Effectiveness of three different storage structures and curing process for the storage of sweet potato (*Ipomoea batatas*) in Ghana

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ABSTRACT

Three different storage structures and two curing processes for the storage of sweet potato (*Ipomoea batatas*) were studied at the CSIR-Food Research Institute, Accra. Sweet potato roots initially cured under warm (30-35 °C) and very humid (90-95% relative humidity) conditions for 7 and 14 days were stored in local (traditional), pit, and clamp storage structures for 84 days. After 0-84 days of storage, the roots were sampled and physically assessed into wholesome, sprouted, fungal-infected, and insect and rodent-damaged. The decrease in percentage wholesome roots corresponded to an increase in percentage fungal-infected roots from 0 to 84 days of storage in all the three different storage structures. Clamp storage structure recorded the highest percentage wholesome roots (20.0%) compared to pit (16.3%) and local (0%) after 84 days of storage when roots were cured for 7 days. However, for 14 days cured roots stored for 84 days, local storage structure recorded the highest percentage wholesome roots (20%), pit (0%), and clamp (10%). Higher percentages of fungal-infected sweet potato roots were recorded from roots cured for 14 days. Percentage sprouted roots was higher in clamp, followed by pit and local storage structures. Sprouting was delayed for sweet potato roots that were cured for 14 days in all the storage structures. Percentage damage of sweet potato roots by insect and rodent was lower in all the three storage structures compared to the fungal-infected sweet potato roots.

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RÉSUMÉ

TORTOE, C., OBODAI, M., AMOA-AWUA, W., ODURO-YEBOAH, C. & VOWOTOR, K.: *Efficacité de trois structures différents de stockage et procédés de traitement pour le stockage de la patate douce au Ghana.* Trois structures différentes de stockage et deux processus de traitement pour le stockage de la patate douce (*Ipomoea batatas)* ont été étudiées. L'étude a été entreprise à l'Institut de Recherche d'Alimentation, Accra. Des racines de patate douce au départ traitées dans des conditions chaudes (30-35 °C) et très humides (90-95% d'hygrométrie) pour 7 et 14 jours ont été stockées dans des structures de stockage traditionnel, de la fosse et sous paille pendant 84 jours. Après 0-84 jours de stockage les racines ont été prélevées et physiquement évalué et groupé comme sain, poussé, fongique-infecté et l'endommagement par l'insecte et le rongeur. La diminution des racines saines en pourcentage a correspondu à une augmentation des racines fongique infectées par pourcentage de 0 à 84 jours de stockage dans toutes les trois structures différentes de stockage. La stockage sous paille a enregistré le pourcentage des racines saines le plus élevé (20%) par rapport a la fosse (16.3%) et traditionnelle (0%) après 84 jours de stockage quand des racines ont été traitées pour 7 jours. Cependant, pour des racines traitées pour 14 jours et stockées pendant 84 jours, la structure de stockage traditionnel a enregistré les racines saines les plus élevées en pourcentage (20%), la fosse (0%) et sous paille (10%). Le pourcentage le plus élevé des racines fongiques infectées de patate douce a été enregistré des racines qui ont été traitées pendant 14 jours. Le pourcentage de racines poussées était plus haut dans le stockage sous paille suivie des structures de la fosse et du stockage traditionnel. La poussent a été retardé pour des racines de patate douce traitées pendant 14 jours dans toutes les structures de stockage. Par rapport aux racines fongique-infectée les dommages en pourcentages des racines de patate douce par l'insecte et le rongeur étaient inférieurs dans toutes les trois structures de stockage.

Introduction

Sweet potato (*Ipomoea batatas* (L.) Lam) is a root crop that belongs to the family Convolvulaceae sp. According to Harton (1987), sweet potato ranks seventh in total production on the list of world crops, and eighth in the world in providing energy and protein (FAO, 1987). Sweet potato has a high energy efficiency ratio than the cereals when produced in a non-mechanized field (Norman, Pearson & Searle, 1984). In monetary terms, it is 13th globally in the production value of agricultural commodities, and fifth on the list of most valuable food crops in the developing countries (FAO, 1987). In sub-Saharan Africa, sweet potato is an important food crop grown on about 2.1 million ha, with an estimated production of 9.9 million tonnes (FAOSTAT, 2002).

