CASSAVA

Processing and Storage
Proceedings of an Interdisciplinary Workshop, Pattaya, Thailand, 17-19 April 1974

Editors: E.V. Araullo
Barry Nestel
Marilyn Campbell
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Storage of Cassava Roots and Related Post-Harvest Problems

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Abstract
This paper reviews the present knowledge of post-harvest deterioration and storage of fresh cassava roots and summarizes recent experimental work undertaken by the senior author at the Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia.

Two types of post-harvest deterioration are recognized: primary deterioration, which involves internal discolouration and which is usually the initial cause of loss of acceptability; and secondary deterioration due to pathogenic rots, fermentation, softening of the roots, or all three. The rate at which primary deterioration occurs differs between varieties but it always commences at the sites of mechanical injury. Curing and wound healing of the roots is described and is reported to prevent the onset of primary deterioration. These processes are reported to occur in simple field storage structures similar in design to European potato clamps and in which cassava roots have been stored for periods in excess of 2 mo. Following successful curing and storage, certain quality changes, notably a longer shelf life, a conversion of starch to sugars, and a reduction in HCN levels, are reported and discussed. The possible use of the curing process to aid other types of storage practices is discussed.

The paper concludes that the prospects of storing fresh cassava roots for several weeks or even months appears very promising.

Résumé
Le texte en question procède à un examen des connaissances actuelles sur les problèmes de détérioration des racines de manioc après récolte et au cours du stockage; il résume également les travaux expérimentaux effectués récemment par le principal des deux auteurs au "Centro Internacional de Agricultura Tropical" (CIAT), Cali, Colombie.

On a classé les détériorations après récolte en deux types: la détérioration primaire, qui implique une décoloration interne et constitue généralement la cause première de non-acceptabilité, puis la détérioration secondaire due à des pourritures pathogéniques, à la fermentation ou au ramollissement des racines, quand ce n'est pas les trois à la fois. La rapidité avec laquelle intervient la détérioration primaire diffère suivant

1The experimental work reported in this paper was undertaken at the Centro Internacional de Agricultura Tropical (CIAT), where the senior author is currently on secondment, and forms part of a joint Tropical Products Institute/CIAT cassava storage project.
UNTIL recently, it was generally accepted that cassava roots could not be kept in the fresh state for more than a few days after harvest. This has presented serious problems in the marketing and utilization of the crop and has resulted in heavy losses. Under the subsistence farming conditions under which most of the world's cassava is produced, the normal way of overcoming the difficulty is to leave the plants in the ground until needed, and once harvested, to process roots immediately into some form of dried product of inherently longer storage life.

It has been estimated (Ingram and Humphries 1972) that the practice of leaving the cassava in the ground until required unnecessarily occupies three-quarters of a million hectares of agricultural land. Furthermore, susceptibility to loss is reported to increase by allowing the roots to remain too long in the ground (Affran 1968; Doku 1969; Irvine 1969): although the roots may continue to increase in size they become more fibrous and woody and their starch content declines (Greenstreet and Lambourne 1933; Holleman and Aten 1956; Jones 1959). Where attempts have been made to increase the scale of production of the various dried products, the difficulty of holding stocks of cassava roots for even a few days at a processing plant has been a major factor inhibiting such industrial developments.

It is thus seen that the ability to store fresh cassava will not only assist the small subsistence producer but also the large-scale marketing and industrialization of the crop. However, little research has been undertaken on this subject and Ingram and Humphries (1972) were forced to conclude that "knowledge of techniques for preserving and storing fresh cassava is still rudimentary and few reliable data exist."

