ETIOLOGY OF STORAGE ROT OF SWEET POTATO

(*IPOMOEA BATATAS* (L.) LAM.) AND ITS CONTROL BY CURING

BY

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DECLARATION

I hereby declare that this is a product of my original work and has not been submitted to another university for the award of a degree. Any help received in the compilation of this thesis and all sources have been duly acknowledged.

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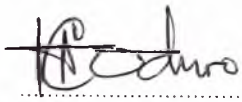

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DEDICATION

To my dear father, G. K. Sowley

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ABSTRACT

A survey was carried out to assess the extent of rot, and susceptibility of different types of sweet potato, and methods of storage in Ghana. Pathogens were isolated, identified and their pathogenicity established. The effectiveness of curing in extending the shelf-life of sweet potatoes was also studied. The market survey revealed that there are four types of sweet potato tubers (based on external colour). The local names of three of the sweet potato types are "Fante" (yellow skin with yellow flesh), "Kwahu" (yellow skin with white flesh) and "Ayigbe" (red skin with white flesh). The fourth type, which is relatively scarce, is the one with red skin and yellow flesh. Sweet potatoes are transported mainly by road from the areas of production to the markets in Accra and this takes 1-2 days. Deliberate curing of sweet potatoes before storage is not practised in Ghana. Nine methods for storing sweet potato are practised in Accra. They are (a) Packed in roofed and open-sided sheds (b) Heaped in airy place and covered with tarpauline (c) Packed in sacks in a room (d) Exposed on the floor in a room (e) In baskets under a shed (f) In sacks in open-sided shed (g) In sacks in open place (h) In wooden boxes under a shed (i) In sacks in airy place. The maximum period sweet potatoes can be stored is one month. The major insect pest associated with sweet potato storage is the sweet potato weevil, *Cylas* sp. All respondents have experienced sweet potato tuber rot and there are differences in the degree of rot between different types of sweet potato. Between 1-100% of tubers per sack get rotten depending on the storage conditions.

From the laboratory studies, five fungal species namely *Aspergillus ochraceus, Botryodiplodia theobromae, Fusarium moniliforme, Fusarium oxysporum* and *Rhizopus stolonifer*, were isolated and proved to be pathogenic. *Botryodiplodia theobromae* had the highest percentage

(85.8%) of occurrence both in the markets and in the barn. *Aspergillus ochraceus, Fusarium moniliforme, Fusarium oxysporum* and *Rhizopus stolonifer* had the same frequency of occurence (6.7%) in the markets. *Rhizopus stolonifer* was the second most frequent organism in the barn (6.1%). *Aspergillus ochraceus* and *Fusarium oxysporum* were not encountered in the barn. With respect to both the markets and the barn, *Rhizopus stolonifer* was the most frequent, after *Botryodiplodia theobromae. Aspergillus ochraceus* and *Fusarium oxysporum* had the same frequency of occurrence in both the markets and the barn. *Fusarium moniliforme* was the third most frequent in both the markets and the barn. When the virulence of the five pathogens were determined on the "Fante" and "Ayigbe" sweet potato types they were all virulent. Based on the size of the necrotic area, the most virulent organisms were *Aspergillus ochraceus* in the "Ayigbe" type ($5.2cm^2$) and *Fusarium oxysporum* in the "Fante" type ($3.2cm^2$) and the least virulent were *Botryodiplodia theobromae* in the "Fante" type and *Fusarium oxysporum* "Ayigbe" type.

Curing experiments involving incubator-curing, polyethylene-curing and solar-curing revealed that there was wound periderm formation in all the treatments except the control which was wounded but not cured and the other control that is unwounded, uncured, which had normal periderm. There were significant differences (P= 0.05) in the thickness of the periderm formed in all the treatments. When the cured and uncured tubers were stored in the barn at temperature and relative humidity ranges of 25-34 ^{o}C and 46-80% ERH, respectively, for 18 weeks, the incidence of rot of incubator-cured tubers (35.5%) was significantly lower (P= 0.05) than the values for unwounded and uncured (89.2%), wounded and uncured (82.1%), wounded and sun-cured (100%) and wounded and polyethylene-cured (94.6%). Fresh weight

loss in incubator-cured tubers was significantly lower (P= 0.05) than those of the other treatments and the controls from week 1 to week 8. Sprouting in incubator-cured tubers reached 98.1% by the 8th week and this was significantly higher (P= 0.05) than the other treatments and the two controls.

It can be concluded that, proper curing (incubator-curing) leading to formation of a thick periderm is important, in prolonging the shelf-life of sweet potatoes provided weevil damage is taken care of.

CHAPTER ONE

INTRODUCTION

Sweet potato *(Ipomoea batatas* (L.) Lam.) is one of the world's major starchy food crops. In most tropical countries sweet potatoes are primarily grown for their edible tubers which are boiled, baked, fried and candied. Tubers are used as livestock feed or for industrial preparation or extraction of starch, glucose, syrup and alcohol in some countries. These tubers in addition to starch contain moisture, ether-extract protein, reducing sugars, non-starch carbohydrates, mineral matter and vitamins (Onwueme, 1982).

World production of sweet potatoes in 1981 was 146 million metric tons (FAO, 1981). Most of the crop is produced in Asia, with China being the leading producer. The largest producing countries in Africa are Rwanda and Uganda. Sweet potatoes are widely grown in seasonally dry areas of most West African countries. In Ghana production of sweet potatoes is concentrated almost entirely in the Northern, Upper-West and Upper-East Regions (Tweneboah, 1998). However there is some production in relatively wet areas in Southern Ghana. Sweet potato production in Ghana in 1972 was estimated to be 3000 metric tons (FAO, 1972). Unfortunately recent production figures for sweet potatoes in Ghana are not available (Boateng-Siriboe, 1999. Personal communication.)

Sweet potatoes are extremely perishable (Cook,1953). The rotting of sweet potatoes is influenced by wounds which are created during harvesting, transporting, and handling before storage. The wounds serve as entry points for rot-causing organisms. Rots mostly due to

fungi, destroy 20 to 40 percent of the sweet potato crop in the field, in storage and in transit (Cook, 1953). Friedman (1960) reported 19% losses of sweet potatoes in the United States of America during storage and wholesaling, 4% during retailing and 12% within the household. Information on the extent of rot in sweet potatoes in Ghana and factors influencing the problem is not available.

Several workers including Tomkins (1951), Harter *et al.* (1921), Taubenhaus (1913), Ray *et al.* (1994) have identified a number of fungi and bacteria associated with rot of sweet potatoes. Ray *et al.* (1994) in India, isolated three fungi from rotten tissues namely *Rhizopus oryzae, Botryodiplodia theobromae* and *Fusarium oxysporum*. The commonest fungus in Nigeria associated with soft rot of sweet potatoes is *Rhizopus stolonifera* or *Rhizopus nigricans* (Arene and Nwankiti, 1978). Clark (1992) in the U.S.A. isolated *Erwinia chrysanthemi* as the causal agent of bacterial tuber rot. So far there is no available record on the isolation of rot-causing organisms of sweet potatoes in Ghana. There is also no available information on the types of sweet potato and the differences of the various types of sweet potato with respect to rotting in Ghana.

A number of methods are available for controlling postharvest losses due to rotting. These include chemical control, refrigeration, high temperature treatment, use of improved handling methods, irradiation and curing (Booth, 1974). Curing is among the most current approaches to controlling postharvest diseases of sweet potatoes (Clark, 1992). It is a pre-storage treatment which is meant to reduce the incidence of rot and therefore prolong the shelf-life of the crop. Curing is a wound healing process during which the damaged skin is replaced with a wound periderm. The process is stimulated by conditions of relatively high temperatures and

humidities and involves suberisation followed by the development of wound periderm, that is effective in retarding water loss and acts as a barrier against infection (Booth, 1974). The merits of curing for reducing disease losses in potatoes and sweet potatoes is well established (Burton, 1966, Kushman and Wright, 1969 and Booth and Proctor, 1972).

Various methods for achieving curing are:-

1. Solar curing by exposure of freshly harvested tubers to sunlight for about 3-4 days (Numfor and Lyonga 1986, Bunn and Parker, 1991).
2. Curing by covering freshly harvested tubers with dry grass or tarpauline in the open at ambient temperature for 4 days (Booth, 1978).
3. Curing by spreading out tubers in a single layer in a cupboard, a cabinet or a box and covering with plastic sheeting, newspapers or jute sacks at a curing temperature of 29 to 32 ^{o}C (Kordylas, 1990).
4 Curing by placing freshly harvested tubers in a room and covering with polyethylene or tarpauline sheet at temperatures of about 30 ^{o}C with a relative humidity around 90% for about one week (Doku, Personal communication, 1987).

