Variations	Short Period D.F.	S.S.	M.Sq.	F.	Long Period D.F.	S.S.	M.Sq.	F.
Total	8	244,281			44	549,649		
Between Reg.	2	166,508	83,254	6.4**	2	176,082	88,041	10**
Within Reg.	6	77,773	12,929		42	373,567	8,894	

**Significant at 1 percent level

**Significant at 1 percent level

TABLE XV

ANALYSIS OF CAROTENE DATA FOR STORAGE OF PORTO RICO UNIT I 1947

Source of Variations	Short Period D.F.	S.S.	M.Sq.	F.	Long Period D.F.	S.S.	M.Sq.	F.
Total	122	591,372			104	259,821		
Between Reg.	2	249,753	124,877	43**	2	80,197	40,099	23**
Within Reg.	120	341,619	2,847		102	179,624	1,761	

**Significant at 1 percent level

**Significant at 1 percent level

The averages of the carotene content of the whole root data of the 1947 crop of the Unit I sweet potato data for the short storage was larger than those data for the longer storage period. T-tests indicate that this difference is significant. This was also true for the stem-end data and those for the middle region but was not true for the root-end. The differences for the "whole root", stem-end, and middle were larger than the differences which may be due to weight losses but were not larger for the root-end.

C. Effect of Storage on the Transverse Distribution of Carotene

Transverse carotene content differences were found as well as longitudinal differences. The changes during storage in the carotene content of peelings and core of the Porto Rico and the 1947 crop of the Porto Rico Unit I sweet potatoes and their standard deviations are shown in Table XVI and are graphically presented in Figures 8 and 10. Here, too, the data presented are based upon the carotene content of sweet potatoes bought by the pound in the market regardless of weight changes during storage due to losses of moisture or dry weight.

TABLE XVI

THE CAROTENE CONTENT OF PEELINGS AND CORE OF PORTO RICO AND PORTO RICO UNIT I 1947 SWEET POTATOES DURING TWO STORAGE PERIODS

	Micrograms carotene per gram, fresh weight									
Storage	Peelings				Core				Peel/Core Ratio			
	P.Rico	SD	UI'47	SD	P.Rico	SD	UI'47	SD	P.Rico	SD	UI'47	SD
To Jan.	165	± 5	118	± 9	107	± 19	150	± 9	1.59	±.72	.85	±.09
Aft. Jan.	101	± 16	123	± 7	142	± 18	132	± 7	0.76	±.10	.95	±.07

(1). Peelings. It will be noted that the carotene content of peelings of the Porto Rico sweet potato appeared to decrease about 40 percent per unit of fresh weight during prolonged storage. This difference was found to be significant. The Porto Rico Unit I sweet potatoes, to the contrary, had increased amounts of carotene per unit of fresh weight after prolonged storage. But this difference was not statistically significant.

(2). Core. The changes in carotene concentration in the core region were also opposite for these two varieties. The change in the

carotene content per unit of fresh weight in the Porto Rico core region was approximately 32 percent after the longer storage period. But this difference was not significant. The core region of the Porto Rico Unit I difference for the two periods was about 12 percent. This difference was significant.

(3). General effect of storage on peelings and core. By the use of the analysis of variance it was found that the average of the carotene determinations for the short storage period for the differences between peelings and core areas were significantly different for the Unit I. An analysis of the data for the same regions for the longer storage period revealed that they were not significant. The ratio peel/core was significantly different for data to January and after January storage for both sweet potato varieties.

Tables XVII and XVIII show an analysis of the data for storage for the Porto Rico Unit I 1947 crop for peelings and core carotene content.

TABLE XVII

ANALYSIS OF CAROTENE DATA FOR STORAGE OF PEELINGS AND CORE OF UNIT I 1947

Source of Variations	Short Period D.F.	S.S.	M.Sq.	F.	Long Period D.F.	S.S.	M.Sq.	F.
Total	41	74,687			9	5,064		
Between Reg.	1	10,124	10,124	6**	1	221	221	.4
Within Reg.	40	64,563	1,614		8	4,843	605	

**Significant at 1 percent level Not significant

By the use of T-tests for peelings/core data for the Unit I 1947 early storage data were significant, however, for both early and late

storage, data for peelings and core regions were not significantly different.

TABLE XVIII

ANALYSIS OF CAROTENE DATA TO AND AFTER JANUARY FOR PEELING TO CORE RATIOS OF PORTO RICO UNIT I 1947

Source of Variations	D.F.	S.S.	M.Sq.	F.
Total	25	12.3292	.	
Between Periods	1	8.5033	8.5033	53**
Within Periods	24	3.8259	.1594	

**Significant at 1 percent level

It is evident that there may be transverse changes in the carotene concentration as well as longitudinal changes.

DISCUSSION

Carotene content of whole potato. The three varieties of sweet potatoes which were studied contained different amounts of carotene. The total carotene concentration was highest in the Queen Mary, intermediate in the Porto Rico Unit I, and lowest in the Porto Rico. The amounts of carotene in these varieties were found to be higher than those reported by some investigators and lower than those reported by others. The absolute amounts of carotene are not so important to the present study, however, as is the use of these values to determine the relative changes in carotene content during storage and the distribution of carotene in the potato.

Stem-end, middle, and root-end differences. The results of the present study corroborate those of other investigators in that they indicate a longitudinal difference in the carotene concnetration in the sweet potato root. In general, it was found that the stem-end had the highest concentration of carotene, the middle zone intermediate amounts, and the root-end had the lowest concentration. These differences may be associated with either different rates of synthesis and accumulation of carotene within the sweet potato in these different parts or with the transport of carotene from the stem after synthesis in the leaves.

Several theories have been postulated for the synthesis of carotene by plants. Goodwin (10) states that as far back as 1837 Berzelius considered that the carotenoid pigments were breakdown products of chlorophylls. Willstätter and Mieg (38) suggested that the alcohol

phytol, one of the components of chlorophyll, might represent a precursor in carotenoid synthesis. Bonner (4), however, thought that though phytol may be a precursor in carotenoid synthesis it is formed independently of chlorophyll and may represent a reduction product of some common precursor of both phytol and carotenoids rather than the precursor itself. Bandurski (3) suggested a light accelerated synthesis of carotene which involved compounds accumulated during previous photosynthetic activity but was independent of photosynthesis. He also found carotene could be synthesized in the dark in the presence of glucose but synthesis occurred only one fifteenth as rapidly as the corresponding synthesis in light. The carotene in the sweet potato root appears as though it might be transported from the leaves with smaller amounts coming from a synthesis within the potato.

Carotene is of special interest because it may be converted into vitamin A in the animals body. Roberts and Southwick (30), however, using the electron microscope suggested that vitamin A may represent a step in the anabolism as well as the catabolism of carotene bodies and that the carotene bodies, likewise, represent steps in the anabolism and catabolism of chromoplasts.

Porter and Lincoln (29) suggested ..." a scheme which is probably valid for all yellow and red carotene containing fruit and vegetables" where carotene is formed from lycopene. Tomes, Quackenbush, and Kargl (34) found that beta-carotene may be derived from lycopene in the tomato as suggested by Porter and Lincoln but their data did not exclude the possibility that a common precursor could give rise to both beta-carotene and lycopene.

Wenzinger (36) suggested that there is no sound basis for assuming that the site of accumulation of carotenoids is also the site of their formation. Johnson and Miller (14) suggested that in corn the formation of carotenoids in the leaf and formation and/or storage in the endosperm are independent processes. This may also be the case for the sweet potato root.

