VASCULAR STREAKING OF STORED CASSAVA ROOTS*

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C. W. Averre

Department of Plant Pathology, Georgia Exp. Sta., U.S.A.

Cassava, manioc, or yuca *(Manihot utilissima* Pohl. *(Manihot esculenta* Crantz)), is an important fresh vegetable and commercial source of starch in the tropics. It has been grown in the Southern United States and Florida for many years (9), but sustained interest in this crop never developed until the recent immigration of Cuban refugees to Dade County. It is grown on approximately 200 acres in Dade County and is sold largely in the Miami area. However, shipments of cassava to New York have been rejected because of decay and dark discoloration in the fleshy roots. Shipping was in wooden boxes with moist sawdust and took approximately four days.

It appeared that in storage fresh cassava roots were affected by two disorders — a soft rot that was caused by fungi and bacteria, and a dark bluish discoloration of vascular bundles. This vascular discoloration usually started from cut surfaces and progressed rapidly inward, so that, within four days, roots twelve inches long were completely affected. Vascular streaking was more common toward the periphery of the root. In some cases the parenchymatous tissue between the vessels near the cambium was slightly discoloured with a light bluish cast.

The purpose of this study was to find the cause, conditions for development, and methods of control of vascular streaking.

REVIEW OF LITERATURE

Storage of cassava for more than a few days has been a continuing problem (2 and 7). There is a considerable amount of work reported on the botany, culture, and utilization of cassava, as well as chemical aspects of toxicity of the roots; but there have been no detailed studies on storage problems of fresh roots.

Most reports state that the cassava roots must be used within one to a few days of harvest because of rapid deterioration after harvest (3, 4, 5, 6, 7 and 9). However, neither the cause of the streaks nor the factors that contribute to the streaks were understood. Successful storage procedures reported include : slicing the roots, drying in the sun, and storing in a dry place (7 and 8); burying the roots in a cool place (7); refrigerating the roots at 0°—2.5°C and 85—90 per cent relative humidity (4 and 7); and desiccating the roots to 10—12 per cent moisture (7). Normancha and Pereira (7) suggested that harvested roots should receive a minimum of sun.

The cause of the discoloration is believed by a number of workers to be enzymatic. For example, Normancha and Pereira (7) state that enzymes acting

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on the carbohydrate cause the discoloration. Akinreile (1) stated that the brownish discoloration during fermentation of the cassava was due to the oxidation of leucoanthocyanins and that deeper layers under anaerobic conditions were not discoloured. He concluded that contact of the root with air and iron should be avoided. It was not clear, however, if this discoloration was the same as the vascular streaking problem.

METHODS AND RESULTS

Attempts to isolate fungi and bacteria from the leading edge of discoloured vascular tissues were negative. The following culture media were used : potato dextrose agar, corn meal agar, V-8 juice agar, and nutrient agar. Microscopic examination of wet sections from discoloured tissue did not reveal the presence of a microorganism.

Because of the absence of microorganisms and the rapidity of the development of the streaking, it was concluded that the disorder was solely physiological. Five storage tests were conducted with mature roots. In each case mature roots were selected and were thoroughly washed in tap water and dried before starting the tests.

Test 1. The roots were dug 24 hours before starting the test and were held at room temperature until used. The duration of the test was one week. Neither surface sterilization of the roots in a 10 per cent solution of Clorox (5.25 per cent sodium hypochlorite) for 10 minutes with storage at room temperature, nor storage in moist or dry sawdust at room temperature resulted in severe rot. However, storage at 5°C or at 35°C avoided the problem.

Test 2. Roots were obtained as in Test 1. The treatments and results are presented in Table 1. Roots with slight discoloration would probably have been acceptable on the market. The commercial practice of storage in moist sawdust at room temperature was ineffective and also resulted in severe rot.

Table 1.—Effect of 60-minute ice water dip and packaging on vascular streaking of cassava roots stored for five days at different temperatures.