There is no available information on the use of any of the above methods of curing in Ghana. The effectiveness of curing is determined through anatomical and shelf-life studies of the cured tubers. It has been observed that soon after the tuber is cut or injured, starch begins to disappear from the peripheral cell layers; the outermost layer, however, composed mostly of

cut or injured cells retains its starch content. Cell division begins within the starch-free zone parallel to the cut surface below the suberin deposit, which functions as a cork cambium and which continues to divide giving rise to a layer of wound periderm. The periderm thus formed is permanent and offers a more effective protection against the entrance of pathogens. The contour of the cork cambium appears to be related to the types of tissues exposed in the cut. It is uniform in an uninterrupted zone of cortical tissue, but dips down more or less where it traverses elongated parenchyma cells between the vascular bundles, and rises close to the surface in the region of the exposed vascular strands. Near the periphery of the cut tuber both suberin layer and wound periderm are sunk deeply into the tissue beneath the exposed surface (Artschwager and Starrett, 1931). Artschwager and Starrett (1931) also showed that wound cork in sweet potato developed rapidly when the humidity was held practically at saturation, but that the development of this protective layer was much belated or even inhibited at lower humidities. Previous studies on shelf-life have revealed that cured sweet potatoes can be stored for several months. For instance, Doku (1987, Personal communication) reported that tubers cured at a temperature of about 30 ^{o}C and a relative humidity of 90% for one week and stored at a temperature of 13-15 ^{o}C can remain wholesome for at least 6 months without deterioration. MOFA (1988) also reported that tubers cured at a temperature of 23-28 ^{o}C and 90% RH can be stored for 6 months without deterioration if the storage temperature is maintained close to 12-14 ^{o}C. Though reports on curing have been made by Doku (1987) and MOFA (1988), the findings are not based on work done in Ghana (Doku, 1999. Personal communication).

The objectives of this study are therefore:-

1. To ascertain the postharvest problems of sweet potato in Ghana.
2. To isolate and identify the pathogens which cause post harvest rotting in sweet potatoes.
3. To evaluate some of the curing methods through anatomical and tuber rotting studies and to recommend the most effective method for use in Ghana.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution

The sweet potato (*Ipomoea batatas* (L.) Lam.) is a native of tropical America, although it has also been cultivated throughout the warm islands of the Pacific Ocean for an equally long time. The introduction of sweet potato to Europe, Africa, Asia and even North America occurred in more recent times. Apparently, Columbus introduced it into Europe during his voyages of discovery, while subsequent Spanish and Portuguese explorers and traders introduced it into Africa and Asia. Today, sweet potato is grown in nearly all parts of the tropical and subtropical world and in warmer areas of the temperate regions. It has remained, for centuries, an important staple for many tropical communities (Onwueme, 1982). The sweet potato is believed to have been introduced to Ghana (Gold coast) in the second half of the 17th century (MOA, 1988).

2.2 Botany

Sweet potato, is a dicotyledonous plant belonging to the family Convolvulaceae. This family includes about 45 genera and 1000 species, but only *Ipomoea batatas* is of economic importance as food (Onwueme, 1982). It is a perennial herb, but treated as an annual in cultivation, with vine-like, trailing or twining stems, 1-5m long, with latex in all its parts.

An extensive, fibrous, adventitious root system is produced from nodes of cutting; trailing stems in contact with soil also root at nodes. About 10 tubers per plant, develop in top 9 inches (22.9cm) of soil by secondary thickening of some of the adventitious roots, both from those of original cutting and those from creeping stems. Final structure of the tuber is very complex with conducting tissue, parenchymatous storage cells, latex vessels, and normal periderm which replaces ruptured epidermis; secondary roots on tubers in 5-6 rows. Tubers are fusiform to globular, smooth or ridged. The periderm is white, yellow, orange, red, purple or brown while the flesh is white, yellow, orange, reddish or purple (Purseglove, 1968).

2.3 Composition, Nutritive value and uses

2.3.1 Composition

Sweet potatoes belong to the general group of root and tubers, such as yam, cocoyam and cassava. The major component of sweet potato is starch, forming about 65-85 % of the dry weight of the tuber (Osei-Opare and Adjei-Poku, 1988).

The approximate composition of the fresh sweet potato tuber is as follows:

Moisture	50-81 %
Starch	8-29 %
Protein	0.95-2.4 %
Ether extract	1.8-6.4 %
Reducing Sugars	0.5-2.5 %
Non-starch carbohydrates	0.5-7.5 %
Mineral matter	0.88-1.38 %

The vitamins present in mg/100g fresh weight are:

Carotene	1-12
Thiamine	0.10
Riboflavin	0.06
Nicotinic acid	0.90
Ascorbic acid	29-40

data after Onwueme, 1982.

2.3.2 Nutritive Value

Fresh sweet potatoes provide about 50 percent more calories than Irish potatoes (Purseglove, 1968). The protein of sweet potatoes is of high nutritive value since it contains reasonable amounts of most essential amino acids. As with yam, cassava, and the edible aroids, the peel is higher in protein, minerals and other non-carbohydrate constituent than the rest of the tuber. The predominant minerals in the sweet potato tuber are potassium, sodium, chloride, phosphorus and calcium. Most sweet potato varieties are rich in carotene. Sweet potato is also a good source of ascorbic acid (Onwueme, 1982). The sweet potato shoots are also nutritionally valuable. A total analysis of the tops of 100g of edible shoot is moisture 0.57g; ether extract 0.67g; fibre 1.4g; ash 1.5g of which 81.2mg is calcium, 67.3mg phosphorous, and 10.37mg iron. The vitamin content is 3.61mg carotene, 0.06mg thiamine, 0.17mg riboflavin, 0.94mg niacin, and 25mg ascorbic acid. (Dahniya, 1980).

2.3.3 Economic Importance / uses

Sweet potatoes, *Ipomoea batatas* (L.) Lam., has many uses. Primarily they are used for human

consumption because of their high nutritive value. Roots and foliage are used for animal feed in many countries (Moyer, 1982). Sweet potato is an exceptionally rich source of vitamin A (100 g provide 7,100 IU, about two-and-a-half times the daily minimum requirement for adults) and with its appreciable quantities of ascorbic acid, thiamin, riboflavin, niacin, phosphorous, iron and calcium, it in combination with legumes can form an ideal food to combat protein calorie malnutrition (PCM) which is widespread in almost all developing countries (Winarno, 1982). Both roots and leaves are used and are good sources of pro vitamin A, vitamin B, vitamin C, calcium, iron, potassium and sodium (Alvarez, 1986).

Sweet potatoes are usually eaten boiled or baked, and may be candied with syrup or used as a puree. They are used for canning, dehydrating, flour manufacture, and as a source of starch, glucose, syrup and alcohol (Purseglove, 1968). Sweet potatoes may also be cut into small pieces and cooked like Irish stew. The sweet varieties may be roasted or fried in oil and taken as dessert. The tender leaves are used as spinach. Portions of the tubers left in the field soon sprout and become serious weeds in the midst of the following crop (Doku, 1987. Personal communication).

2.4. **Causes of Tuber Rot in Sweet Potatoes**

Rots caused by fungi can be grouped into soft rot, black rot, surface rot, scurf, dry rot, charcoal rot and Java black rot (Cook, 1953).

Soft rot is usually caused by the common bread mould fungus, *Rhizopus nigricans* but several other species of *Rhizopus* also cause it (Cook, 1953 and Harter *et al.*, 1921). *Rhizopus* is essentially a wound pathogen infecting only bruised spots such as those where the potato is

broken from the stem and at cuts and bruises caused in digging, clearing and packing (Cook, 1953). Decay in storage becomes apparent by the appearance of cottony tufts of greyish sporangiophores capped with masses of black sporangia on the tubers which are at advanced stages of watery rot (Arene and Nwankiti, 1978).

Black rot is caused by the fungus *Ceratocystis fimbriata*. Harvested potatoes become infected by spread of the fungus spores during grading, brushing and washing. Most infection takes place through wounds (Cook, 1953). Black rot is the most destructive disease of the sweet potato in the United States of America and is wide spread (Edmond, 1971). The disease is characterized by dark greenish circular spots on the tuber. These roundish spots are encountered more often in infected sweet potatoes in the store house (Taubenhaus, 1913).

Surface rot is a common storage disease, which causes shallow, circular, depressed spots on the surface of tubers followed by a gradual drying out. Surface rot is shallow seldom penetrating the fibro-vascular ring (Harter and Weimer, 1919). Both *Fusarium oxysporum* and *Fusarium solani* cause cortical decay but the former is also believed to cause surface rot . Infection takes place through the small rootlets that are damaged when the potatoes are harvested (Cook,1953).

Java black rot ranks next to soft and black rot in importance as a storage disease. It is caused by the fungus *Diplodia tubericola* which causes a dry rot of the tubers. The decayed tubers become brown at first and then turn black and hard. The fungus forms black protuberances on the tuber surface.

Scurf is caused by *Monilochaetes infuscans*. It has been reported in Brazil, Japan, Australia, and the U.S.A. It causes brownish blotches on the roots, tubers, and other subterranean parts of the plant (Onwueme, 1982).

Charcoal rot is caused by *Macrophomina phaseoli*. Although the fungus is sometimes found within the basal portions of the stems in the field, it occurs more commonly in the storage house. Apparently the fungus invades the fleshy roots through non-healed wounds and the mycelium grows slowly producing three more or less distinct colour zones in the flesh; chocolate brown, reddish brown, and black (Edmond, 1971).

Dry rot is caused by *Diaporthe batatasis* Harter and Field. In the fleshy roots the fungus usually but not always invades the stem end and forms pycnidia in the tissues just below the surface. Finally the pycnidia appear as dark-like protuberances on the surface. At the same time the fleshy root become dry, hard and mummified (Edmond, 1971).