Miller and Johnson (23) reported from 196 ug/gm to 495 ug/gm (dry basis) of carotene in sweet potato leaves. This is about twice the amount of carotene which is found in the root. Since carotene is not water soluble it would not be translocatable, Goodwin (10), however, states that the carotenoids are almost always solubilized by attachment to proteins. Then the presence of carotene in the root of the sweet potato might be attributed to its translocation from the leaves since the light accelerated synthesis of carotene in leaves has been shown to be more rapid than the synthesis in the root. The slow rate of carotene synthesis in the dark may not be sufficient to produce the amounts of carotene which are present in the root. The presence, however, of precursors in the root at harvest may account for the continued dark synthesis of carotene during storage. If carotene or its precursor were translocated from the sweet potato leaves where most of it is synthesized to the root where it accumulates then the gradient from the stem-end to the root-end might be ascribed to this transport.

Evidence for another possible explanation for the gradient of carotene from the stem-end to the root-end is suggested by Ezell, Wilcox, and Crowder (7). They noted that sprouting in the sweet potato occurs first and most profusely near the stem-end and suggested that there may be a corresponding longitudinal difference in metabolic activity. Thus

a higher metabolic activity in the stem-end of the sweet potato root may be associated in some way with the higher concentration of carotene in this region. Moore (28), however, cautions against the conclusion that the presence of a high concentration of carotenoid in a particular site necessarily implies that its action in this site is correspondingly intense.

Comparison of carotene content of peelings and of core in the sweet potato

If translocation activity were responsible for longitudinal differences in the concentration of carotene in the sweet potato root one would expect to find a higher concentration near the phloem elements. Thus in studies on the carrot Werner (37) found that from 70 percent to 87 percent of the carotene was in the phloem region. Harper and Zscheile (12) reported as much as 200 percent more carotene in the phloem of the carrot than the inner region. The present study, on the contrary, indicated that in the sweet potato there were larger amounts of carotene in the core region than in the peelings.

The difference in the distribution of carotene in the carrot and the sweet potato may be due to the unusual anatomical structure of the sweet potato. Artschwager (2) and McCormick (21) showed that the epidermis of the sweet potato is replaced by periderm and that the stele in the young root is typicall for the dicots. Continued growth and enlargement into fleshy roots, however, give rise to a perplexing anomalous structure. Thus, in the older fleshy roots there may be no single layer of phloem but rather scattered phloem elements including sieve-tubes and companion cells throughout the root. Artschwager (2) found

that the larger vascular strands of secondary tissue may be arranged in either of three ways: (a) the groups are distinct and arranged at the periphery of a narrow circle; (b) the groups are scattered much like the vascular bundles in a corn stalk; (c) the bundles bifurcate, join each other laterally and form in their entirety an intricate network which makes it difficult to trace the individual component parts thoughout the vertical extent of the organ. Some varieties possess characteristics of all of these groups. The sweet potato varieties used in the present study appear to have vascular strands of the network type. In all cases secondary phloem tissue (made up of phloem parenchyma, sieve-tubes, companion cells) is present which lies outside the vascular cambium. The fact that the carotene content of the core is greater than that of the peelings of sweet potatoes does not preclude the possibility that carotene may be translocated to the roots from the leaves.

The role, if any, which carotene plays in the metabolism of plants is not clear. Goodwin (10) reviewed the literature pertaining to the function of carotenoids in phanerogams under five headings, namely, carotenoids in oxidation-reduction systems, carotenoids as oxygen transporters, carotenoids in photosynthesis, carotenodis in photokinetic responses, and carotenoids in reproduction. He concludes that rigorous proof of any specific function is still lacking. Gortner (11) also believed that there is as yet no proof that carotenoids play a major role in any single physiological mechanism. Frank (9) suggests that phytol may be formed from carotene and thus carotenoids may form a pool for the phytol part of the chlorophyll molecule.

Variation in crops of two different years. The difference of 9 ug/gm between the carotene content of the Porto Rico Unit I sweet potato crop of 1945 and of 1947 was probably due to climatic differences in these two years. As indicated earlier the 1947 growing season had 67 clear days whereas the 1945 growing season had only 40. The precipitation during the 1947 growing season was less. The month of July especially may have been critical for there were but 0.94 of an inch rainfall, whereas, in 1945 there were 5.03 inches compared with the normal amount of 6.84 inches.* Goodwin (10) states that it is well established that a period of drought reduces somewhat the carotene concentration of plants.

The 1945 samples were secured from the Louisiana State Experiment Station farm and the 1947 samples from Henry Wells' farm some ten miles north of the station. The propagation stock for both crops was from the Experiment Station farm. The soil is classed as the same type for both locations.

In both crops the stem-end had the highest carotene concentration, the middle intermediate amounts, and the root-end the lowest concentration. The 1945 crop had higher average carotene content for the combined samples. The 1945 crop also had more carotene in the stem-end and the peelings. However, the 1947 crop had more in the middle, and the core regions.

Although the total amounts of carotene may be quite different the data show that even in crops of two different years the characteristic longitudinal distribution pattern remains the same. Transverse distribution, however, was not the same for both years.

*See appendix for weather data.

Changes in carotene distribution during storage. Investigators do not agree on the effect of storage on the carotene content of sweet potatoes. Ezell and Wilcox (6) and Anderson (1) presented evidence to show that the carotene content increased during storage, however, Mitchell and Lease (25) and Speirs et al. (33) could find no such increases. The loss of weight due to moisture loss and/or loss of dry matter undoubtedly have contributed to the lack of agreement among investigators.

The data in the present investigation show that there was a great variation in the carotene content of the roots during storage. In the Queen Mary and the Porto Rico varieties the carotene concentration seemed to increase for some time after harvest and then decrease as storage was prolonged. On the contrary, the Unit I variety did not show this initial increase.

Queen Mary: The carotene content per unit of fresh weight of the whole root of the Queen Mary sweet potato changed throughout storage. The stem-end carotene content per unit of fresh weight was considerably less, the middle region change was small, whereas the root-end had more carotene per unit of fresh weight. The RE/SE ratio was larger for the longer storage than it was for the short storage period.

Porto Rico: The carotene content of the whole root of the Porto Rico sweet potato also changed during storage. The stem-end concentration was less, but the middle and the root-end had more carotene per unit of fresh weight. The RE/SE ratio also increased with storage time.

Porto Rico Unit I: The carotene content of the whole root of both crops of the Unit I had less carotene per unit of fresh weight during storage. All regions of this variety had less carotene after the longer

storage period. The difference in carotene content per unit of fresh weight was greater than that which may have been due to loww of weight during storage for the 1947 crop. The difference for the 1945 crop was not larger than that which may have been due to loss of weight during storage. The 1947 crop had a similar increase in the RE/SE ratio as did the other varieties however, the 1945 crop had only a very slight change for this ratio. Whereas only the Porto Rico Unit I, 1947, showed statistically significant data the other groups indicated only certain trends.

It must be recognized that the loss of weight due to moisture loss and/or loss of dry matter as reported by Scott and Matthews (31) may affect the relative carotene concentration. An estimate of "correction" in absolute carotene content due to losses in moisture and dry weight during storage was shown in Table XI. If there were different losses between regions of the sweet potato root this would affect the relative carotene concentration in these regions. The data presented in the present paper are based upon the carotene content of sweet potatoes bought by the pound in the market regardless of weight changes due to either moisture or dry weight losses.

The change in the ratio of the carotene contained in the root-end compared to that contained in the stem-end may be due to either transport from the stem-end to the root-end, to differential utilization, to differential destruction or to differential synthesis of carotene in these regions of the root, or to differential moisture and dry weight loss during storage.

Transverse carotene concentration differences before and after storage were of smaller magnitude than the longitudinal differences.

Two different crops of the Porto Rico Unit I sweet potato had opposite carotene concentration differences in transverse section. These changes in carotene, expressed as peeling to core ratios, were relatively small, however, and often were in the same direction. Although the differences for the Unit I 1947 crop were small the increase of the peelings to core ratio was statistically significant. The anatomy of the sweet potato root offers avenues of communication between outer and inner regions if one wishes to assume that carotene as such is transported.