Sweet potato does not normally require high level of inputs because vines cover the field and, thus, eliminate the need for weeding, or the use of herbicides is minimal.

Hayma (1982) estimated that in the tropics, between 25 and 40 per cent of agricultural products are lost each year because of inadequate farm and village-level storage. According to Boot (1974), these quantitative and qualitative losses, or a combination of both from post-harvest storage, result from physical, physiological or pathological factors or various combinations of these factors. The losses often result from wounds caused by harvesting implements, insect and rodent bites, and growth of fungi. Further, damage to sweet potato roots occurs during handling and marketing because of overpacking in sacks and inefficient transportation. When sweet potato roots are left in the sun after harvest or during uncontrolled conditions of storage, they are exposed to high temperatures, which may increase moisture losses and susceptibility to decay (Hayma, 1982). Higher temperatures promote sprouting and increase respiration, leading to heat production and dry matter loss (Hayma, 1982). The high water content and thin skin of roots encourage microbial attack, resulting in substantial losses. A natural loss of dry matter is observed during storage, as well as loss of water through transpiration (or wilting) (Hayma, 1982).

Storage of sweet potato is not a recent innovation. Ancient methods practised by Marvis of New Zealand for hundreds of years have been described (Cooley, 1951; Kelery, 1965). Lancaster & Courtesy (1984) reported on the pit storage of sweet potato in Zimbabwe and Malawi where the roots are placed in pits with alternative layers of wood ash. In Papua New Guinea, roots are alternated with layers of grass in holes lined with grass and sprinkled with wood ash, and are finally covered with dry leaves or grass (Numtor & Lyonga, 1987). In Ghana, a similar local storage method is available, which consists of a hole dug in the ground and lined with grass at the floor.

Sweet potatoes stored under controlled conditions have been shown to produce carbon dioxide and lose water in such a way that the dry matter/water ratio changes (Kushman & Wright, 1969). Sweet potato roots at 13-15 °C and high humidity were stored for a year in the USA (Picha, 1986). Unfortunately, application of temperature-controlled environment for sweet potato storage is inaccessible to small-scale farmers in tropical developing countries. However, without temperature control, Hall & Devereau (2000) and Van Oirschot *et al.* (2000) reported that sweet potato roots were stored in local, pit, or clamp storage structures in which high humidity was maintained for 3 to 4 months after careful selection of the roots.

Curing of sweet potato roots have been reported to improve their storage (Thompson, 1972; Demeaux & Vivier, 1984). Curing allows injured roots with high water content to heal, and protects them from storage diseases and excessive shrinkage (Demeaux & Vivier, 1984). Wounds in sweet potatoes cure most efficiently when roots are exposed to 28-30 °C and relative humidity (RH) greater than 85 per cent (Kushman & Wright, 1969). During curing a layer of cork cells, a few cell layers thick, is formed around the roots. The layer greatly reduces the desiccation process and prevents infection by bacteria and fungi (Hayma, 1982). The percentage weight loss during storage of cured and uncured roots in the West Indies for 113 days was 17 and 43 per cent, respectively (Thompson, 1972).

In the developing countries, investment of small-scale farmers in land, energy, herbicides, and others on sweet potato cultivation could be wasted because of improper post-harvest handling and storage. Sweet potato roots are either sold at the farm gate at reduced price, or stored in local storage structures with severe losses. Heavy storage losses from the local storage structures have been recorded because of sprouting, rodent destruction, pest and microbial damage (Rees, Van Oirschot & Kapinga, 2003). These losses do not motivate the farmer to grow more sweet potatoes for storage. To address the problem and increase the economic returns of farmers, this study evaluated the effectiveness of two improved storage structures (pit and clamp) and a local storage structure, and two curing processes for storing white variety sweet potato roots.