Other types of rot are blue mould rot, end rot, foot rot, grey mould rot, ring rot, mucor rot, soil rot or pox which are caused by *Penicillium sp., Fusarium sp., Plenodermis destruens* Harter, *Botrytis sp.*, *Pythium ultimum* Trow, *Pythium scleroteichum* Drechs, *Mucor racemosus* Fres. and *Streptomyces ipomoea* (Coursey and Booth, 1972).

Alternaria, Sclerotinia and *Penicillium* can also cause various rots during storage and transportation (Blay, 1988). Sciven, *et al.* (1988) also reported that *Diarpothe theobromae* and *Pythium ultimum* cause rot in sweet potatoes. *Aspergillus sp., Botrytis cinerea, Mucor sp.* and *Penicillium sp.* were reported by Gatumbi *et al.* (1994) as some of the rot-causing

organisms of sweet potatoes. Lauritzen (1935) also reported *Fusarium oxysporum, Pythium, Mucor racemosus* Fres. *Botrytis cinera* Pers., *Alternaria sp., Diplodia tubericola* and *Sclerotium bataticola* as rot-causing organisms of sweet potato.

Clark (1992) reported that *Erwinia caratovora* causes tuber rot of sweet potatoes. A more recently recognized soft rot disease of sweet potatoes is caused by *Erwinia chrysanthemi*. This disease has only been reported as a severe problem in the state of Georgia, U.S.A. (Martin and Dukes, 1977).

Viruses can also cause storage disease of sweet potato. Internal cork disease of root is caused by an unidentified virus. This disease can be particularly serious because affected roots cannot be detected without slicing into the root itself. Lesions occur in the interior of the root as dark brown, corky areas. (Moyer, 1982).

The sweet potato weevil (*Cylas puncticollis (*Sum*)*) is a serious pest on susceptible varieties planted in soils which have previously carried affected crops. Exposed tubers or tubers near the soil surface are heavily attacked. The weevil attack is also serious during long periods of drought (Doku, 1987. Personal communication). The sweet potato weevil has been reported to cause extensive damage to sweet potatoes in the U.S.A., Brazil, Venezuela, Central America, and Malaysia. The larvae cause considerable damage to the tuber by feeding on it and burrowing extensively into it. Frass is also deposited within the tunnels, so that the tuber is rendered unfit for human or animal consumption. The activities of the larvae also promote the spread of, and infection by fungal decomposers (Onwueme, 1982).

2.5. Control of Postharvest Tuber Rots

Postharvest rotting of sweet potatoes is controlled mainly by two methods, namely physical and chemical.

2.5.1. Chemical Control

Postharvest disease losses can be curtailed by adhering to good phytosanitary practices such as the elimination of plant debris and the cleansing and sterilising of implements, boxes, buildings, etc. Such losses may in some cases be reduced by the direct application of pesticides. Pesticides may be classified by method of application into fumigants, treated wraps, dips, sprays and dust. Dips, sprays and dusts have been the most commonly used with root crops. Many chemicals have been used in reducing postharvest rotting; those reported to reduce storage losses of root crops include sodium orthophenyl phenate, borax, captan, thiabendazole and benomyl (Booth, 1974). Also various waxing techniques have been experimentally shown to reduce postharvest rotting (Booth, 1974). Disinfection of storage houses can control black rot caused by *Ceratocystis fimbriata* as well as tuber rot caused by *Plenodermis destruens* (Danquah and Lamptey, 1988). Immersion of sweet potato tubers for 3 minutes in 1% NaOCl solution could reduce incidence of soft rot caused by *Rhizopus stolonifer* as well as that caused by *Erwinia caratovora* (Danquah and Lamptey, 1988).

Sodium o-phenylphenate has been used to control black rot (*Cerastomella fimbriata*) and soft rot (*Rhizopus sp.*) on sweet potatoes (Eckert, 1969). Postharvest sprays of dicloran have proved highly effective in reducing *Rhizopus* rot of sweet potatoes (Eckert, 1969). A tolerance level of 10 ppm for residues of dicloran has been established in the United States of America (U.S.A) for control of *Rhizopus* rot of sweet potatoes (Eckert, 1969). Calcium hypochlorite is

an effective sanitizer used against *Erwinia chrysanthemi* (Moyer, 1982). Chloropicrin is the common fumigant recommended in the U.S.A. for the control of storage rots caused by various fungi (Winarno, 1982).

2.5.2. Physical Control

Physical methods of controlling postharvest rotting of sweet potatoes include refrigeration, high temperature treatment, use of improved handling methods and curing.

A. Refrigeration

Refrigeration slows down the metabolism of pathogens and so frequently arrests rotting. However, the rot organisms are rarely killed, so that when the produce is returned to ambient temperatures, rotting will start again.

B. High temperature treatment

High temperature treatment of produce may in some instances be used to control storage diseases. For example, holding tubers at temperatures over 38 ^{o}C is reported to control black rot of sweet potatoes (Booth, 1974). Some tropical strains of the pathogens are however heat tolerant (Booth, 1974) thus the temperature required to kill the pathogen may also damage the host.

C. Handling methods

Mechanical damage can only be reduced by improved methods of crop harvesting and handling. Food handling techniques are generally poorly developed in the tropics and fresh produce is only too frequently treated as an inert object. Emphasis must be put on proper

packaging especially if the produce is to be consumed away from the production area. In general, boxes or cartons are considered far more suitable than large sacks for handling and transportation of root crops in the tropics (Booth, 1974).

D. Curing

Curing is a simple wound healing process during which general skin strengthening occurs. It is one of the most effective and simple means of reducing postharvest rotting of several root crops (Booth, 1974). To form wound periderm, certain metabolic processes are necessary. These processes use energy which is gained by respiration of starch in the tuber. During the respiration process, water carbon dioxide and heat are released into the environment. Thus the healing of wounds is always connected with loss in tuber weight. (GTZ, 1993). The purpose of curing is not to remove moisture. Between 1913 and 1931 new ideas developed as to the primary purpose of curing. These ideas centered around the healing of wounds and the development of the periderm rather than drying out of the fleshy roots (Edmond and Ammerman, 1971). In 1915, Hauman-Merck discovered that *Rhizopus stolonifer*, the organism responsible for soft rot, cannot invade intact periderm. Between 1921 and 1931, Weimer and Harter (1921), Lauritzen and Harter (1926) and Artschwager and Starrett (1931), found that rapid healing of wounds requires prompt and complete suberisation of the wounded surface and rapid formation of the wound periderm just back of the suberised layer. In suberisation, the cells and intercellular spaces just back of the wound become filled with sap, some of the starch changes to unsaturated fatty acids, and the unsaturated fatty acids combine with oxygen to provide energy in the formation of suberin, a compound which has the remarkable property of retarding the escape of water from cells and preventing the entry of the soft rot organism into the storage tissues beneath the wound. However, the suberised layer is

effective for a short time only, hence the relatively long lasting and effective periderm is formed. In wound periderm formation, certain cells just below the suberised layer lose their large vacuoles and assume the function of meristematic cells which are collectively called wound cambium. These cells divide tangentially and the walls of the daughter cells finally become impregnated with suberin, tannin and other water and fungus-resistant materials and are collectively called wound periderm. Indeed the more rapidly the wound and normal periderm are developed, the sooner the fleshy tubers will be protected against the attacks of rot pathogens, and against the drying effects of the air.

Tubers intended for storage are harvested a little later than normal and then cured to harden the skin and hasten the healing of any surface wounds. Healing the wound should be carried out directly after harvesting the tubers (Booth, 1978). Clean and smooth cuts heal best of all. Injuries due to squashing do not normally heal but remain as a center of infection (GTZ, 1993). All wounds, squashed areas and other injuries should be consequently cleanly cut out before curing. Weimer and Harter (1921), Lauritzen and Harter (1926) and Artschwager and Starrett (1931) found that under the right temperature and relative humidity conditions, the wound periderm develops in a short time and as a result the cuts, the bruises and the broken ends heal in a short time.

Cured tubers stored between 13°-15 °C can remain wholesome for at least 6 months without deterioration. Such cool conditions can be obtained by burying the cured tubers in slightly moist (5-10% moisture) saw-dust contained in baskets or wooden boxes of medium size held at room temperature (Doku, 1987. Personal communication). During storage, the weight of tubers decrease due to biological processes like respiration, sprouting and microbial activity

(Winarno, 1982). Booth (1974) reported that loss in weight in sweet potato after 113 days of storage was 17% in the cured sample and 42% in the uncured one. During curing and storage, some tuber starch is converted into sugars and dextrins which improve the eating quality of sweet potato.

The traditional methods of curing are typified by the Indian practice of spreading the tubers in the sun for one week, providing a suitable water proof covering at night and then storing in a well ventilated room with frequent inspections to eliminate unhealthy roots. In the U.S.A., where sweet potato processing industry is well developed, the common practice is to cure at about 30 ^{o}C with a RH of 85-90% for seven days. This is followed by storage of cured tubers at 13-16 ^{o}C with RH of 85-90%. Curing can also be carried at a temperature of 26.7-29.4 ^{o}C with high RH of >80%, for a period of 10-20 days depending on local climate and tuber variety (Winarno, 1982).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Field survey

A limited survey was carried out between July and October, 1998 to ascertain the extent of the postharvest problem of sweet potato in the Greater Accra Region. Thirty (30) questionnaire (Appendix 1) were administered to sweet potato sellers and users (i.e. those who fry it for sale and housewives who purchase it for domestic use) in order to obtain information on extent of rot, differences of sweet potato types with respect to rotting, curing and methods of storage in Ghana. The questionnaire were administered to randomly selected sweet potato sellers and users from five markets in Accra namely Madina, Makola, Kaneshie, Agbogbloshie and Mallam Atta. The questionnaire were also administered to users from other locations such as the Tema lorry station and the University of Ghana, Legon Campus.

