THE STORAGE OF FRESH CASSAVA ROOTS

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SUMMARY

Internal streaking and discolouration are the primary causes of the loss of acceptability of harvested cassava roots. Mechanical damage is a major cause of rapid post-harvest deterioration. Curing occurs in cassava roots stored in structures similar to potato clamps. These are inexpensive and easy to build using readily available materials. In such clamps unselected roots have been stored with acceptable levels of loss for up to two months under the conditions prevailing at Cali, Colombia during cool seasons. During storage internal quality changes included an increase in sweetness, and a softening of the root core. After successful curing, cassava roots had a longer shelf-life than freshly harvested roots.

RESUME

La pourridié interne et la décoloration sont les premières causes qui privent le manioc récolté de ses qualités, Les dégâts dûs aux opérations mécanisées sont à la base de la détérioration rapide subie après la récolte. Le manioc stocké recouvre ses qualités dans des structures semblables aux silos à patate. On les construit aisément et à peu de frais en utilisant du matériel déjà existant. Dans ces silos on a stocké les racines rejetées pour leur niveau de perte, pendant environ deux mois en conditions prevalant au Cali, et en Colombie pendant les saisons fraîches. Pendant le stockage il y a eu changement dans la qualité interne du produit qui par ailleurs est devenu plus sucré et plus doux. Quand le traitement réussit, le manioc acquiert une durée de conservation plus longue que le manioc fraîchement récolté.

RESUMEN

El rayado interno y la decoloración son las causas primarias de la pérdida de aceptabilidad de las raíces de yuca cosechadas. El daño mecánico es la mayor causa de una deterioración rápida post-cosecha. El curado ocurre en las raíces de yuca almacenadas en estructuras similares a las prensas para papa las cuales son baratas y fáciles de construir, con materiales disponibles. En este tipo de prensas se han almacenado raíces no seleccionadas hasta dos meses, observándose pérdidas aceptables bajo las condiciones que prevalecen en Cali, Colombia, durante la temporada de frío. Durante el almacenaje la calidad interna cambia lo que incluye un incremento de dulzura y el ablandamiento de la parte central de la raíz. Después de un curado exitoso, las raíces de yuca tienen una vida de almacenaje mayor que la de las raíces recién cosechadas.

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REVIEW

Cassava roots cannot be kept in the fresh state for more than a few days after harvest. This presents serious problems in the marketing and utilization of the crop and often results in heavy losses. Most of the literature on storage of cassava has been reviewed by Ingram and Humphries[13]. They concluded that "knowledge of techniques for preserving and storing fresh cassava is still rudimentary and few reliable data exist." Similarly, little reliable information is available about the nature of the rapid post-harvest deterioration in newly harvested cassava. This has been reported as decay or rotting, dark bluish or brownish discolouration, dark or vascular streaking and/or softening of the affected areas. Several workers[1,6,10,17,21], have isolated and identified many microorganisms from deteriorated cassava and in some instances these organisms have in turn been shown to cause decay and discolouration. Other workers,[3,14,18,19,20] have suggested that both discolouration and softening result from enzymatic reactions. Ingram and Humphries[13] concluded that "It appears that the spoilage arises from a combination of physiological and pathological factors."

Mechanical damage has recently been emphasized as a major factor in post-harvest loss of all tropical root crops[5]. Averre[3] reported that vascular streaking of cassava roots commenced at cut surfaces and several workers[4,24] have emphasized the need for careful handling of roots intended for storage. Montaldo[18] reported differences between cultivars in the rate of development of vascular discolouration.

While extensive mechanical damage can only be reduced by improved harvesting and handling methods, a process of wound healing which occurs in several other root crops, such as potato[7], sweet potato[16] and yams[11,23] has been shown to reduce storage losses of slightly damaged produce. This process, generally referred to as 'curing', is stimulated by conditions of relatively high temperature and humidity and involved suberisation which is followed by development of a wound periderm. This retards water loss and acts as a barrier against infection.