Materials and methods

Plant material

Sweet potato (white variety) used in the studies was collected from CSIR-Crops Research Institute, Kumasi, in the Ashanti Region of Ghana. Two batches of freshly harvested roots (580 kg) were piled under a shed and covered with jute sacks and cured at 30-35 °C and relative humidity of 80-90 per cent for 7 and 14 days.

Storage structures

The three storage structures used in this study were local, pit, and clamp types. Two of each storage structure were constructed on a suitable well-drained ground at the Pilot Plant of the Food Research Institute, Accra. The local storage structure consisted of a cylindrical hole (1.0 m × 1.0 m × 1.0 m) dug in the dry ground and lined thickly at the floor and walls with 20 kg of dry grass. The grass helped to cushion the sweet potato roots and to absorb excess moisture. To prevent flooding and excessive sunshine, the local storage structures were constructed on raised ground under a tree. Sweet potato roots, which had been cured, were carefully placed in the hole, closed and sealed with grass, and the soil up to ground level (Fig. 1A).

The pit consisted of a cylindrical hole (1.0 m × 1.0 m × 1.0 m) dug in dry ground and lined with 20 kg of dry grass on the floor and walls of the hole, with a sloping thatched roof over it to prevent rain getting in and also exposure to sunshine. A small space was left between the base of the roof and the ground to allow for ventilation. The cured sweet potato roots were placed carefully in the pit on the dry grass and covered with more dry grass (Fig. 1B).

The clamp storage structure consisted of a circular bed of 20-cm thick dry grass on a raised flat mound of earth surrounded by a concrete wall of 30 cm above the ground level. A hut was constructed on the concrete wall, supported by wood and wire gauze that prevented rodents from entering. A thatched roof was placed on the hut to prevent undue exposure to sunshine or damage by heavy rains. Cured sweet potato roots were carefully placed on top of the circular bed of dry grass and covered with more grass to protect the roots from drying out and weevils from entering (Fig. 1C). After being cured for 7 and 14 days, 140-kg wholesome sweet potato roots were placed in each of the local, pit, and clamp storage structures.

Sampling

During storage, 20-kg samples were randomly removed fortnightly from the three different storage structures, kept separately, and physically assessed for wholesome, sprouted, fungus-infected, insect and rodent-damaged sweet potato roots, based on the descriptions presented in Table 1. This procedure was followed for 84 days.

Statistical analysis

Results reported were means of duplicate experiments in the three different storage structures and two curing processes for the