3.2. Isolation and identification of pathogens causing sweet potato tuber rot

3.2.1 *Isolation and Identification*

Partially rotting sweet potato tubers were obtained from markets and the barn in the Department of Crop Science, University of Ghana in which the sweet potato tubers were stored. The barn used for storing the tubers was a roofed and open-sided shed measuring 3.8m x 2.0m x 22m. The sides of the barn were protected from rodents with a strong wire mesh. A total of 240 rotten sweet potato tubers were used for the isolations. Out of these 160 were obtained from the markets and 80 from the barn.

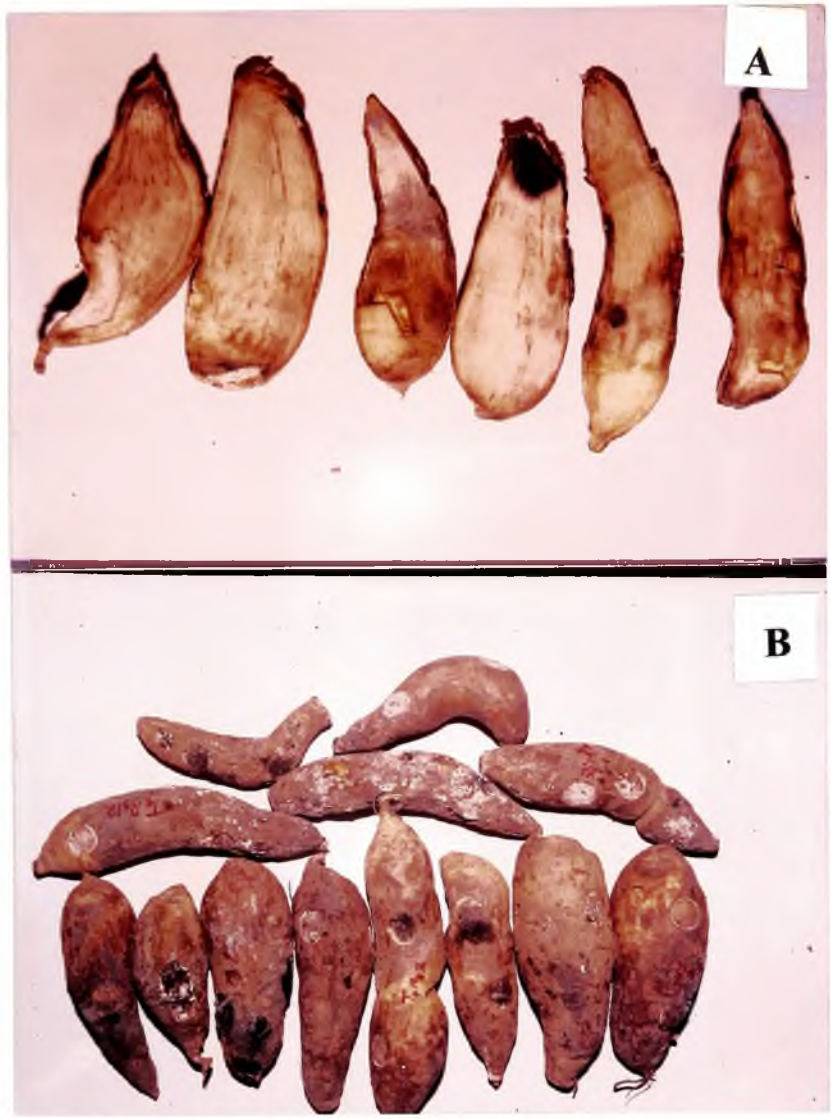
Fig. 1 shows some of the rotten tubers from which isolations were made. Isolation of fungi associated with postharvest rot of sweet potatoes was done first on water agar (WA) prepared from Agar agar (OXOID). Organisms were then transferred to potato dextrose agar (PDA) for further growth. Rotten sweet potato tubers were cut with a knife. Portions of the advancing rot margin in sweet potato tubers were then removed with a flamed scapel, surface sterilized in 1% sodium hypochlorite solution for two minutes and placed on water agar plates (four pieces per plate). The plates were covered and tied up in clean cellophane bags and incubated under ambient conditions (23-30 ^{o}C) in the laboratory. The plates were examined daily for fungal growth or the growth of other rot-causing micro-organisms. Pure cultures of the fungi which grew from the plated tissues were sub-cultured on PDA plates. The pure cultures of the isolated fungi were maintained on PDA slants.

A calibrated binocular compound microscope was used in studying the morphological characteristics of the isolated micro-organisms. In the preparation of permanent slides of the isolates lactophenol was used as a mountant. They were then observed with the microscope. Photomicrograghs of the isolated micro-organisms were taken using a Carl Zeiss microscope fitted with a pentacon camera. A final identification of fungal isolates was made based on morphological and cultural characteristics as described by Thom and Raper (1945), Booth (1971), Barnett and Hunter (1972), and Samson and van Reenen-Hoekstra (1988).

Where a culture maintained on PDA could not sporulate, it was induced to sporulate as follows. Using the methods described by Johnston and Booth (1968) and Neergaard (1977) the fungus was placed in an incubator fitted with a 20W Tungstram fluorescent tube, to provide

Fig. 1. Partially rotten sweet potato tubers from which fungal isolations were made (x 0.25)

A, Longitudinal sections of partially infected sweet potato tubers obtained from the market. Note the discolouration of tubers (brown, grey, black) caused by the resident fungi B, Partially decomposed sweet potato tubers obtained from the barn where uninoculated but wounded and unwounded tubers were stored.



near ultraviolet light. The distance between the plates and the fluorescent tube was 50 cm. The plates were left under the light for one week by which time the fungus sporulated. Where necessary the spores were classified into macro- and micro-conidia and the number of each group determined (Mesolaen, 1959).

The details were as follows:

Spores were scooped from $0.5cm^2$ area on the PDA plate in which the fungus was cultured with a sterile inoculation loop. The spores were then suspended in $0.5cm^3$ of sterile distilled water in a small specimen bottle. The spore suspension was poured into a slit on a stage micrometer which was already covered with a cover slip. The stage micrometer was then mounted on a binocular compound microscope and observed first under low power and then high power. The spores were counted under high power (X40). The number of macro-conidia and micro-conidia within each square on the stage micrometer for a total of 16 squares was counted. The total number of spores of each type was then estimated using the equation below.

$$\text{Number of spores} = N \times D \times V \div DC$$

where, N = Count; DC = Depth of chamber in stage micrometer; D = Dilution

V = Volume

The above technique is based on the one used for red blood cell count which involves the use of a haemocytometer. (Schalm, 1961)

After the isolation and identification of rot-causing organisms the number of isolations in which a particular organism occured was determined. The total number of isolations was also determined. The percentage occurrence of the rot-causing organisms out of total organisms isolated was estimated.

3.2.2. Determination of pathogenicity of the isolates

The fungi were tested for pathogenicity by inoculating into healthy sweet potato tubers using a modified method of Cornelius (1998). Sound sweet potato tubers free from bruises, cuts, rots or any visible defects were washed in running tap water for 10 minutes, surface sterilized by immersion in 1% sodium hypochlorite solution for four minutes and dried at room temperature. Each tuber was wiped with 95% ethanol prior to inoculation. Sterile 5mm cork borer was driven to a depth of about 8mm into the tubers to remove cores of tissue. The cut surfaces of the tubers were wiped with 95% ethanol. Mycelial plugs removed from the margin of three-day old cultures of the fungal isolates were placed into the wound cavities before the tissue plugs were replaced into their respective cavities and wounds sealed with paraffin wax (Fig.2). A control was set up in a similar manner but instead of fungal mycelium, PDA plugs devoid of fungal growth were deposited into the wound cavities. There were four replicated inoculations for each fungal isolate. Inoculated tubers were stored at ambient conditions in the laboratory for 7 days with temperature ranging between 23-30 ^{o}C. The tubers were then cut longitudinally across the points of inoculation with a knife and the extents of rot which had developed recorded and compared with the symptoms visible in the diseased tubers from where the isolates were obtained. Re-isolation and identification of the rot-causing fungi were accomplished to complete Koch's postulates.

Fig. 2. Tubers of sweet potato which were inoculated with isolated organisms. The wounds are sealed with paraffin wax (Arrowed) (x 0.25)

3.2.3 Virulence of isolated pathogens on two of the types of of sweet potato identified in the survey

Two of the sweet potato types identified in the survey namely yellow skin with yellow flesh (Fante) and red skin with white flesh (Ayigbe) were available and used. Twenty-four tubers of each type were inoculated with the five PDA-grown fungal isolates (*Aspergillus ochraceus, Botryodiplodia theobromae, Fusarium moniliforme, Fusarium oxysporum* and *Rhizopus stolonifer).* Tubers inoculated with sterile PDA plugs served as controls. Fig.3 shows the inoculated tubers. Inoculated tubers were incubated under ambient conditions in the laboratory for 7 days with temperature ranging between 26.8-28.5 ^{o}C. The tubers were then cut first transversely across the points of inoculation and afterwards longitudinally with a knife, for easy determination of the necrotic area. A graph sheet was used in estimating the area of necrosis by tracing the outline of the rotten area on it.