Superficially it appears that the carotene in sweet potato roots is mobile and is transported along a concentration gradient. However, the carotene may in some way be utilized or destroyed at different rates in the various parts of the sweet potato or synthesis may occur in variable degrees in these regions of the sweet potato root. The fact that the various regions of the sweet potato root contain fluctuating amounts of carotene even after prolonged storage tends to disprove the possible transport of carotene from one region to another. Kehr, Ting, and Miller (14) concluded from graft union experiments that transfer of carotenoids as such from stems of sweet potato plants to the roots did not occur. Until simultaneous analyses of carotene and moisture content and dry weight are made the question of synthesis, distruction or transport of carotene are premature.

The relatively high carotene content of sweet potato peelings indicate that a considerable loss of carotene results from the practice of peeling the root. Thus discarding this region of the root results in the substantial loss of pro-vitamin A.

The Queen Mary and the Porto Rico sweet potatoes retained higher percentages of carotene during storage than did the Unit I variety.

This was probably due to the greater reduction of carotene in the middle region and in the root-end in the latter variety. The Porto Rico variety is apparently superior to the newer variety, Unit I, for retention of carotene during storage.

SUMMARY AND CONCLUSIONS

1. Three sweet potato varieties were analyzed for their carotene content. The Queen Mary sweet potato contained more carotene than the other varieties. The Porto Rico Unit I variety ranked second in carotene content and the Porto Rico variety last.

2. The carotene is not uniformaly distributed throughout the sweet potato root. The stem-end contained more carotene than the middle region which, in turn, had more than the root-end.

3. The core region contained more carotene than the peelings.

4. Two different crops of the Porto Rico Unit I sweet potato had similar longitudinal distribution of carotene in the root. The transverse distribution of the carotene was, however, not the same for the crops of two years.

5. The three sweet potato varieties showed, in general, an increase in carotene content per unit of fresh weight during early storage and a decrease upon longer storage.

6. The three sweet potato varieties showed, in general, a higher root-end to stem-end ratio of carotene during storage. Changes in the peelings to core ratio were also noted.

7. Considerable carotene is lost when the peelings of sweet potatoes are discarded.

8. The Queen Mary and the Porto Rico varieties retained higher percentages of carotene during storage than the Porto Rico Unit I variety.

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FIGURES

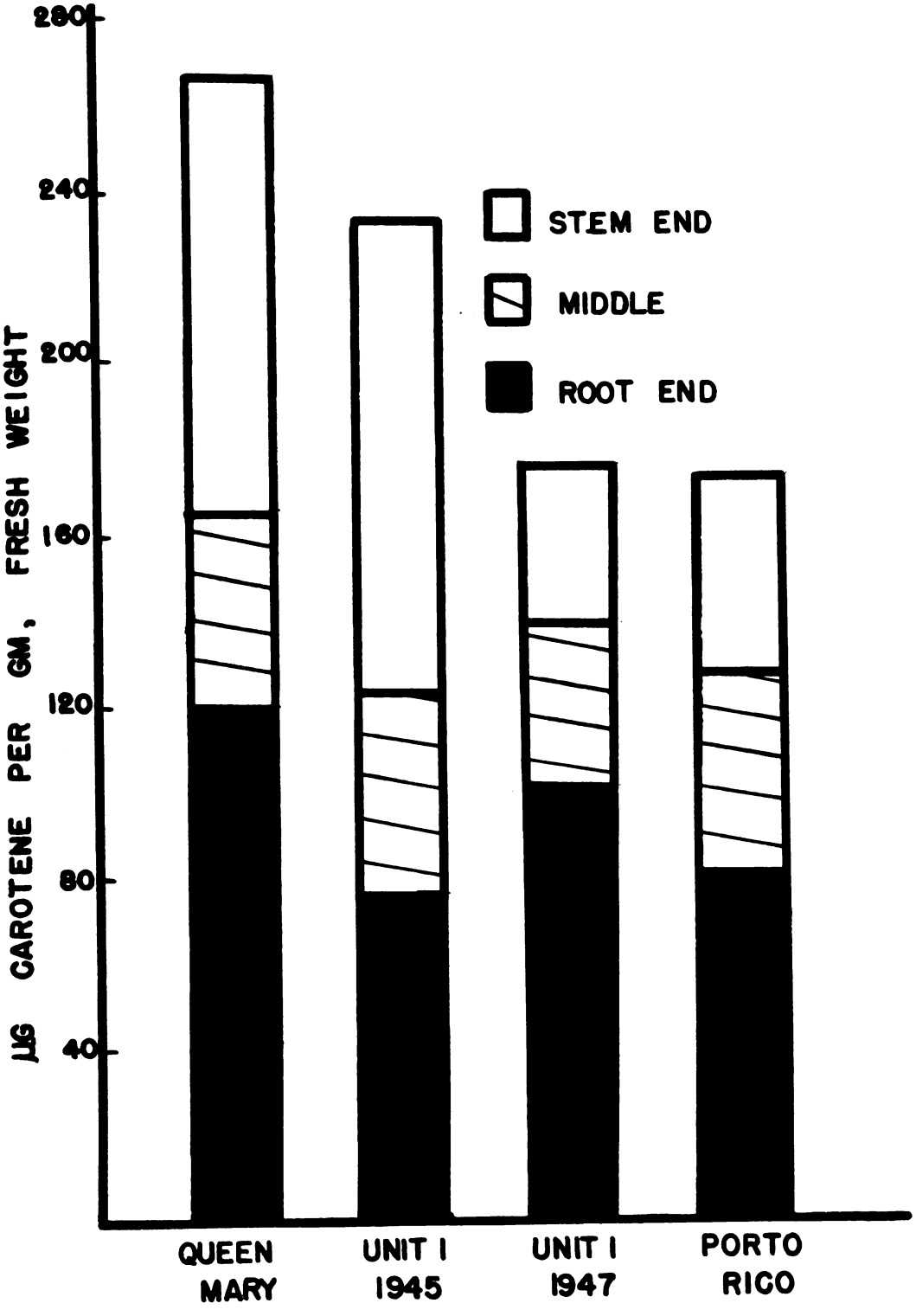


FIGURE 1. AVERAGE CAROTENE CONTENT OF STEM-END, MIDDLE, AND ROOT-END REGIONS OF THREE SWEET POTATO VARIETIES.