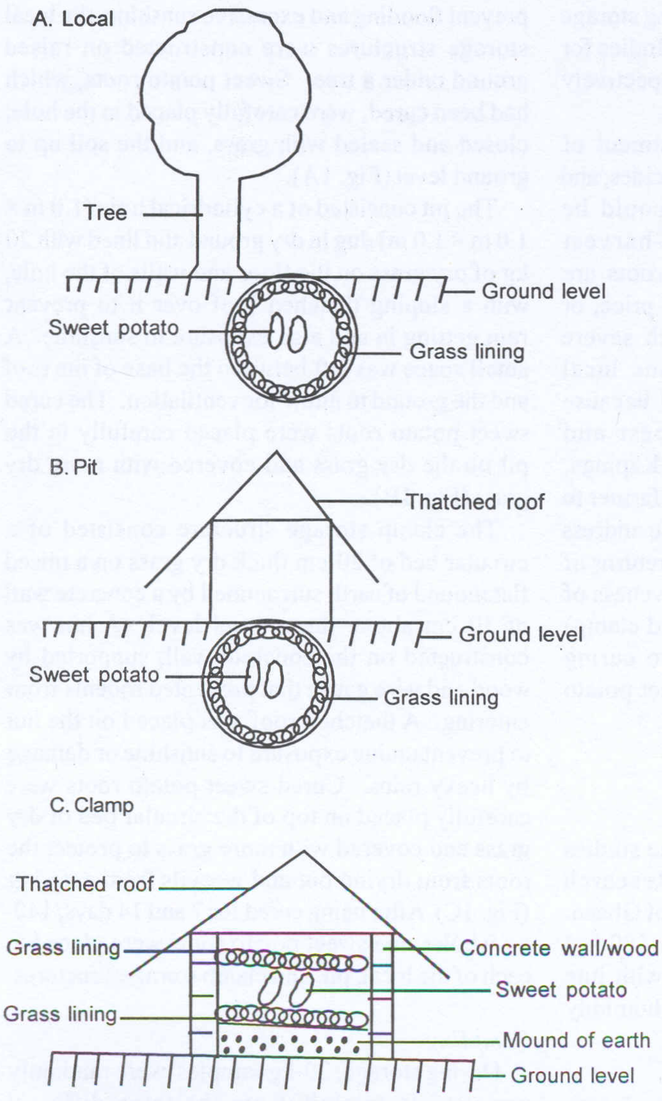

Fig. 1. Storage structures.

storage of sweet potato (*I. batatas*). The data were statistically analyzed, using Statgraphics (Graphics Software System, STCC, USA). Mean separation was by Duncan's Multiple Range Test (DMRT) defined at $P < 0.05$.

Results

Wholesome sweet potato roots

After 28 days of storage, 100 per cent wholesome roots cured for 7 days at the beginning of the experiment decreased to 39.0 per cent, and no wholesome roots were recorded after 42 to 84 days in the local storage structure (Fig. 2). In contrast, the 100 per cent wholesome roots cured for 14 days at the beginning of the experiment decreased to 62.0 per cent after 28 days, and further decreased to 20.0 per cent after 84 days in the local storage structure (Fig. 2). However, wholesome roots cured for 7 days decreased from 100 to 16.3 and 20.0 per cent in the pit and clamp storage structures, respectively, after 84 days of storage (Fig. 2). In addition, wholesome roots cured for 14 days decreased from 100 to 20.0 and 10.0 per cent in the local and clamp storage structures, respectively, after 84 days of storage. However, no wholesome roots were recorded after 70 and 84 days in the pit storage structure (Fig. 2).

Sprouted sweet potato roots

Percentage sprouted sweet potato roots were higher in the clamp storage structure. The highest sprouted sweet potato roots (37.0%) were recorded in the clamp storage structure for the 7-day cured roots after 28 days of storage; whereas the lowest sprouted sweet potato roots (3.0%) were recorded in the pit storage structure for the 14-day cured sweet potato roots (Fig. 3). The first appearance of sprouted sweet potato roots were recorded during 14 and 42 days of storage among the 7 and 14-day cured sweet potato roots, respectively (Fig. 3).

Fungus-infected sweet potato roots

Fungus-infected sweet potato roots ranged from 12.5 to 100 per cent and 10.0 to 40.5 per cent

TABLE 1

Description for Sweet Potato (Ipomoea batatas) Roots Sampled from the Three Storage Structures

Sweet potato roots	*Description*
Wholesome	Perfect rind, rind intact, no blemish on rind, smooth and rough outer covering of tuber, tuber in excellent condition.
Sprouted	Rind is broken, 1 to 3 sprouts, 0.1 to 3.0 cm in length occurring at one end of tuber.
Fungal infection	Patches of black and brown moulds on outer covering of tuber. Presence of dirty white fluffy mycelium spreading on outer covering. Presence of wet and dry rot on tuber.
Insect and rodent damage	Presence of insect and rodent bites on tuber. Tubers aesthetically unacceptable.