3.3. Curing as a pre-storage treatment for controlling postharvest rot of sweet potato

3.3.1 Various curing treatments:-

Three hundred sweet potato tubers (of the yellow skin with yellow flesh type) free from visible defects were used for this study. These were divided into five (5) equal lots, of 60 per lot. The five lots were subjected to three different treatments with two controls as follows:

1. ***Treatment 1 - Curing in an incubator***

The artificially controlled environment for curing the sweet potato tubers was obtained by the use of an incubator (Fig.4). The temperature was set at a range of 29-32 ^{o}C and the relative

Fig.3 Tubers of sweet potato of the red and yellow types which were inoculated with the fungal isolates. a, Yellow type; b, Red type; and c, Points of inoculation (Arrowed) (x 0.25).

Fig. 4 Incubator in which a controlled environment of temperature and relative humidity was obtained for curing wounded sweet potato tubers (x 0.03); i, Plastic bowls containing water in the top compartment (Arrowed 1); ii, Tubers of sweet potato arranged in incubator and covered with a thin perforated polyethylene sheet (Arrowed 2); iii, Thermohygrograph used to monitor the temperature and relative humidity conditions in the incubator (Arrowed 3).

humidity range of 85-90% ERH was obtained by placing plastic bowls containing water in the top compartment of the incubator. A thermohygrograph was used in monitoring the temperature and the relative humidity to ensure that they were within the required ranges. When the required temperature and relative humidity ranges were obtained 60 wounded tubers were placed in the incubator for four days. The method of wounding was that used by Walter *et al.* (1989). Each tuber was hand-wounded in three areas by removing a circular patch of tissue about 18mm in diameter and 1-2mm deep using a No.12 cork borer.

2. ***Treatment 2 - Curing by covering with polyethylene: -***

Sixty wounded tubers were placed in a wooden tray, covered with polyethylene and kept in the open under ambient conditions in the Sinna's Garden of of the Crop Science Department of the University of Ghana for four days (Fig.5). A thermohygrograph was placed inside a curing environment to monitor the temperature and relative humidity. The method of wounding was the same as that described under treatment 1.

3. ***Treatment 3 - Curing by exposure to sunlight***

Sixty tubers wounded as done in the control (wounded and uncured) were placed on a wooden frame and exposed to direct sunlight in the Sinna's Garden (Fig 6). They were covered each night with polyethylene to prevent their destruction by rodents and other pests. A thermohygrograph was used in monitoring the temperature and relative humidity. The specimens were exposed to sunlight for 4 days.

Fig. 5 Sweet potato tubers in a wooden tray covered with transluscent polyethylene sheet and held at 25-50 ^{O}C and 40-100% ERH (x 0.25). Thermohygrograph (Arrowed) used to record temperature and relative humidity .

Fig. 6 Sweet potato tubers placed on a wooden frame and exposed to sunlight at 22-35 ^{o}C and 20-80% ERH. (x 0.25). Thermohygrograph used to monitor temperature and relative humidity (Arrowed).

4. ***Control (wounded and uncured)***

The tubers were wounded but not cured. The method of wounding was the same as that described under treatment 1. The tubers were stored in a barn at 23-33 ^{o}C and 45-82% RH.

5. ***Control (unwounded and uncured)***

The sixty tubers were neither wounded nor cured. They were kept in a well ventilated barn in the Sinna's Garden while the curing of the other tubers was in progress. This was meant to allow for the determination of the thickness of the normal periderm as well as the characteristics of the cells.

3.3.2 Determination of wound periderm formation to verify the curing process

Four (4) tubers were randomly selected from each of the three treatments and the two controls at the end of the curing period of 4 days and used for anatomical studies. The method used for the anatomical studies was that described by Artschwager and Starrett (1931). Tubers were first cut transversely through the wounded areas. Blocks of tissue of dimensions 5 x 10 x 40 mm, containing the wounded surface were removed from the transverse section. These blocks of tissue containing the wounded area were put immediately into an ordinary chrome acetic acid fixer, dehydrated and embedded in paraffin. Blocks of paraffin containing the sections of the sweet potato tubers were trimmed so as to get a straight ribbon when sectioning. Sections (15µm thickness) were cut with a sharp microtome knife to obtain thin sections. The sections were stretched on a spirit lamp flame making sure not to melt them with the flame. After draining off the water carefully with a filter paper, the slides bearing the sections were allowed to dry for one day. The sections which were then ready for staining were dewaxed in two changes of xylene for 5 minutes each. The staining was based on the procedure described by

Fowell (1962).

Below are the steps involved in the procedure:-

1.	Stain in safranin	(10 min.)
2.	Differentiate in 50% alcohol	(1 min.)
3.	Dehydrate in 70% alcohol	(1 min.)
4.	Dehydrate in 90% alcohol	(1 min.)
5.	Dehydrate in Absolute alcohol. Two changes	(5 min,)
6.	Stain in light green (in clove oil)	(!/2 -1 min.)
7.	Clear and wash in clove oil	(5 min.)
8.	Mount in Canada balsam.	

The permanent slides which were prepared using the above methods were viewed with the binocular microscope. For the measurement of the thickness of the periderm and size of periderm cells, the binocular microscope was calibrated using the x 3.2 ocular and x 10 objective. Pictures of the periderm and related tissues as well as measurements of the thickness of the periderm were taken. For each treatment, the measurement was taken across 20 different portions of the periderm and the mean was determined. The relative thickness of the wound periderm from the various treatments also served as a basis for evaluating the various curing techniques mentioned above.

3.3.3. Effect of different curing processes on rot of sweet potato tubers in storage

Fifty six tubers from each of the three treatments and the two controls were arranged in a randomized complete block design (RCBD) in a well ventilated barn (Fig.7) situated in the

Fig.7 Sweet potato tubers cured with different treatment methods as well as the untreated control arranged in a well ventilated barn at the Sinna's Garden, University of Ghana, Legon (x 0.25). i, The thermohygrograph for recording the temperature and relative humidity in the barn (Arrowed); and ii, The complete randomized block layout of the three prescribed treatments along with the controls.

Sinna's garden. Each treatment was replicated four times with fourteen 4 tubers per replication. A thermohygrograph was used in determining the temperature and relative humidity range in the barn which were 25-34 ^{o}C and 46-80% RH respectively. The experiment was conducted between September, 1998 and March, 1999. Tubers were examined every week for 18 weeks for rot. Incidence of rot associated with each treatment was also calculated as a percentage of total tubers stored.

The severity of rot was also determined on a weekly basis for 18 weeks. To determine the severity of rot, rotten tubers were cut through the necrotic areas with a knife and the outline of the necrotic area was then traced on a graph sheet. The area of a healthy tuber was estimated by cutting it transversely and then longitudinally and tracing the outline of the cut sufaces on a graph sheet. The procedure was repeated for 20 tubers and the average was taken. The severity was then obtained by expresing the rotted area as a percentage of the healthy tuber area.

Sprouting and weight loss were also determined during the first 8 weeks of storage because by the 8th week, all the tubers belonging to treatment 3 which is curing by exposure to sunlight were rotten. Tubers which were rotten were either shrivelled in appearance, had a peculiar scent, or were soft to touch. Where there was doubt, the peeling off of the skin at the affected site normally revealed brown rotten tissue. All tubers showing any degree of rot were removed and used for the isolation of micro-organisms associated with the rot as described earlier.

Analysis of variance (ANOVA) was used to identify statistically significant trends and to identify differences between means.

CHAPTER FOUR

RESULTS

4.1 Field survey

Four types of sweet potato based on skin and flesh colour were identified during the survey but most of the respondents knew only two or three as "Fante" (yellow skin with yellow flesh), "Kwahu" (yellow skin with white flesh) and "Ayigbe" (red skin with white flesh). The fourth type, that is the one with red skin and yellow flesh is rare. Sweet potatoes are normally available in May/June (66.7%) and July/August (33.3%). They are transported mainly by road (96.7%) from the producing areas to the markets in Accra and this normally takes 1-2 days (83.3%). Sweet potatoes that are retailed in Accra are mostly obtained from Afram plains (53.3%) where the bulk of it is produced. Other sources of supply are Somanya (3.3%), Kpandu (3.3%), Akatsi (3.3%) and Begoro (3.3%). The questionaire used for the field survey is presented in Appendix 1.

Deliberate curing involving the following methods *viz.* (a) solar-curing (b) pit-curing (c) covering tubers with dry grass (d) covering tubers with jute sacks (d) covering tubers with polyethylene or tarpauline (f) incubator-curing , are not practised in Ghana.

Sweet potatoes can be stored for one week (23.3%), two weeks (33.3%), three weeks (16.7%) or one month (23.3%) depending on the storage conditions. Normally sweet potatoes were not stored beyond one month.