It has long been known that cassava roots can be preserved for a few days using several simple techniques such as reburial, placing under water and coating in mud. There are, however, few recorded instances, with the exception of the use of high cost systems, such as refrigeration[9,21] and waxing[14,22] of successful long term storage of fresh cassava roots. The normal practice in much of the tropical world is to leave cassava unharvested in the ground until required. However, it has been estimated that this practice occupies 0.75 million hectares of land unnecessarily[13]. While refrigeration and waxing techniques may be of use in some situations, they cannot be extensively applied to practical farm or local market storage.

There is an account in early ethnological literature[12] that Amazonian Indians successfully stored fresh cassava during the annual flood period by burying the roots in the soil. Also, in Mauritius in 1741[2], M. de Reine successfully stored fresh cassava roots in a trench resembling a European potato clamp for periods of up to twelve months. In the Philippines, Baybay[4] showed that cassava roots could be stored for up to twenty-five days in a trench. It has also been reported[2,22] that roots piled up and covered with straw alone, or with straw and soil, inside a building, could be stored for periods of one to two months. Similar structures have also been used to store sweet potatoes under tropical conditions[15]. Conditions of above-ambient temperature and relative humidity develop in potato clamps in Europe[7,8].

OBSERVATIONS ON THE DETERIORATION OF CASSAVA ROOTS

Post-harvest observations at CIAT have revealed two distinct phases in the deterioration of cassava roots.

Primary deterioration

The initial cause of loss of acceptability is internal discolouration which normally develops within one to five days after harvest. This internal discolouration is first evident as fine blue/black vascular streaks as reported by Averre[3] and was described and illustrated by Montaldo[18]. This streaking increases in intensity with time and spreads to non-vascular tissue where a more diffuse brown discolouration, accompanied by dry white lesions, develops, This discolouration renders the roots unacceptable both for human consumption and for most industrial purposes. This is what will be called 'primary deterioration'. (Fig. 1).

Secondary deterioration

Later, pathogenic rotting, fermentation and/or softening of the roots occur. This type of root deterioration will be referred to as 'secondary deterioration'. However, in West Africa, softening can sometimes render cassava partially or completely unacceptable even when little or no primary deterioration has occurred (D.G. Coursey, private communication).

Occurrence of deterioration

In harvesting operations, cassava roots are always damaged and frequently severely so. Roots are often cut during digging, and the tips of the roots are commonly broken off and the 'shoulders' bruised as they are pulled out of the ground. Cutting the roots from the plant creates a further lesion, while transport from the field can often result in additional mechanical damage by bruising. Only minor differences between cultivars have been found in susceptibility to primary deterioration. The importance of mechanical damage in post-harvest deterioration has been confirmed by artificial wounding.

Roots grown in sandy soils can be harvested with greater ease and with less damage and thus have a greater storage potential than roots produced in heavy soils. Cultivars of cassava differ widely in tuber shape, size, distribution through the soil and in the length of the 'neck' of non-storage root at the proximal end of the tuber. These factors, some of which may be modified by cultural practices, all influence the final amount of damage. Table 1 shows the effect of damage on water loss and deterioration of freshly harvested roots.

Nature of deterioration

The onset of primary deterioration was delayed when roots, portions of roots, or root slices were surface sterilized. For example, 10 mm thick transverse root slices untreated or dipped for thirty seconds in sterile distilled water and stored on moist filter paper in petri dishes became completely discoloured within twenty-four hours. Similar root slices dipped for thirty seconds in calcium hypochlorite (2.0%) or commercial alcohol (40%) showed no such deterioration for between two and four days, depending on the concentration of surface sterilant used (Table 2).

As a result of these observations and those on the effect of mechanical damage, it seems that the rapid primary deterioration that occurs after harvesting cassava roots may be due to colonization by epiphytic microorganisms naturally present on the root surface. While these organisms, at present uncharacterized, do not normally cause rotting or decay of undamaged roots, they may enter wounds produced by mechanical damage and stimulate the onset of discolouration which subsequently spreads throughout the root.

STORAGE OF CASSAVA ROOTS

Storage in structures like potato clamps was re-investigated and several clamp units were built at C.I.A.T. from November 1972 to June 1973. Each clamp was built, on well-drained ground, by first placing a circular bed of rice straw of 1.5 m. diameter and of sufficient thickness so that, when later compacted, it was approximately 150 mm thick. Five hundred roots were heaped on this straw in a conical pile. These roots weighed approximately 300 kilos which is about the quantity one man can harvest in a day. Unselected roots were used, so that there was a large variation in root size and a substantial proportion of roots were mechanically damaged. The pile of roots was then covered with straw which compacted to a layer 150 mm thick. The whole clamp was then covered to a thickness of 100-150 mm with soil dug from around its circumference so as to form a drainage ditch. (Fig. 2).