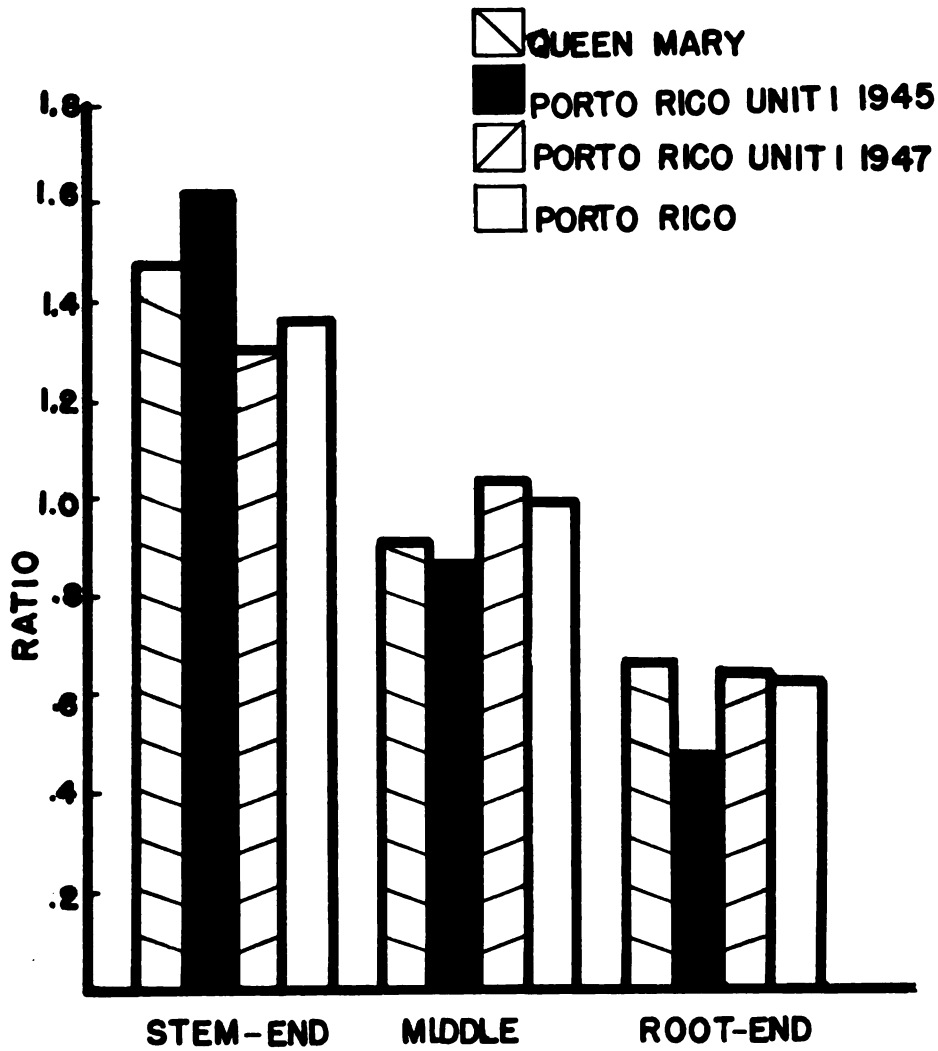
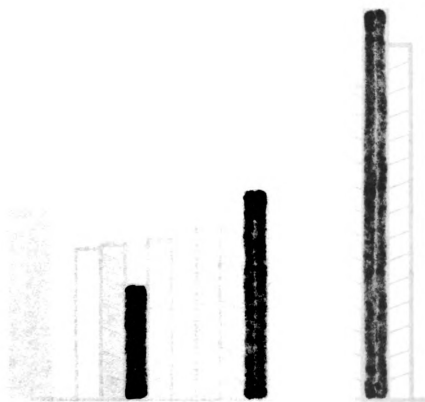


FIGURE 2. CAROTENE CONTENT RATIOS FOR STEM-END, MIDDLE, AND ROOT-END BASED ON AVERAGE CAROTENE CONTENT OF WHOLE ROOT.



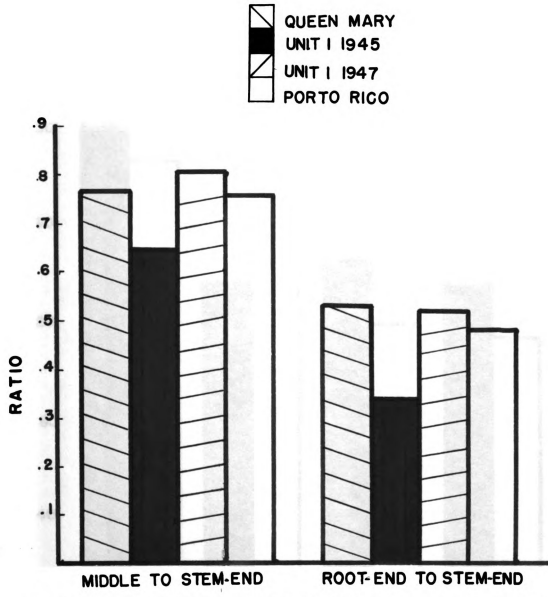
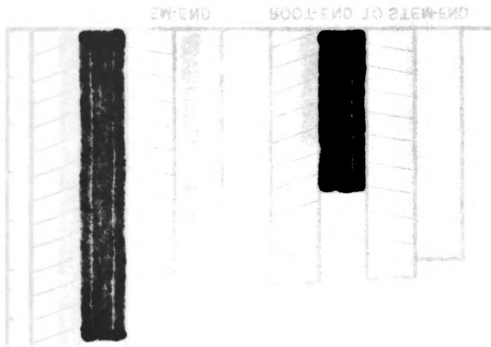


FIGURE 3. CAROTENE CONTENT RATIOS FOR MIDDLE TO STEM-END AND ROOT-END TO STEM-END FOR THREE SWEET POTATO VARIETIES.



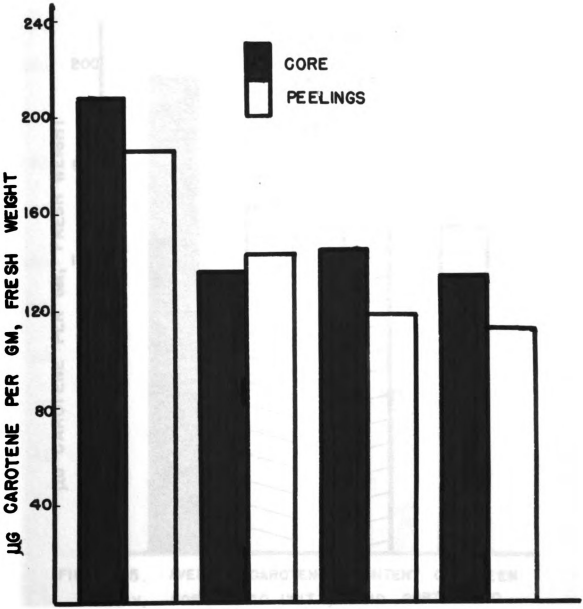


FIGURE 4. AVERAGE CAROTENE CONTENT OF PEELINGS AND CORE REGIONS OF THREE VARIETIES OF SWEET POTATOES.