From the survey there are nine methods of sweet potato storage (Table 1). Majority of the respondents store the sweet potatoes in sacks in open places. Some sellers store the tubers in roofed and open-sided storage sheds. Others store sweet potato tubers in baskets under a shed. A few others store their consignment in wooden boxes under a shed. Some sellers buy small quantities of sweet potato tubers which they can quickly dispose of to avoid the problems associated with storage. If they however fail to dispose of all the tubers, the rest are kept on the floor in a room. The rest of the sellers either heap their sweet potato tubers in an airy place and cover them, pack tubers in sacks and store in a room, store tubers in sacks in open-sided shed or store tubers in sacks in airy place (Table 1).

4.2 **Problems associated with storage**

4.2.1 ***Sprouting and pest damage***

Most of the respondents (70.0%) have experienced sprouting in stored sweet potato. The problem of pest damage has also been experienced by many of the respondents (80.0%). The major pest associated with sweet potatoes in storage is the sweet potato weevil (96.0%) while the minor pests are rats and mice (4.0%).

4.2.2 ***Rot***

Sweet potato tuber rot during storage has been experienced by all respondents and it can occur at any time. All sweet potato varieties have storage rot problem. However the yellow type of sweet potato rots faster than the red type. The quantity of sweet potatoes that can get rotten out of a consignment varies from one storage barn to another as shown in Table 2.

Table 1 :- Methods of sweet potato storage employed by retailers of the produce

Method of storage	Percentage respondents involved (%)
Packed in roofed and open-sided storage sheds	16.7
Heaped in airy place and covered with tarpauline	10.0
Packed in sacks in a room	13.3
Exposed on the floor in a room	6.7
In baskets under shed	10.0
In sacks in open-sided shed	3.3
In sacks in open place	30.0
In wooden boxes under shed	6.7
In sacks in airy place	3.3
Total	100

Table 2 :- **Percentage losses of sweet potatoes tubers recorded from various respondents to the questionnaire**

Quantity	Percentage rot (%)	Percentage respondents involved (%)
5-10 tubers/sack*	1-2%	35.7
1/4 of a sack of tubers	25.0%	3.6
1/3 of a sack of tubers	33.3%	3.6
2 *baskets/sack of tubers	40.0%	25.0
1/2-full sack of tubers	50-100%	10.7
I do not know	-	21.4
Total		100

* A sack can contain about 500 tubers ; A basket can contain about 100 tubers

The consignments are made up of sack loads of sweet potato tubers with each sack being larger than a maxi-bag and capable of containing about 500 tubers. For instance, some respondents reported that 1-2% of tubers can get rotten out of a sack while others indicated that as much as 25.0%, 33.3% or 50-100% of tubers in a sack can get rotten. Other respondents indicated that they do not know the quantity that can get rotten out of a sack. Some also claimed that 40% of tubers in a sack can get rotten out of a consignment. Most of the respondents sell 1-100 sacks of sweet potatoes per year while the rest sell either 100-500 sacks or 500-1000 sacks of sweet potatoes per year. A majority of respondents can detect sweet potato rot in the interior of the tubers with little or no external evidence. This is done by applying pressure on the tuber; through appearance of the skin which is dark when the tuber is rotten; through a peculiar scent or through oozing from the tubers. Though all respondents have observed sweet potato tuber rot, no preventive measures were taken. From casual observation, almost all tubers that got rotten had the rots coming from the stem end.

4.3 Isolation and identification of micro-organisms associated with sweet potato tuber rot

Five fungal isolates were isolated from rotten tubers of sweet potato sampled between July and December, 1998. The five fungi were; *Aspergillus ochraceus* Wilhelm, *Botryodiplodia theobromae* Pat., *Fusarium moniliforme* J. Sheld, *Fusarium oxysporum* Schlectend, and *Rhizopus stolonifer* (Ehrenb.: Fr.)Vuill. Fungi were identified using standard references (Barnett and Hunter, 1972, Booth, 1971 and Samson and van Reenen-Hoekstra, 1988).

***Botryodiplodia theobromae* Pat.**

Culture on PDA filled a 9cm diameter plate within two days, consisting of fluffy aerial myceluim. Culture was initially grey, but turned black by the 5th day (Fig.8A). The mycelia also turned dark-brown (Fig.8B). The conidia were hyaline and aseptate when immature and dark-brown with two cells when mature (Fig.8C) (Barnett and Hunter, 1972).

***Fusarium oxysporum* Schlectend**

Mycelial growth of the fungus on PDA attained a diameter of 4.5cm in 4 days. Aerial mycelium was sparse and became light-purple at the older portions (Fig.9A). The underside was yellowish-brown (Fig.9B). Micro-conidia were elliptical and borne on lateral, simple phialides and not in chains. Macro-conidia were elongated and pointed at both ends (9C). Chlamydospores were present. The walls of the macro-conidia were not parallel (Booth,1971).

***Rhizopus stolonifer* (Ehrenb. : Fr.) Vuill**

Culture filled a 9cm-diameter plate in 2 days. The fluffy aerial mycelium was whitish and became greyish brown with age (Fig.10A). Smooth-walled and aseptate sporangiophores were in groups arising from stolons opposite the branched rhizoids. Sporangia measured about 150µm in diameter, globose and brownish at maturity with globose columella (Fig.10B) (Samson and van Reenen - Hoekstra, 1988).

***Aspergillus ochraceus* Wilhelm**

Colonies attained a diameter of 3-4cm within 7 days and consisted of a dense felt of yellowish-brown colour (Fig.11A). Conidial heads radiated, conidiophores hyaline with globose vesicle

Fig. 8 Photographs showing characteristics of *Botryodiplodia theobromae;* A, Two and five-day old cultures of *Botryodiplodia theobromae* on potato dextrose agar plates (x0.8); Left, five-day old culture with black aerial mycelium; Right, two-day old culture with grey aerial mycelium; B, Dark-brown mycelium of *Botryodiplodia theobromae* obtained from five-day old culture (x400); C, Conidia of *Botryodiplodia theobromae* prepared from host tissue (x400); (a) Hyaline and aseptate immature conidia and (b) Dark-brown bi-celled mature conidia.

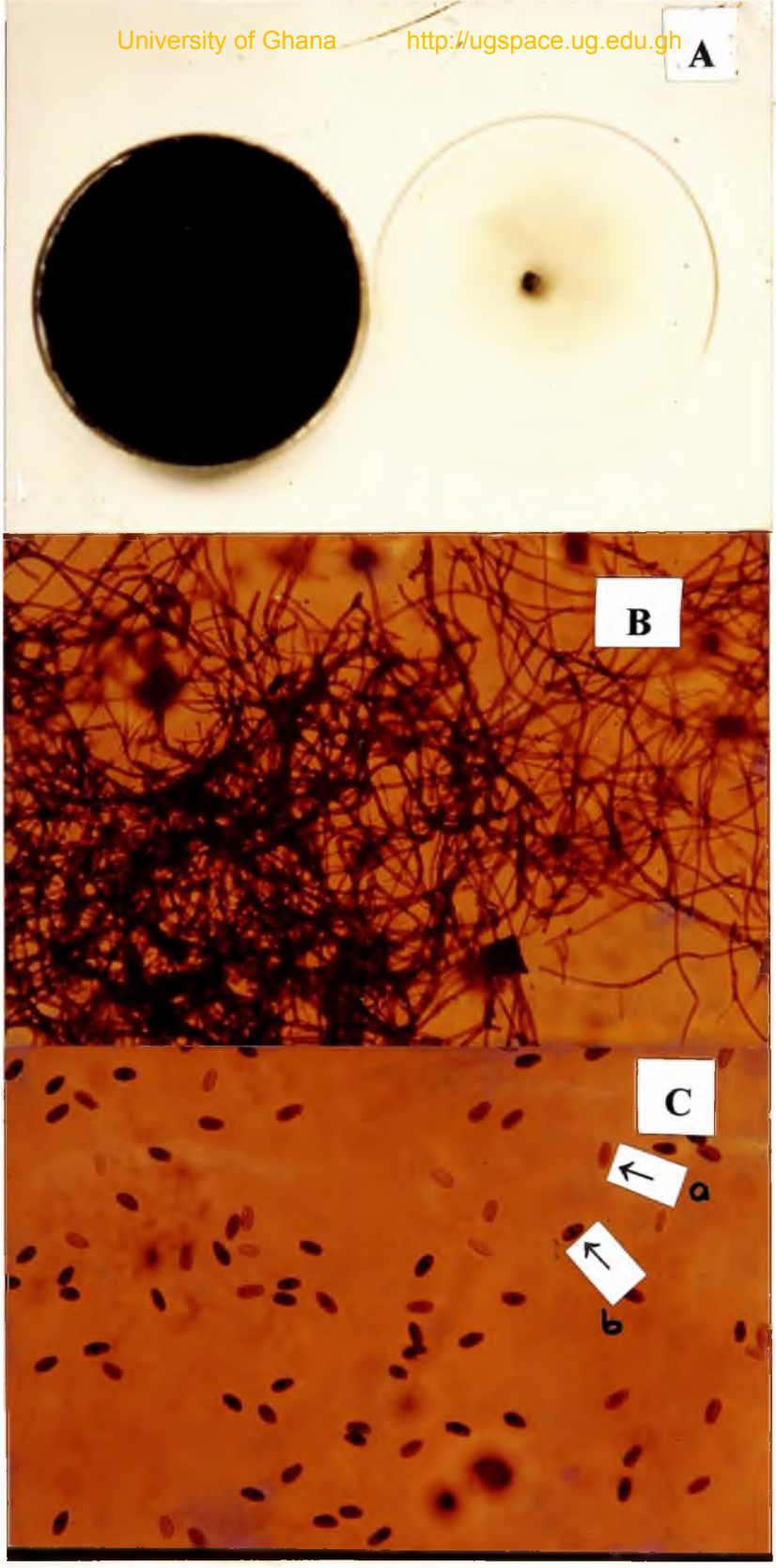


Fig.9 Photographs showing characteristics of *Fusarium oxysporum;* A, Eight-day old culture of colonies of *Fusarium oxysporum* on potato dextrose agar (x0.8). Note light-purple colour at older portion; B, Underside of eight-day old culture of colonies of *Fusarium oxysporum* on potato dextrose agar (x0.8). Note Colour is yellowish-brown; C, Spores of *Fusarium oxysporum* under the light microscope (x400) (a) Macro-conidia (b) Micro-conidia.