Storage clamps were opened and the roots examined after periods of one, two and three months (Table 3). During cooler periods or during periods of frequent but light rainfall, the roots were successfully stored, with an acceptable level of loss, for two months. During such periods the temperature inside the clamps was between 30° C and 35° C. This temperature was found to remain constant throughout the storage periods, whereas the temperature of the soil cover fluctuated with the day and night temperature variations. A large proportion of the stored roots were successfully cured, and there was visible evidence of wound healing after one month in storage (Fig. 3). After two months storage, the bulk of the roots remained undeteriorated (Fig. 1). However, a few of the stored roots, although remaining undiscoloured, had softened in the centre. After three months storage, the percentage of unmarketable roots had increased considerably as there was some central softening in otherwise undeteriorated roots.

During long, hot and dry periods when the temperature of the stored roots inside the clamps rose to more than 40° C, high percentage losses had occurred by one month. Also, during periods of prolonged heavy rainfall when water penetrated the clamps, wetting the roots. There were heavy losses.

The main causes of loss were attributable to rots of pathogenic origin. Little loss attributable to primary deterioration was observed. On several occasions roots at harvest time were observed to be coated with hyphae of *Corticium rolfsii* Curzi which, during storage, rapidly invaded wounds before effective curing could take place and resulted in considerable decay. Other organisms associated with rotting and fermentation have not yet been identified.

All the clamps in the main series of experiments were constructed using rice straw. However, some additional clamps were built using dry sugarcane leaves, dry maize stems and leaves, and dry grass. These gave similar results to the rice straw clamps. Also, two large clamps of similar cross-sectional design and size, but elongate instead of conical were built to accommodate one and two thousand roots respectively. These gave similar results to those obtained in the smaller clamps.