Treatment description				No. roots discoloured		
No.	Hydrocooled	Packaging	Storage Temp. (°C)	Severe	Slight	None
1	No	Open crate	22	5	0	0
2	No	Moist sawdust	22	5	0	0
3	Yes	Open crate	22	4	1	0
4	Yes	Open crate	7	0	0	5
5	Yes	Moist sawdust	7	0	1	4

Test 3. The roots were obtained as in Test 1; in addition they were surface sterilized in a Clorox solution before starting the test. The treatments and results are presented in Table 2. The internal temperature of the roots was taken by removing a core with a cork borer and inserting a thermometer. The results indicated that dipping in water of 60°C for 45 minutes was effective in inactivating

the cause of the streaking. The data suggest that longer dips at lower temperatures may also be effective. Storage at 40°C was also effective.

Table 2. Effect of high and low temperature water dips on vascular streaking of cassava roots stored five days at different temperatures.

No.	Treatment description: Water dip Temp (°C)	Water dip Time (Min.)	Root internal temp. (°C)	Storage temp. (°C)	No. of roots discoloured: Severe	Slight	None
1	Not dipped		21	21	4	0	0
2	Not dipped		21	40	0	0	4
3	43	23	38	21	4	0	0
4	52	10	31	21	4	0	0
5	52	33	45	21	1	2	1
6	54	10	32	21	4	0	0
7	54	30	49	21	1	2	1
8	60	10	53	21	0	2	2
9	60	45	53	21	0	0	4

Test 4. The roots were freshly dug and immediately taken to the laboratory and prepared as in Test 3. The roots were then wrapped in moist paper towelling and placed in polyethylene bags. Storage time was eight days. Roots stored at 25°C developed slight vascular streaking. Vascular streaking did not develop at 10°C or at 40°C. Unbagged roots kept submerged in tap water did not develop streaking in this time; however, a severe slimy bacterial rot developed. This test was of interest because of the mild development of streaks at 25°C. Since the roots were placed in plastic bags it was speculated that perhaps the storage atmosphere may have had an effect on the streaking. Possibly the freshness of the roots at the time of storage avoided some of the streaking.

Test 5. Roots of the variety San Diego were freshly dug, cleaned, kept moist, and refrigerated overnight. The following day sections six inches long were cut and placed under various storage conditions for seven days. Roots were submerged in water containing 200 ppm streptomycin sulphate for seven days at 24°—27°C and were in perfect condition after this storage time. The antibiotic was added to avoid bacterial soft rot. The rest of the treatments and results are given in Table 3.

Table 3. Effects of various root treatments on vascular streaking of cassava roots stored seven days under various conditions.

No.	Treatment description	Storage Temp. (°C)	No. roots discoloured: Severe	Slight	None
1	Open air	24–27	4	0	0
2	Polyethylene bag	18	0	0	4
3	Moist chamber	2–10	0	1	3
4	Moist chamber	24–27	0	2	2
5	Moist chamber	40	0	0	4
6	Ends dipped in hot paraffin	24–27	0	1	3

The roots that were frozen in polyethylene bags were "spongy" when thawed, but the eating qualities were acceptable. Thawed roots did not develop streaks in four days at room temperature. The roots that were maintained at 40°C for seven days in a moist chamber developed streaking in four days when exposed to the air at room temperature. However, streaking did not develop in these roots when left for the same period of time in the moist chamber at room temperature. Vascular streaking developed rapidly in samples previously stored between 2°C and 10°C when these were placed at room temperature.

Discussion

The results obtained do not explain the cause of vascular streaking of cassava, but do suggest that its nature is enzymatic. The evidence for this is (1) absence of microorganisms from discoloured tissue, (2) inactivation of the mechanism when kept at 53°C for 45 minutes, (3) lack of full development of discoloration in roots under anaerobic conditions, and (4) complete lack of development of streaking in roots submerged in water.

Inconsistent results were obtained in development of vascular streaking at room temperature. Variables included varieties, maturity of crop, time of harvest, and drying of roots before and during the tests. The final test indicated that drying of roots may have been a major factor inducing vascular streaking.

These tests confirmed the previous report that post-harvest losses of cassava roots can be avoided by refrigeration (4). The tests further indicated that vascular streaking can be avoided by using a pre-storage hot water dip; by storing roots submerged in water at room temperature; or by storing roots at high temperature or at freezing temperature. It is possible that a number of these procedures could be developed for commercial storage of fresh cassava roots. In the meantime, however, fresh roots should probably be kept moist and removed quickly from the field after digging. The roots should be cooled, packed in moist material, and maintained under refrigeration until sold.

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C. W. AVERRE

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