Post-Harvest Deterioration of Cassava Roots

Little reliable information is available as to the nature of the rapid post-harvest deterioration that prevents the storage of fresh cassava roots. This deterioration has been reported as decay or rotting, dark bluish or brownish discolouration, dark or vascular streaking, or softening of affected areas. Several workers (Affran 1968; Burton 1970; Doku 1969; Majumder 1955; Singh and Mathur 1953) have isolated and identified numerous different microorganisms from deteriorated cassava and in a few instances these organisms appear to have been associated with decay and discolouration. Other workers (Averre 1967; IIT 1972; Montaldo 1973; Normanha and Pereira 1963; Pacheco 1952) have suggested that both discolouration and softening are the results of physiological reactions. Ingram and Humphries (1972) concluded that "the spoilage arises from a combination of physiological and pathological factors." To clarify this situation, it is possible to designate two types of deterioration, which can be termed primary and secondary deterioration (Booth 1973a). Primary deterioration involves internal discolouration of the roots and is usually the initial cause of loss of accept-
ability. It is first manifested as fine blue-black vascular streaks but later spreads to cause a more general brown discolouration. Secondary deterioration, due to pathogenic rots, fermentation, softening of the roots or all three, generally occurs at a later stage, the roots already having become unacceptable due to primary deterioration.

The present studies have confirmed the earlier reports of Averre (1967), Booth (1973b), and Tracy (1903) that discolouration commences at the sites of mechanical damage and that of Montaldo (1973) who reports that varieties of cassava differ considerably in the rate at which discolouration occurs. Both these factors need to be borne in mind in the selection of varieties and harvesting systems: roots intended for storage should always be handled with care. As a result of these observations, together with the fact that discolouration can be delayed by the use of surface sterilants, it was suggested (Booth 1973a) that primary deterioration is the result of a reaction occurring in wounds, which might possibly be stimulated by nonpathogenic microorganisms present at these sites.

Storage Techniques

It has long been known that cassava roots can be preserved for a few days using several simple techniques such as reburial, keeping under water, and coating in mud. There are, however, few recorded instances of successful long-term storage of fresh cassava roots other than by employing high cost systems such as refrigeration (Czyhrinciw and Jaffe 1951; Singh and Mathur 1953) and waxing (lIT 1972; Subramanyan and Mathur 1956). Although refrigeration and certain waxing techniques may be of use in limited situations, such as export marketing, or for experimental purposes, it is not considered that at present such systems can be extensively applied to practical on-farm, local market, or even industrial storage. There are, however, reports in early ethnographic literature (Hakluyt Society London 1922) that Amazonian Indians successfully stored fresh cassava during annual flood periods by burying the roots in the soil. Further, it is reported (Anon. 1944) that M. de Reine in 1741 successfully stored fresh cassava roots in a straw-lined trench for periods of up to 12 mo in Mauritius, and Baybay (1922) in the Philippines stored roots for up to 25 days in a trench. It is also known that roots piled up and covered with straw either alone or mixed with soil, inside a building could be stored for periods of 1–2 mo (Anon. 1944; Subramanyan and Mathur 1956).

As a result of these reports, the possibility of storing fresh cassava roots in small structures similar in design to European potato clamps was investigated at the Centro Internacional de Agricultura Tropical (ciat), Cali, Colombia (ciat 1972; Booth 1973a). Each clamp was built by first placing a circular bed of straw of approximately 1.5 m diam and of sufficient thickness that when it was later compacted it was approximately 150 mm thick, on suitably well-drained ground. On this straw bed, the freshly harvested roots were heaped in a conical pile; for each unit between 300 and 500 k of unselected roots were used. The pile of roots was covered with a similar layer of straw, and the whole clamp covered with soil to a thickness of 100–150 mm, the soil being dug from around the circumference of the clamp so as to form a drainage ditch (Fig. 1).

During cooler periods or periods of frequent but light rain fall, roots, including severely damaged ones, have been successfully stored with acceptable levels of loss (0–20%) for periods of up to 2 mo and on occasions for much longer periods of 3–6 mo with minimal deterioration losses. However, during prolonged hot and dry periods when the temperature inside the clamps was continuously over 40°C, or during periods of excessive heavy rain fall when the roots become wet, heavy losses resulted even after 1 mo storage.