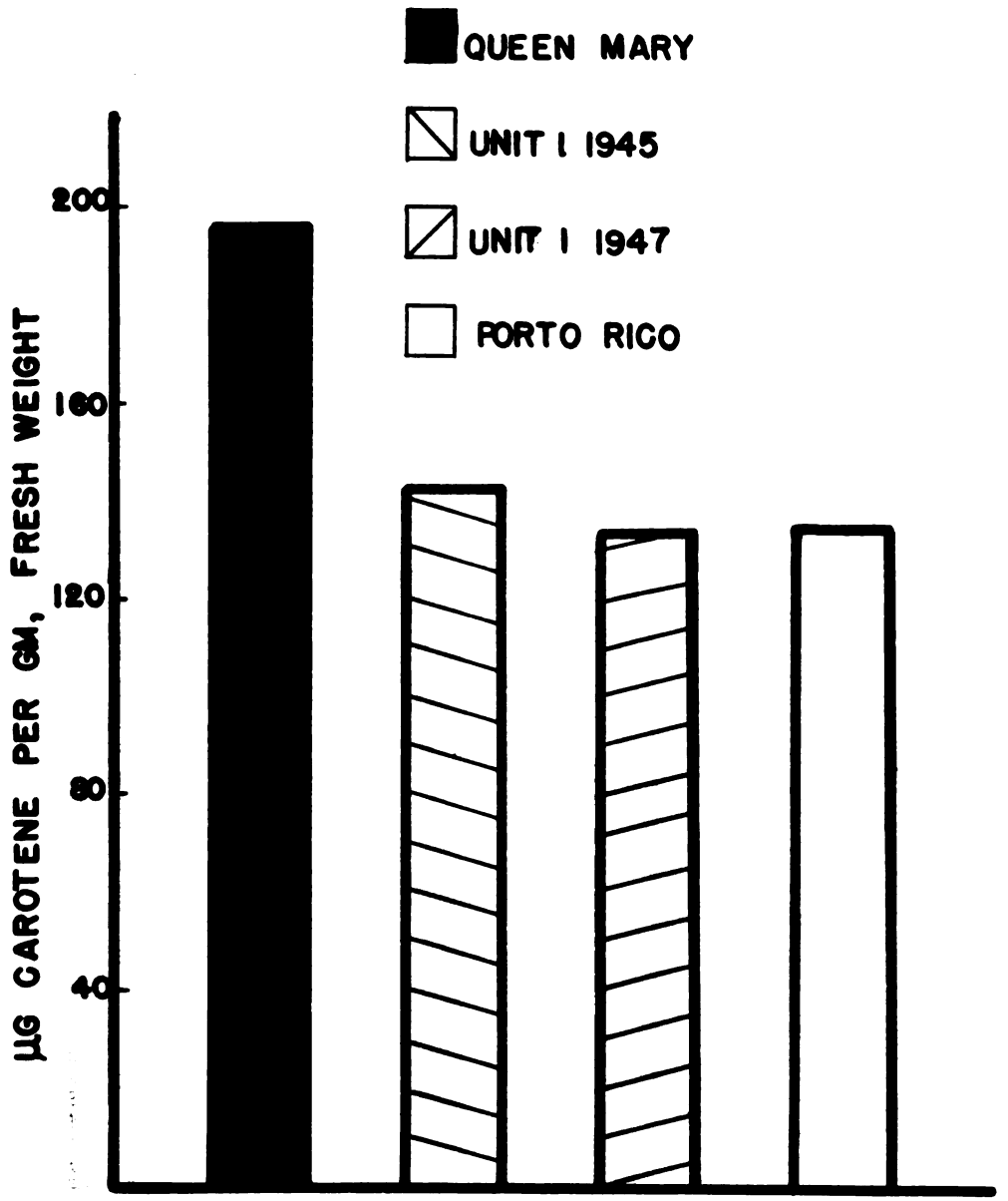


FIGURE 5. AVERAGE CAROTENE CONTENT OF QUEEN MARY, PORTO RICO UNIT I, AND PORTO RICO SWEET POTATOES.

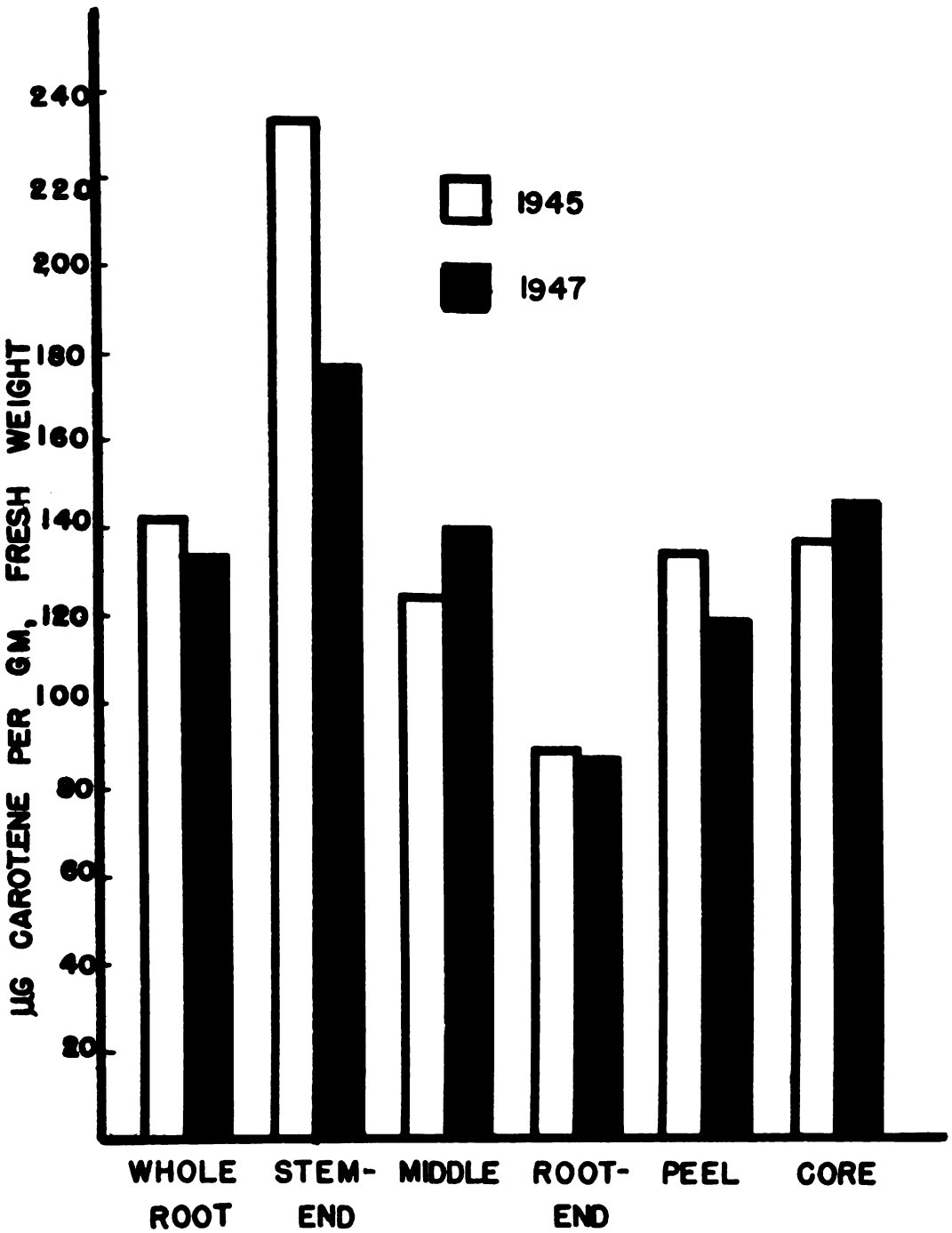
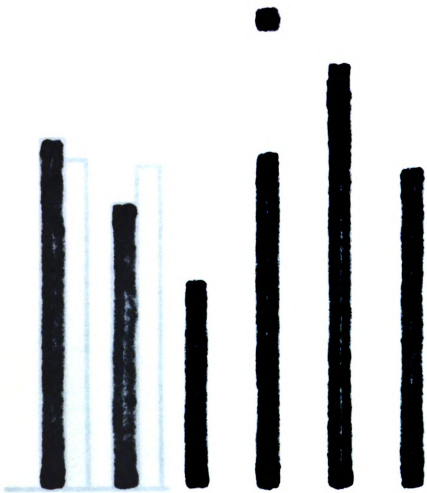


FIGURE 6. CAROTENE CONTENT COMPARISON FOR 1945 AND 1947 CROPS OF THE PORTO RICO UNIT I SWEET POTATOES.



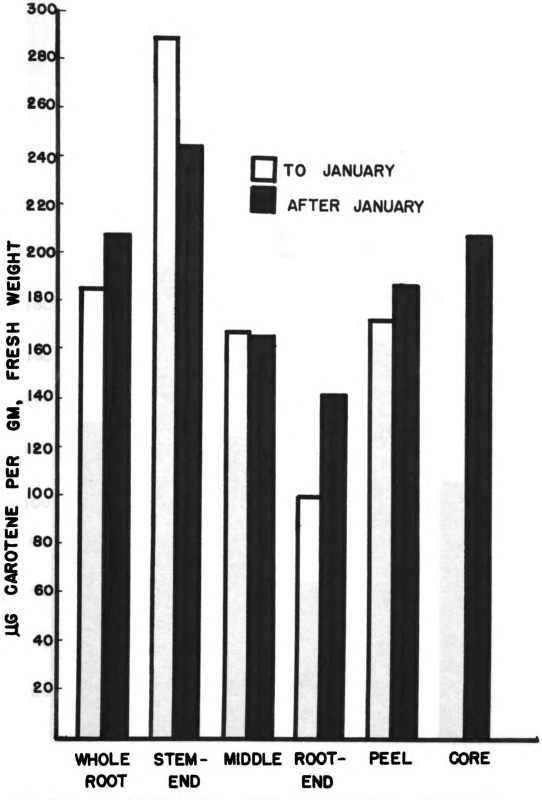
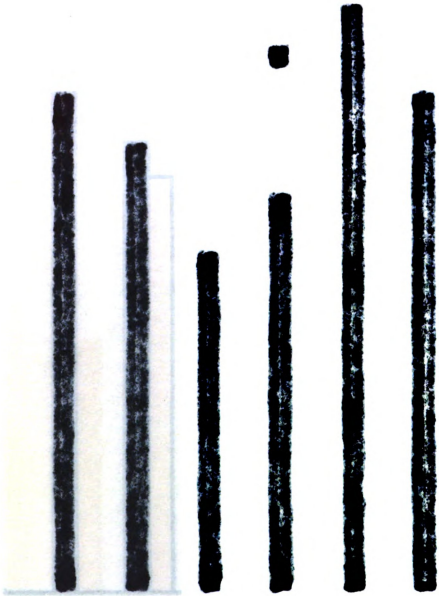