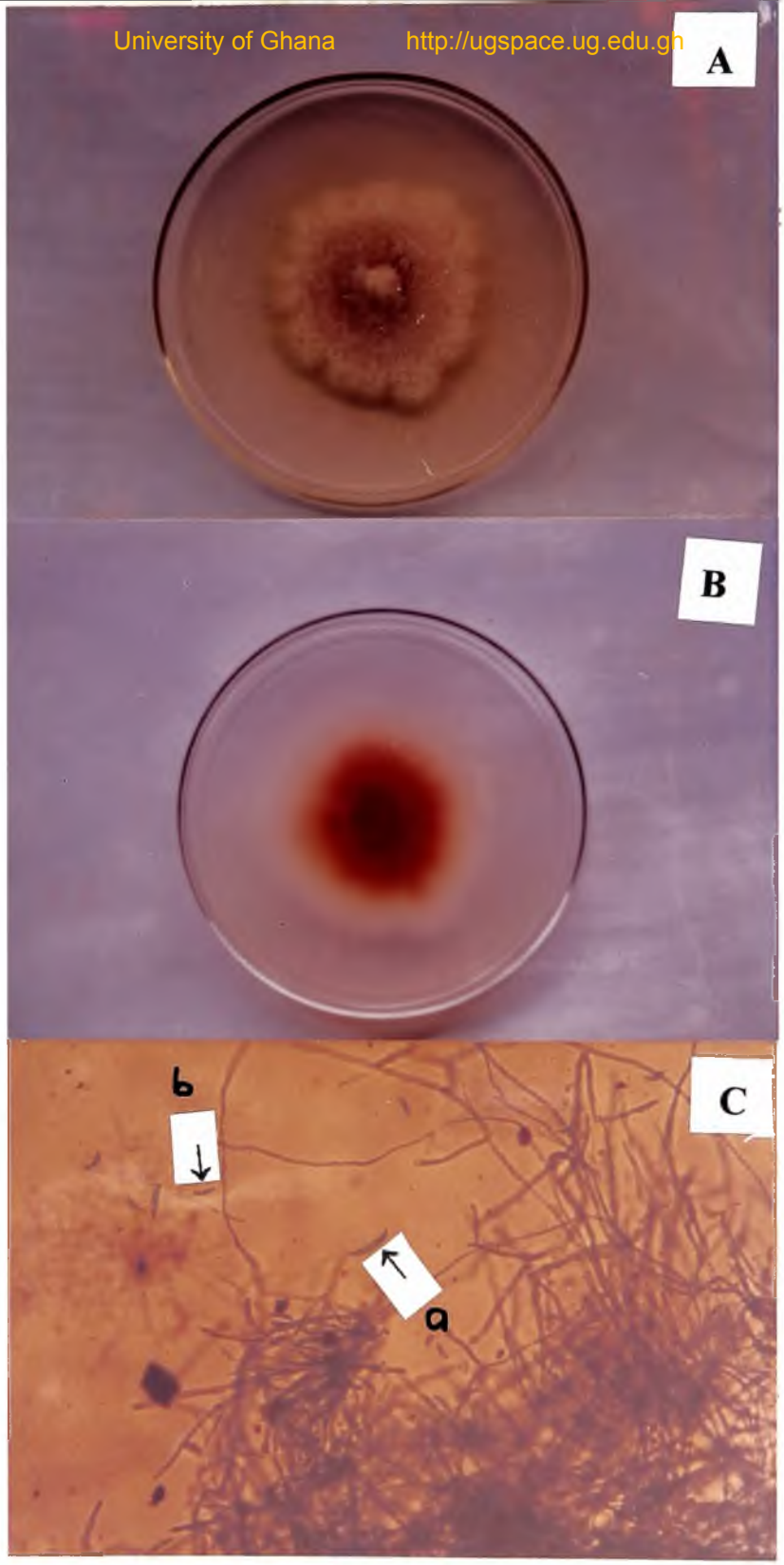
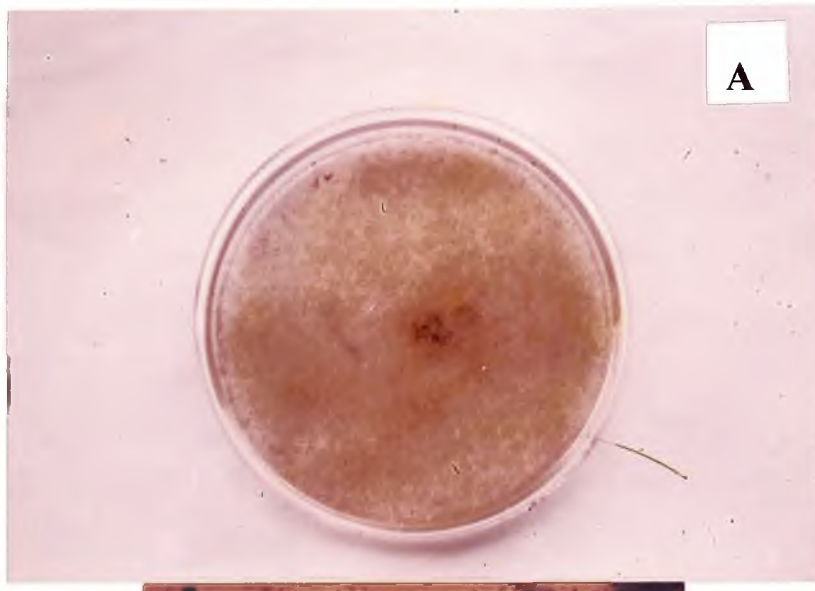


Fig. 10 Photographs showing characteristics of *Rhizopus stolonifer*; A, Two-day old culture of *Rhizopus stolonifer* on potato dextrose agar (x0.8); B, Morphological structure of *Rhizopus stolonifer* under the light microscope (x400); a, Two sporangiophores arising from a common point on a stolon ; b, Rhizoids opposite the sporangiophores; c, Stolon; d, Sporangium



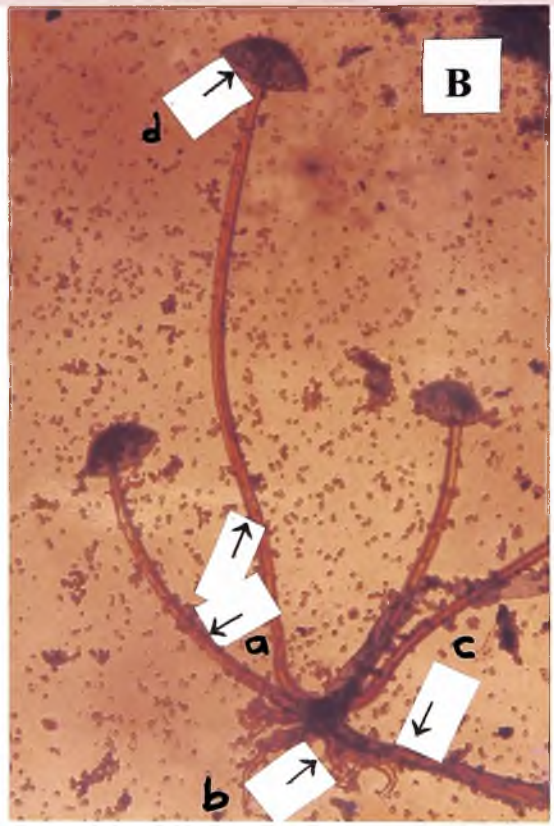
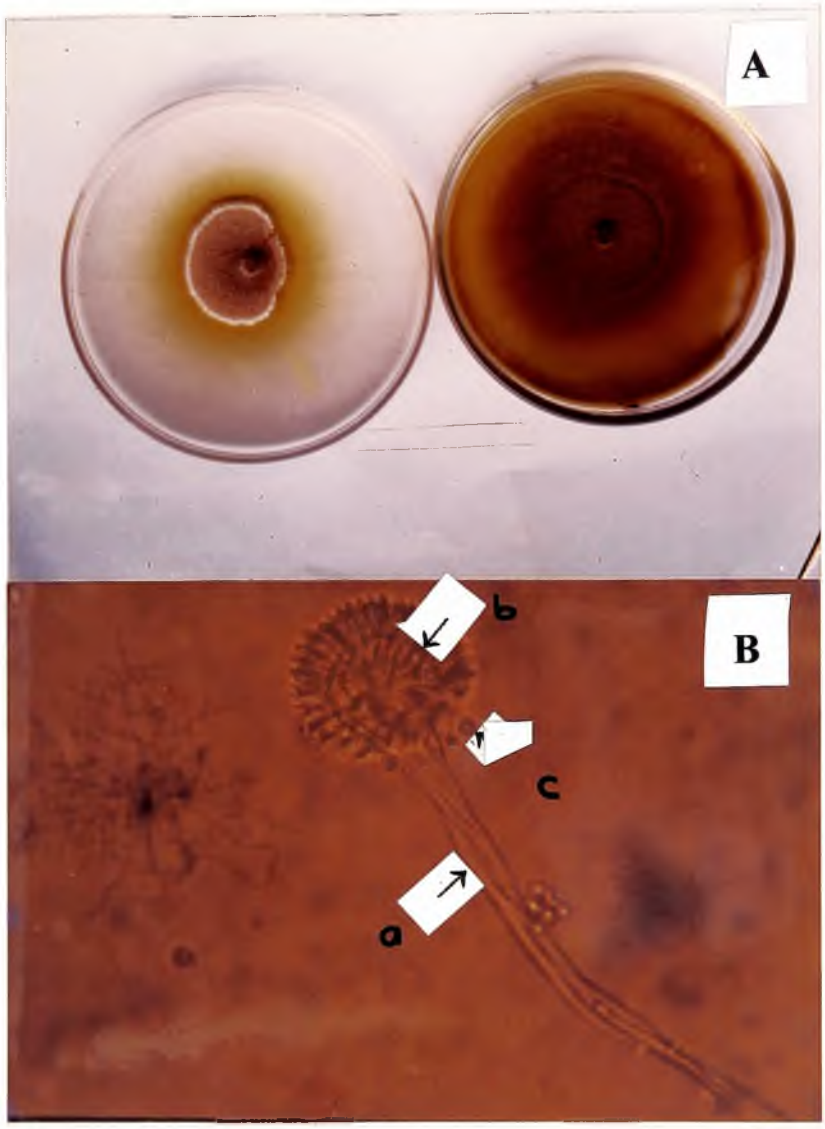