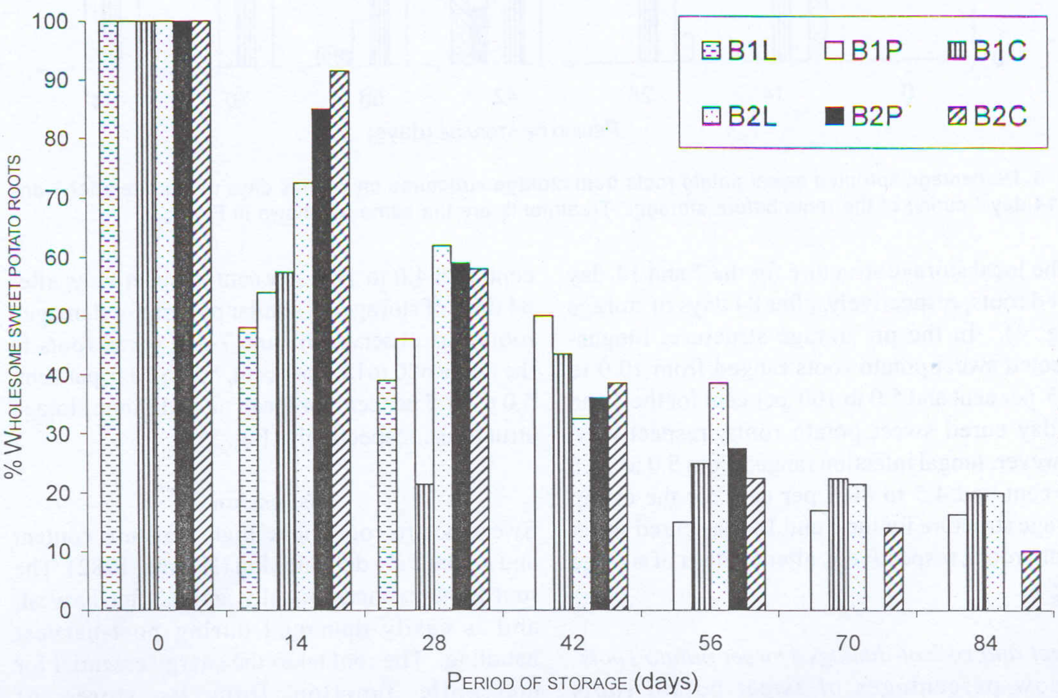

Fig. 2. Percentage wholesome sweet potato roots from storage structures on various days of storage after 7 and 14 days' curing of the roots before storage. Treatments: B1L = 7 days' cured sweet potato roots stored in local storage structure; B1P = 7 days' cured sweet potato roots stored in pit storage structure; B1C = 7 days' cured sweet potato roots stored in clamp storage structure; B2L = 14 days' cured sweet potato roots stored in local storage structure; B2P = 14 days' cured sweet potato roots stored in pit storage structure; B2C = 14 days' cured sweet potato roots stored in clamp storage structure.