FIGURE 7. EFFECT OF STORAGE ON THE CAROTENE CONTENT OF THE QUEEN MARY SWEET POTATO.



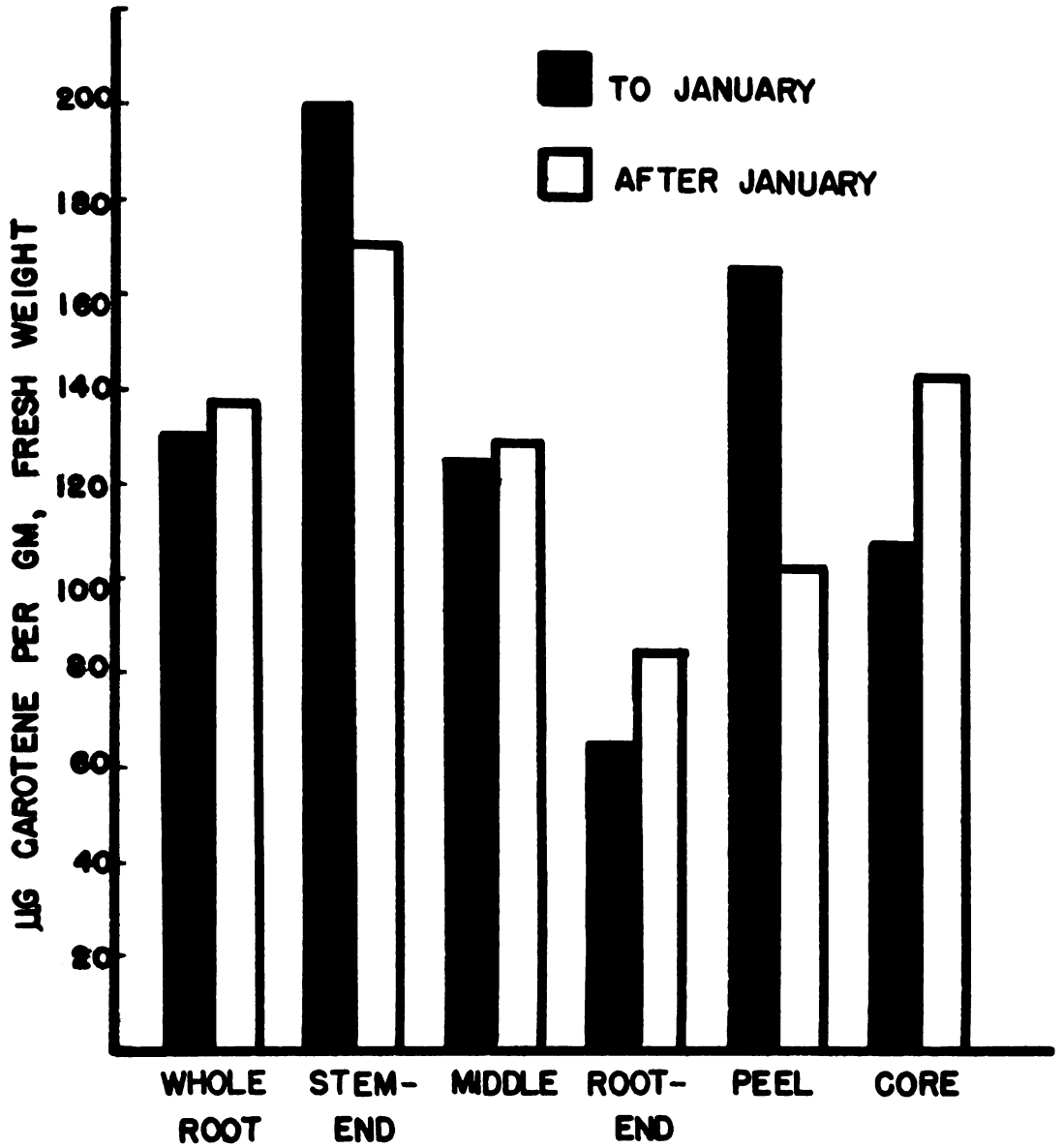
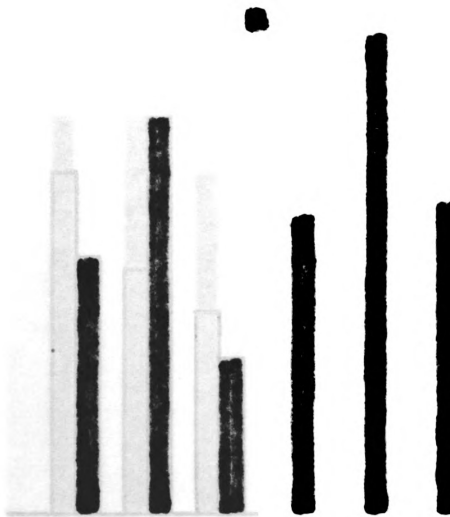


FIGURE 8. EFFECT OF STORAGE ON THE CAROTENE CONTENT OF THE PORTO RICO SWEET POTATO.