During these investigations, it was observed that successfully stored roots are “cured” (Fig. 2 and 3) and that there is frequently visible evidence of wound healing after 1 mo. Furthermore, the losses that occur during clamp storage were observed rarely to be due
to primary deterioration but rather are caused by pathogenic rots or fermentation, or both. It thus appears that the curing and wound-healing processes prevent the onset of primary deterioration.

**Quality of Stored Roots**

Following curing and storage in clamps, it has been noticed that the roots have a much longer shelf life than that of fresh roots kept under the same conditions. So long as the cured and stored roots are not damaged further, they do not discolour internally even after several weeks under ambient conditions and the duration of their shelf life is largely determined by moisture loss. This is, of course, dependent on the ambient conditions under which they are kept. Preliminary biochemical tests have indicated that during clamp storage there is a
conversion of starch to soluble sugars and also a reduction in the hydrogen cyanide content. This is confirmed by the observation that uncooked stored roots consistently taste sweeter and less bitter than freshly harvested roots of the same variety.

In the studies on the quality of stored roots, we are finding that these changes have little effect on the human acceptability of roots when boiled and consumed as a fresh vegetable. It is considered that with certain varieties the sweetening that occurs during storage may in fact be advantageous particularly for animal feed purposes by encouraging a higher consumption. However, a conversion of starch to sugars may obviously be a disadvantage for certain industrial purposes.

Following prolonged storage for 3 or more months, a further loss of quality frequently arises due to a softening of the central core of the root, which is thought to be due to water loss.

These biochemical and quality changes are at present being further investigated and quantified.

**Discussion**

The prospects of extending the post-harvest storage life of fresh cassava roots from several days to several weeks or even months thus appears promising. The small storage clamps provide an excellent research model, which, with certain local modifications, may have direct application to many small subsistence farmers. Preliminary studies also indicate that it may be possible to cure and store roots packed in boxes with air-dry rice husks, sawdust, or similar material under ambient conditions. Packing in such material raises the internal box temperature several degrees above ambient and helps to maintain a high humidity. Such a system of packing and storing cassava may prove to be extreme-
ly useful where the crop is grown at some distance from market outlets.

Similarly, further knowledge of the curing process, which appears to prevent the onset of primary deterioration, may lead to the possibility of building special curing and storage rooms if bulk storage or other more sophisticated practices are required. Following temperature recordings during successful clamp storage, it appears that a relatively high temperature, between 30 and 40°C, and a high relative humidity are desirable for curing. Indications from research or other root crops, however, suggest that the optimum temperature for rapid curing is even higher, but following such rapid curing, a lower temperature would be needed for long-term storage. A high relative humidity appears not only to aid curing but also to prevent excessive moisture loss while the roots are held at the necessary high temperatures.

Curing conditions are also ideal for the growth of many tropical microorganisms and thus, a certain amount of loss due to rotting may be expected when roots are maintained for long periods under these conditions. This has been seen to be especially true when old roots were observed to be coated with mycelium of the fungus Sclerotium rolfsii when harvested; these roots rotted very rapidly when placed in storage clamps. It may thus be anticipated that once optimum curing conditions have been established, the best storage results will be obtained by using a rapid curing procedure followed by storage at a lower temperature (but not below 12°C, at which chilling injury is believed to occur).

It must be emphasized that the condition and health of the roots at the time they are placed in store is amongst the most important factors governing the success or failure of storage. Thus, every effort must be made to reduce the excessive amount of harvesting damage that is normally evident on cassava roots and subsequently to handle them with extreme care. It should also be stressed that although cured roots have a longer shelf life than fresh ones and may also be more robust, they will behave and deteriorate exactly as fresh roots if they are redamaged through bad handling. Thus, as is the case in the handling and storage of all fresh agricultural produce great care must be taken to minimize mechanical damage, but provided this caution is heeded the prospects of storing fresh cassava roots appear very promising.

References

HAKLUYT SOCIETY LONDON. 1922. Journal of the travels and labours of Father Samuel Fritz in the river of the amazons between 1686 and 1723.