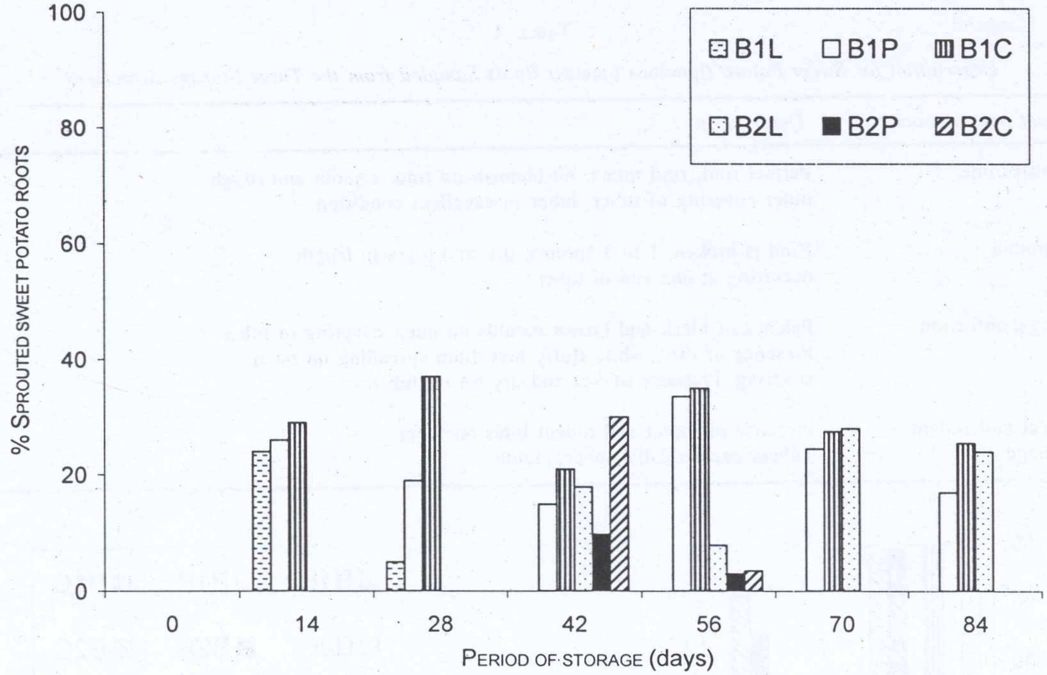

Fig. 3. Percentage sprouted sweet potato roots from storage structures on various days of storage after 7 and 14 days' curing of the roots before storage. Treatments are the same as shown in Fig. 2.

in the local storage structure for the 7 and 14-day cured roots, respectively, after 84 days of storage (Fig. 4). In the pit storage structure, fungus-infected sweet potato roots ranged from 10.0 to 51.5 per cent and 5.0 to 100 per cent for the 7 and 14-day cured sweet potato roots, respectively. However, fungal infection ranged from 5.0 to 32.5 per cent and 4.5 to 80.0 per cent for the clamp storage structure for the 7 and 14- day cured sweet potato roots, respectively, after 84 days of storage (Fig. 4).

Insect and rodent-damaged sweet potato roots

Low percentages of sweet potato roots damaged by insects and rodents were recorded in all the treatments compared to fungus-infected roots. Insect and rodent-infected roots recorded for local, pit, and clamp storage structures containing 14-day cured sweet potato roots were in the range of 5.0 to 17.5 per cent, 0 to 10.0 per cent, and 4.0 to 18.0 per cent, respectively, after 84 days of storage. A similar pattern for damaged roots was observed for the 7-day cured roots in the range of 0 to18.5 per cent, 5.0 to 10.0 per cent, 5.0 to 17.5 per cent for local, pit and clamp storage structures, respectively (Fig. 5).

Discussion

Sweet potato roots have high moisture content and a relatively delicate skin (Hayma, 1982). The root remains metabolically active after harvest, and is easily damaged during post-harvest handling. The root takes the energy essential for metabolic function from its stores of carbohydrates. During storage, sweet potato roots burn carbohydrates to gain energy, during which process carbon dioxide and water are emitted to the environment as gases (Hayma, 1982). Studies by Jenkins (1982) show that respiratory losses are higher and greater under tropical temperatures.