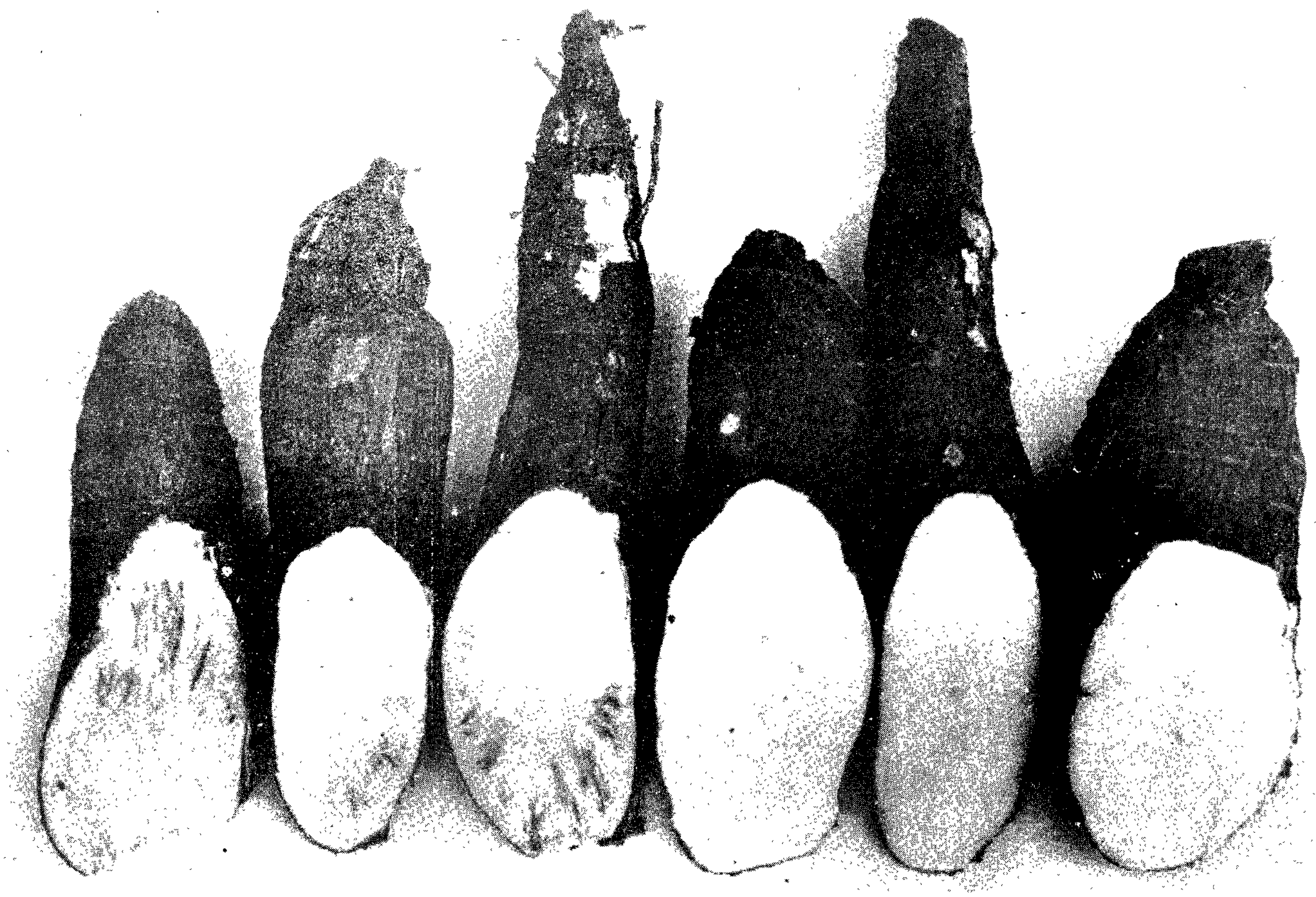

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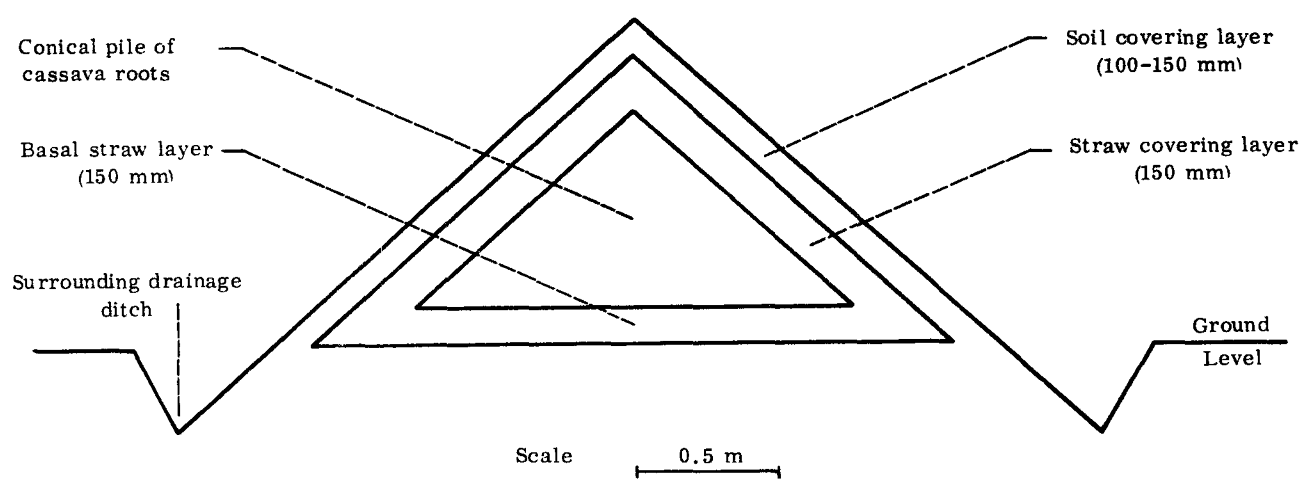
Figure 1. *Three undeteriorated cassava roots after 8 weeks storage in a clump (right) compared with roots showing primary deterioration symptoms after 3 days storage at ambient (left).*