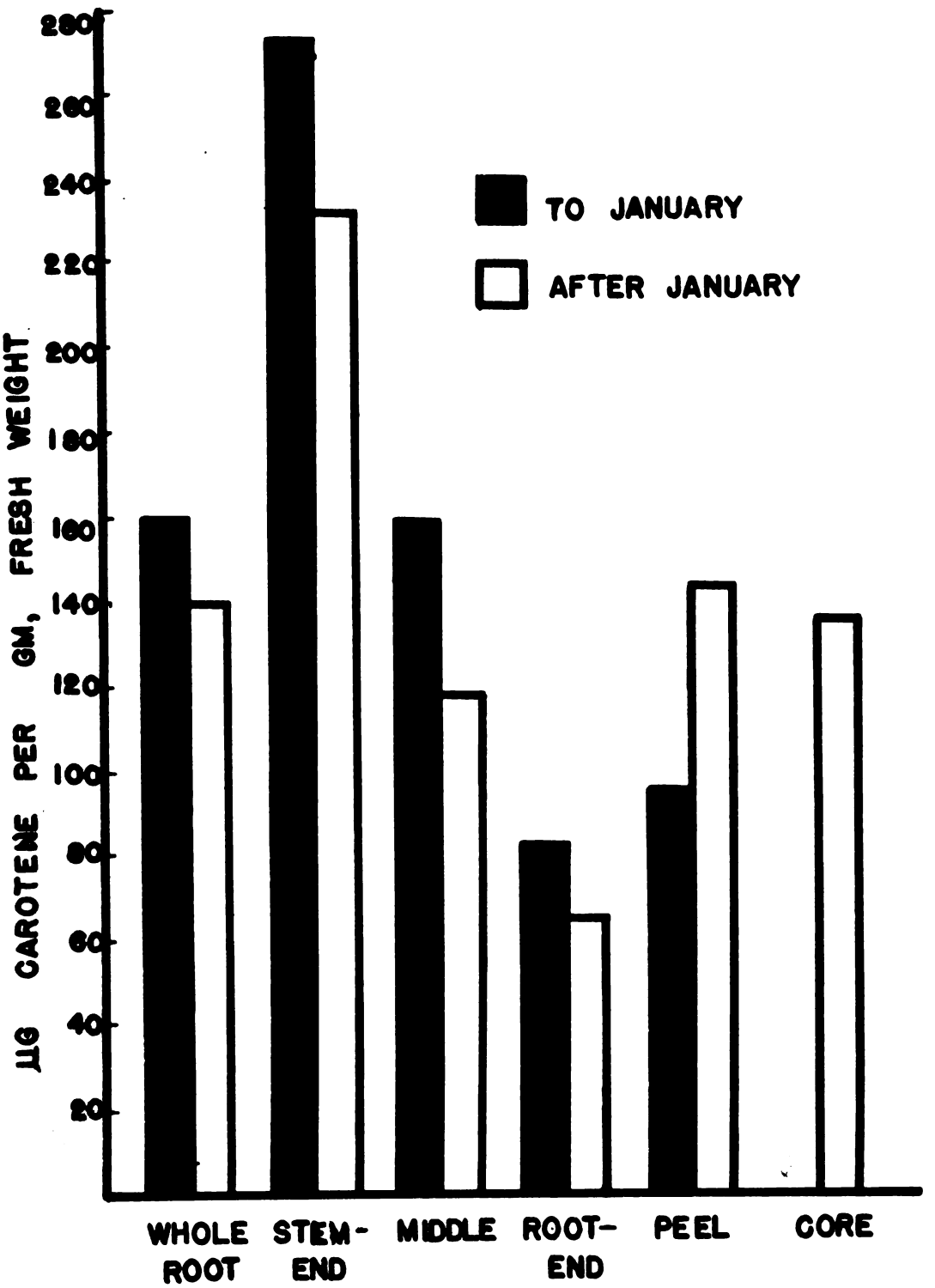


FIGURE 9. EFFECT OF STORAGE ON THE CAROTENE CONTENT OF THE PORTO RICO UNIT I 1945 CROP OF SWEET POTATOES.

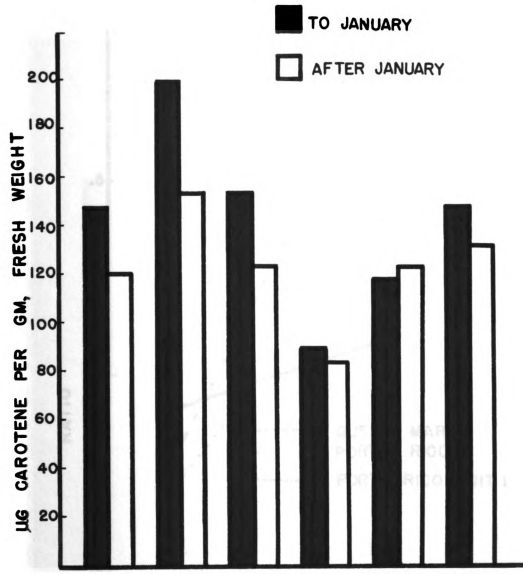
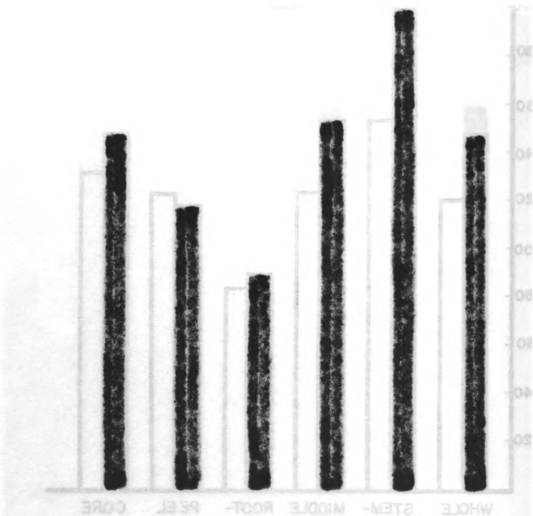


FIGURE 10. EFFECT OF STORAGE ON THE CAROTENE CONTENT OF THE PORTO RICO UNIT I 1947 CROP OF SWEET POTATOES.



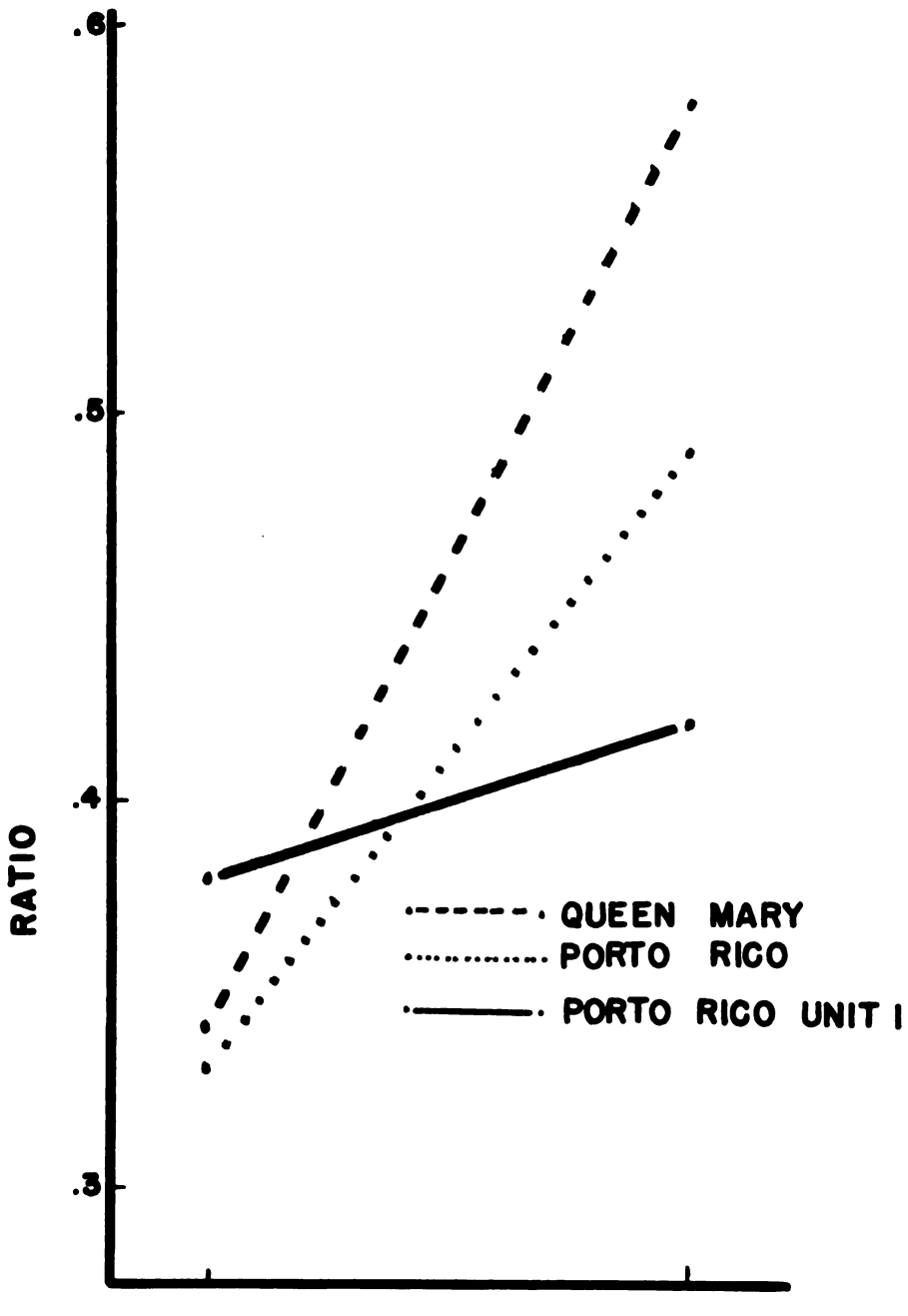


FIGURE II. THE CHANGE OF ROOT-END TO STEM-END CAROTENE CONTENT RATIO DURING STORAGE.