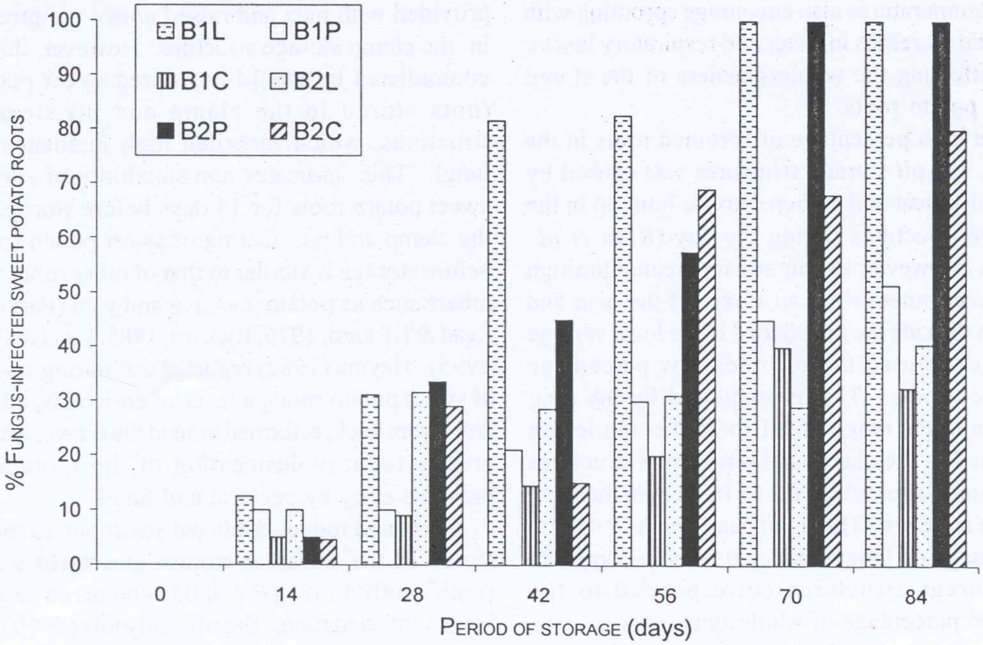

Fig. 4. Percentage fungus-infected sweet potato roots from storage structures on various days of storage after 7 and 14 days' curing of the roots before storage. Treatments are the same as shown in Fig. 2.

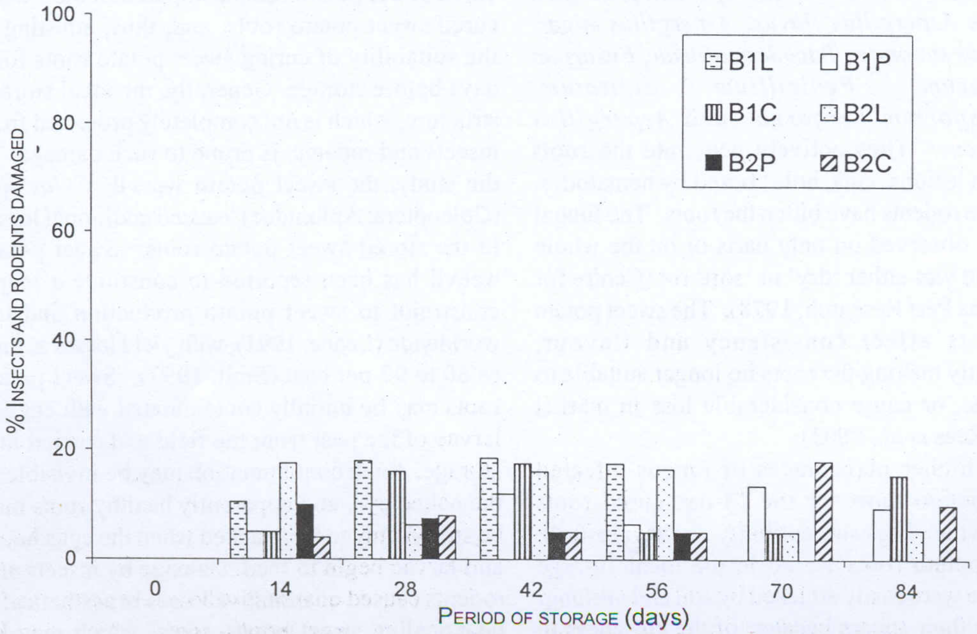

Fig. 5. Percentage insect and rodent-damaged sweet potato roots from storage structures on various days of storage after 7 and 14 days' curing of the roots before storage. Treatments are the same as shown in Fig. 2.

High temperatures also encourage sprouting with frequent increases in water and respiratory losses, thus affecting the wholesomeness of the stored sweet potato roots.