FIG. 2 CROSS SECTION THROUGH CASSAVA CLAMP



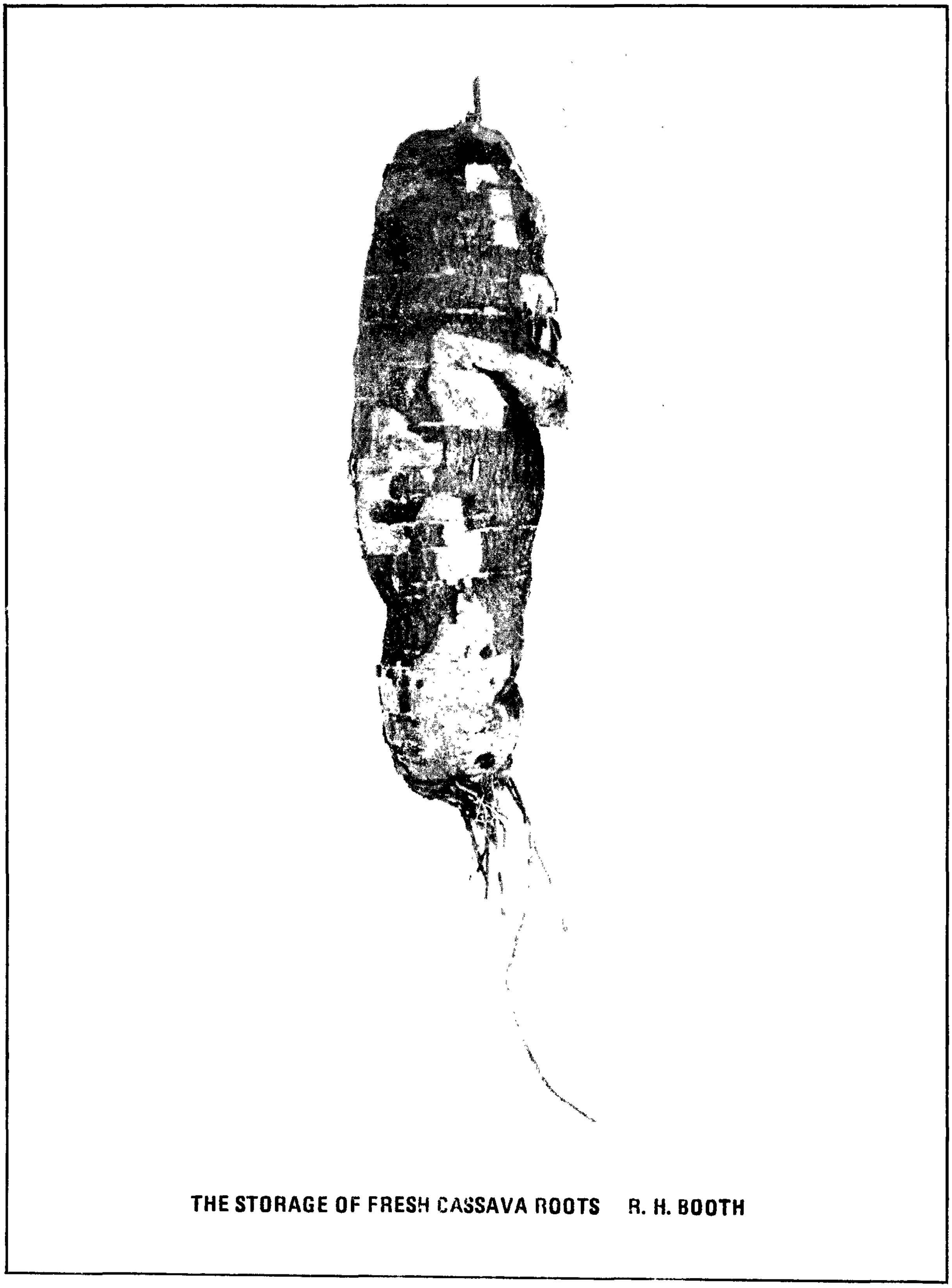


Figure 3. *Cured cassava root after 4 weeks storage in a clump, showing healed wounds (arrows).*

QUALITY OF STORED ROOTS

Numerous root samples, after varying periods in storage, were tested for acceptability. Most visibly undeteriorated roots passed tests locally considered indicative of freshness, i.e. the skin was firm, the flesh moist and latex exudated after cutting.