APPENDIX

1945 SUMMER WEATHER SUMMARY*

Month		June	July	August	September
Total precipitation		4.27	5.03	3.03	4.19
Mean daily temperature	Max.	91.8	90.5	91.9	90.8
	Mean	80.9	81.4	81.6	79.6
	Min.	70.0	72.3	71.3	68.3
Highest daily Temp.		96 16th	96 17th	98 4th	98 2nd
Lowest daily Temp.		64 23rd	69 21st	66 13th	54 15th
Clear days		12	8	8	12
Cloudy days		4	7	6	1
Partly cloudy days		14	16	17	17
Cloudiness scale (0-10)		5.0	5.0	4.9	3.8
Greatest daily precipitation		13th 2.14	25-26th 1.88	16-17th 0.95	11-12th 2.02
Days measurable precipitation(.25")		8	18	13	10

1947 SUMMER WEATHER SUMMARY*

Month		May	June	July	August	September
Total precipitation		3.96	5.23	0.94	2.21	4.85
Normal		5.31	4.77	6.84	5.51	4.56
Mean daily temperature	Max.	84.0	90.0	93.3	93.9	91.2
	Mean	73.8	81.2	81.4	83.2	79.8
	Min.	63.5	71.4	69.6	72.5	68.5
Highest daily temp.		90 5th	96 12th	98 28th	100 31st	99 7th
Lowest daily temp.		56 10th	65 17th	62 27th	70 1st	53 30th
Clear days		17	18	12	22	15
Cloudy days		4	4	15	7	13
Partly cloudy days		8	8	4	2	2
Cloudiness scale (0-10)		5.5	5.6	4.0	4.7	3.4
Greatest daily precipitation		20th 1.48	18th 2.99	18-19th 0.2	7-8th 0.46	19th 3.79
Days measurable precipitation(.25")		4	9	0	4	5

*Courtesy Harding Field United States Weather Station, Baton Rouge, Louisiana.

DATA FOR INDIVIDUAL ROOT ANALYSES

Date	Micrograms of carotene per gram of fresh weight				
	Stem-end	Middle	Root-end	Peelings	Core
		QUEEN MARY			
11/26/45	130	100	110	140	...
12/20/45	360	165	80	155	...
12/28/45	380	238	110	235	...
1/ 5/46	235	195	130	145	160
1/25/46	205	109	165	185	220
2/ 9/46	295	208	130	217	260
4/ 7/46	...	155	120	201	190
		PORTO RICO			
12/31/45	232	155	80	170	125
12/31/45	167	95	50	160	88
1/17/46	157	70	49	48	50
4/19/46	243	128	38	118	100
5/24/46	190	137	119	155	162
5/24/46	195	184	103	93	190
5/28/46	177	130	58	100	200
6/ 1/46	167	110	88	93	100
7/15/46	147	101	64	64	170
11/24/46	190	200	165	195	200
3/ 8/47	78	100	59	45	104
5/29/47	155	128	100	...	...
		PORTO RICO UNIT I 1945			
11/27/45	240	160	90	120	...
11/27/45	115	80	60	80	...
11/27/45	...	80	...	45	...
12/28/45	468	240	100	140	...
1/ 2/46	130	155	...	100	110
1/15/46	278	170	95	165	210
2/ 1/46	210	125	90	115	131
3/13/46	485	82	70	167	185
3/17/46	265	115	65	140	170
3/25/46	50	75	20	95	18
4/ 9/46	363	165	65	132	260
4/12/46	85	47	25	60	47
4/16/46	100	100	78	430	90
4/17/46	115	70	60	73	80
4/23/46	383	165	123	155	185
4/24/46	551	150	108	163	198

Date	Stem-end	Middle	Root-end	Peelings	Core
		PORTO RICO UNIT I 1945 (cont.)			
10/ 1/46	172	149	50	96	110
10/ 5/46	175	130	14	...	...
10/11/46	182	150	58	128	150
10/29/46	137	124	55	107	90
11/21/46	180	92	85	170	150
		PORTO RICO UNIT I 1947			
9/ 1/47	150	120	93	70	120
9/ 1/47	134	150	50	47	128
9/ 3/47	275	190	155	148	158
9/ 3/47	214	182	64	170	142
9/ 4/47	117	127	50	80	180
9/ 5/47	158	70	40	64	65
9/ 8/47	200	189	60	115	110
9/ 8/47	240	150	99	155	150
9/ 9/47	118	97	60	137	148
9/ 9/47	120	138	118	...	...
9/ 9/47	157	113	68	78	140
9/10/47	75	60	50	118	49
9/12/47	180	143	148	...	...
9/13/47	218	170	120	90	180
9/14/47	267	200	128	145	177
9/15/47	192	143	97	127	142
9/15/47	190	140	101	...	...
9/16/47	202	170	67	160	188
9/16/47	101	120	153	...	...
9/17/47	337	229	129	165	222
9/17/47	214	95	89	...	...
9/18/47	180	173	73	128	178
9/19/47	331	199	103	...	...
9/21/47	215	164	93	156	156
9/21/47	201	...	109	...	...
9/23/47	154	150	68	102	157
9/24/47	208	164	80	...	...
9/25/47	229	150	68	...	...
9/26/47	140	147	68	54	164
9/27/47	152	154	68	...	...
10/ 1/47	270	221	123	170	177
10/ 3/47	231	228	92	...	...
10/ 3/47	174	96	67	...	...
10/ 7/47	370	201	97	...	...
10/10/47	235	175	65	166	...
10/10/47	364	228	47	70	...
10/11/47	247	167	107	120	...
10/14/47	193	133	78	...	...
10/14/47	175	162	129	...	...
10/18/47	243	214	132	...	...
10/22/47	22	20	39	...	...

Date	Stem-end	Middle	Root-end	Peelings	Core
		PORTO RICO UNIT I 1947 (cont.)			
11/ 2/47	310	170	160	148	...
6/25/48	108	146	...	...	...
6/25/48	150	116	68	127	116
6/26/48	175	139	78	116	146
6/28/48	170	123	100	116	100
6/28/48	128	120	85	108	118
6/29/48	120	132	60	...	...
6/30/48	160	89	128	146	180
6/30/48	130	110	92	...	...
7/ 2/48	164	150	...	...	...
7/ 9/48	157	139	89	...	...
7/ 9/48	144	137	75	...	...
7/10/48	160	137	85	...	...
7/12/48	124	140	94	...	...
7/12/48	147	89	92	...	...
7/13/48	170	132	128	...	...
7/13/48	200	174	162	...	...
7/14/48	160	114	80	...	...
7/15/48	175	167	103	...	...
7/15/48	146	139	23	...	...
7/15/48	186	155	77	...	...
7/16/48	129	...	78	...	...
7/16/48	154	128	68	...	...
7/17/48	140	89	43	...	...
7/17/48	160	128	115	...	...
7/17/48	199	165	112	...	...
7/17/48	132	105	59	...	...
7/20/48	153	124	103	...	...
7/21/48	150	92	65	...	...
7/21/48	235	150	89	...	...
7/21/48	145	123	74	...	...
7/22/48	123	115	58	...	...
7/22/48	121	74	53	...	...
7/22/48	164	132	78	...	...
7/23/48	82	58	40	...	...
7/23/48	133	146	92	...	...
7/23/48	160	104	68	...	...