The high percentage of sprouted roots in the clamp and pit storage structures was caused by excessive heat and carbon dioxide built up in the storage structures during the day (Rees *et al.*, 2003). However, the air stream created through the sweet potato roots to carry off the heat and carbon dioxide they produced in the local storage structure caused the recorded low percentage sprouted roots. This is supported by the long sprouts in the range of 0.1 to 25.0 cm in length recorded in the clamp and pit storage structures compared to sprouts of 0.1 to 16.0 cm in the local storage structure. The significantly high ($P < 0.05$) percentage of fungus-infected roots recorded in the storage structures corresponded to the reduced percentage of wholesome roots.

Fungi easily attack sweet potato roots because of the high moisture content of the roots. The fungi that cause rot are normally lesion pathogens such as *Aspergillus flavus*, *Aspergillus niger*, *Rhizopus stolonifer*, *Tricoderma viride*, *Fusarium oxysporum*, *Penicillium digitatum*, *Cladosporium herbarum*, and *Aspergillus ochraceus*. They actively penetrate the roots through lesions, cuts, holes bored by nematodes, or where rodents have bitten the roots. The fungal rot was observed on only parts or on the whole root, and was either 'dry' or 'soft' rot (Centre for Overseas Pest Research, 1978). The sweet potato root rots affect consistency and flavour, frequently making the roots no longer suitable to consume, or cause considerable loss in market value (Rees *et al.*, 2003).

The higher percentages of fungus-infected sweet potato roots for the 14-day cured roots indicate their high susceptibility to fungal attack. Sweet potato roots stored in the local storage structure were easily attacked by soil and air fungi through their spores because of the closeness to the soil and the absence of a roof cover compared to the clamp and pit storage structures that were provided with huts and raised above the ground in the clamp storage structure. However, this is contradicted by the 14-day cured sweet potato roots stored in the clamp and pit storage structures, which recorded high incidence of fungi. This indicates non-suitability of curing sweet potato roots for 14 days before storage in the clamp and pit. Curing of sweet potato roots before storage is similar to that of other roots and tubers such as potato, cassava and yam (Passam, Read & Rickard, 1976; Rickard, 1985; Lulai & Orr, 1995). Hayma (1982) reported that during curing of sweet potato roots, a layer of cork cells, a few cell layers thick, is formed around the tubers, which greatly reduces desiccation of the roots and prevents entry by bacteria and fungi.

Insect and rodent-damaged sweet potato roots stored in the different storage structures were significantly lower ($P < 0.05$) compared to the fungus-infected roots. Significantly low ($P < 0.05$) percentages of sweet potato roots damaged by insects and rodents were recorded in the 7-day cured sweet potato roots compared to the 14-day cured sweet potato roots; and, thus, attesting to the suitability of curing sweet potato roots for 7 days before storage. Generally, the local storage structure, which is not completely protected from insects and rodents, is prone to such damage. In the study, the sweet potato weevil, *Cylas* spp. (Coleoptera: Apionidae), caused additional losses in the stored sweet potato roots. Sweet potato weevil has been reported to constitute a major constraint to sweet potato production and use worldwide (Lenne, 1991), with yield losses as high as 60 to 97 per cent (Smit, 1997). Sweet potato roots may be initially contaminated with eggs or larvae of the pest from the field and carried into storage. Such contamination may be invisible to the naked eye, and apparently healthy roots may be stored only to be attacked when the eggs hatch and larvae begin to feed. Damage by insects and rodents caused quantitative losses in aesthetically unappealing sweet potato roots, which may be discoloured and bitter in taste because of unpalatable terpenoids produced in response to weevil feeding (Uritani *et al.*, 1975). Rodents such as rats and mice damage parts of roots by consuming and contaminating them with their excrement in the field and under storage (Hayma, 1982).

Conclusion

The clamp storage structure is the most effective storage structure, based on the high percentage of wholesome and low percentage of fungus-infected sweet potato roots cured for 7 days. This is followed by the pit storage structure, and the least being the local storage structure. However, 14-day cured sweet potato roots performed better in the local storage structure. Further investigation is required to find out whether varieties of sweet potato roots in Ghana will store differently.

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