Uncooked stored roots consistently tasted considerably sweeter than freshly harvested roots of the same cultivar, even after one month in storage. This sweetening was, however, less noticeable in cooked samples. Preliminary results indicate that there is a conversion from starch to sugar during storage.

In a few samples a longer cooking period was required to soften the stored roots than is normally required for freshly harvested roots. Roots which had softened internally during prolonged storage frequently regained an acceptable texture and edible quality during cooking. The biochemical changes that occur during storage and the effect of these changes on the eating quality of roots are being further investigated.

After successful curing, the shelf-life of roots removed from storage was longer than that of freshly harvested roots kept under the same conditions (Table 4). It is considered that during curing not onlv does the wound healing occur but also suberisation and/or thickening of the root skin. This slows down water loss and renders the roots more resistant to further damage. Individual, successfully cured roots have been stored for up to eight weeks under ambient conditions in the laboratory, at the end of which time they were still of an acceptable eating quality.

Thus, usually even after three months storage, undeteriorated roots were acceptable, despite the detectable quality differences between these and fresh roots. The effect of these differences on the marketability, human acceptability and animal feeding qualities of the stored roots is being investigated.

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ACKNOWLEDGEMENTS

I wish to thank the Centro Internacional de Agricultura Tropical, in particular, members of the cassava production system team, and D. G. Coursey of the Tropical Products Institute for their assistance and encouragement throughout this project.

TABLE 1

Effect of severity of damage on fresh weight loss and deterioration of cassava roots stored at ambient conditions[1] in the laboratory.

Time in storage (days)	Fresh weight loss[2] (%)		Deterioration Index[2] (%)	
	Slightly[3] damaged	Severely[4] damaged	Slightly[3] damaged	Severely[4] damaged
1	2.9	3.5	2	15
2	7.4	10.1	27	32
4	12.4	15.9	62	65
7	17.9	21.5	57	67
11	22.1	34.2	72	75

1. Ambient conditions: temperature 20°C±4°C
2. 3 x 10 roots per sample
3. Roots with no obvious gross physical damage.
4. Roots with obvious physical damage.

NOTE

The deterioration index is the deterioration score expressed as a percentage of the total possible score for that treatment where, for any particular root, the score is 0 = no deterioration, 1 = ¼ deterioration, 2 = ½ deterioration, 3 = ¾ deterioration and 4 = complete deterioration.

TABLE 2

Effect of calcium hypochlorite and commercial alcohol on the deterioration of cassava root slices.

Treatment[1]	Deterioration Index (%) Days 0	1	2	3	4
Undipped control	0	100	100	100	100
30 sec. dip in sterile distilled water	0	100	100	100	100
30 sec. dip in 1.0% com. alcohol	0	100	100	100	100
" " " " 5.0% " "	0	75	100	100	100
" " " " 10.0% " "	0	50	75	100	100
" " " " 20.0% " "	0	25	50	75	100
" " " " 40.0% " "	0	0	12	25	30
" " " " 60.0% " "	0	0	0	0	2
30 sec. dip in 0.1% Ca.hypochlorite	0	81	100	100	100
" " " " 0.5% " "	0	25	50	75	100
" " " " 1.0% " "	0	0	12	50	60
" " " " 2.0% " "	0[2]	0[2]	0[2]	2[2]	12[2]
" " " " 3.0% " "	0[2]	0[2]	0[2]	0[2]	2[2]
" " " " 5.0% " "	0[2]	0[2]	0[2]	0[2]	0[2]

1. 4 x 4 slices per treatment
2. slight discolouration attributed to phytotoxicity

TABLE 3

Results of clamp storage at different temperatures.

Time in storage (months)	Undeteriorated roots[1] (%)	
	Temperature of stored roots	
	30-35°C	40°C and above
1	85-90	5-25
2	70-75	0-5
3	40-60	0

1. Average of five clamps within each temperature range. Each clamp contained 500 roots which weighted approximately 300 kilos.

TABLE 4

Comparison of shelf-life of fresh uncured roots (A) with that of roots that had been cured and stored in a clamp for eights weeks (B)

Laboratory storage (weeks)	Deterioration Index[1] A	B
1	45	10
2	80	7
3	100	20

1. 3 x 10 roots per sample.