Fig. 11 Photographs showing characteristics of *Aspergillus ochraceus*. A, Five and Eleven-day old cultures of *Aspergillus ochraceus* on potato dextrose agar in petri plates. Left, Five-day old culture with yellowish-brown pigmentation; Right, Eleven-day old culture with brown pigmentation; B, Morphological features of *Aspergillus ochraceus* under the light microscope. (x800) showing , (a) Conidiophore bearing conidial head, (b) Vesicle over the surface of which are borne phialides and (c) Conidia (one-celled and hyaline).



on which are borne phialides and 1-celled hyaline conidia (Fig.11B). Conidial heads globose when young, later splitting into two or more compact columns. Conidiophore stripe yellow to pale brown, rough-walled. Conidia globose, finely rough or smooth-walled (Thom and Raper, 1945 and Samson and van Reenen-Hoekstra, 1988).

***Fusarium moniliforme* J. Sheld**

Culture attained a diameter of 2.4cm in 14 days (Fig.12) but it failed to sporulate. There was therefore the need to induce sporulation using near ultraviolet light. Sporulation occurred one week after exposure of the culture to near ultraviolet light. The culture of the sporulated form on PDA attained a diameter of 4.5cm in 5 days (Fig.13A). The colours of the cultures of the unsporulated and sporulated forms were cream and pale cream respectively. The aerial mycelium of the sporulated form was dense, delicately floccose to felty or with a powdery appearance due to micro-conidia production. The reverse side was pinkish (Fig. 13B). Micro-conidia are abundant, while macro-conidia are scarce. The estimated ratio of macro-conidia to micro-conidia per microscopic view is 1:12 under high power (x 40) (Mesolaen, 1959 and Samson and van Reenen-Hoekstra, 1988).

4.4 Frequency of occurrence of micro-organisms in rotten sweet potato tubers

Table 3 shows the frequency of occurrence of rot-causing fungi of sweet potatoes isolated from rotten sweet potatoes obtained from five markets in Accra and from the storage barn between July and December, 1998. Of the five fungal isolates obtained from the rotten tubers, *Botryodiplodia theobromae* was most frequently obtained both in the markets and in the barn. However the percentage of occurrence of *Botryodiplodia theobromae* in the barn was lower than that in the markets. *Aspergillus ochraceus, Fusarium moniliforme, Fusariun oxysporum*

Fig. 12 Fourteen-day old culture of *Fusarium moniliforme* on potato dextrose agar before it was induced to sporulate (x0.8).

Fig. 13. Photographs showing characteristics of *Fusarium moniliforme*. A, Five-day old culture of *Fusarium moniliforme* on potato dextrose agar after sporulation (x 1.5); B, Underside of nine-day old culture of *Fusarium moniliforme* (x 1.5); C, Morphological characteristics of *Fusarium moniliforme* under the light microscope (x 400), showing; (a) Macro-conidia (scarce); (b) Micro-conidia (abundant).

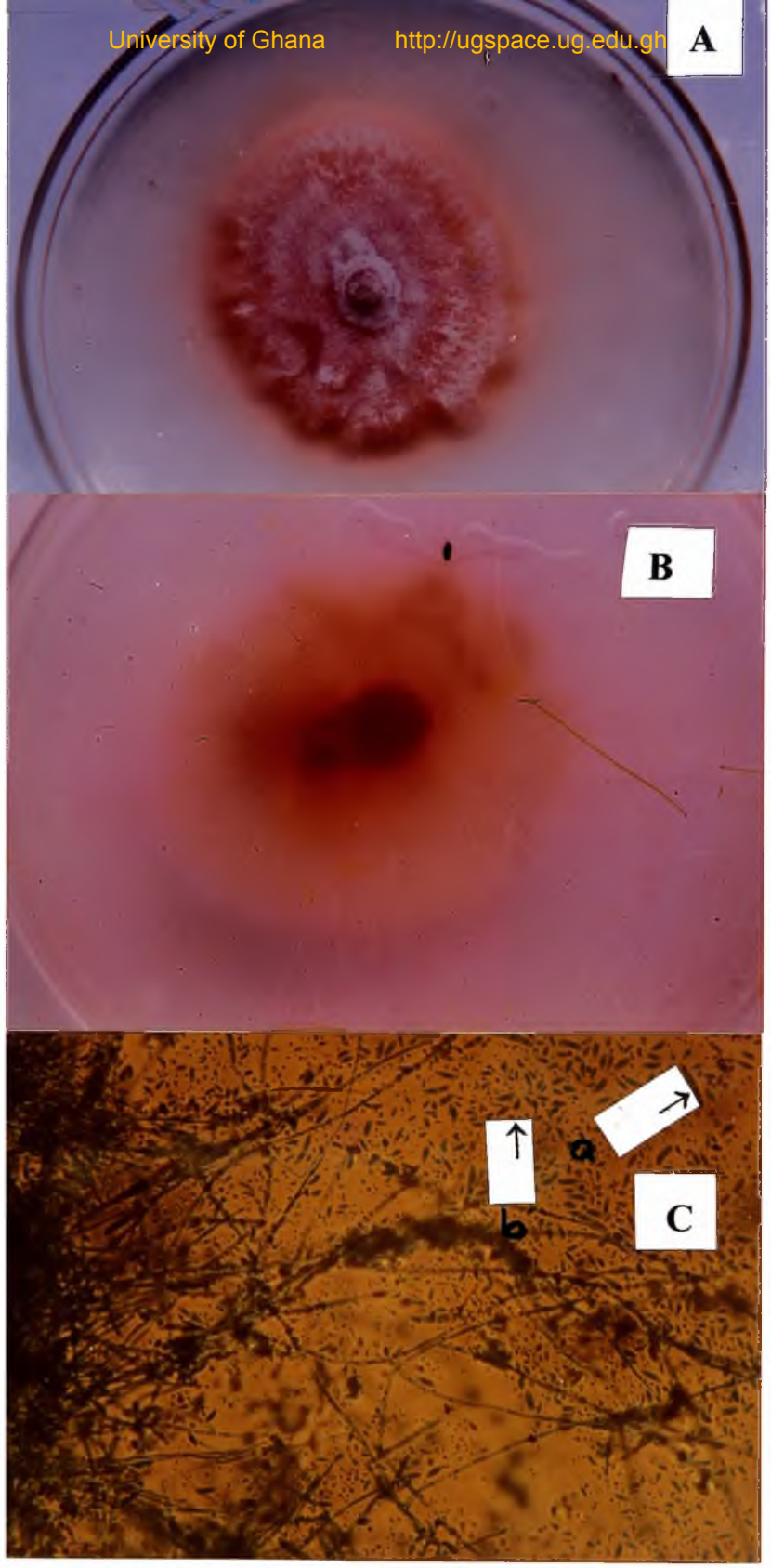


Table 3 - **Percentage of occurrence of fungi causing sweet potato tuber rot**

	% occurrence			
	Barn	**Markets**	**Combined Value***	**Mean**
Aspergillus ochraceus	0(0.0)	6.25(1.0)	2.0(1.0)	3.13
Botryodiplodia theobromae	90.9(30.0)	75.0(12.0)	85.8(42.0)	82.95
Fusarium moniliforme	3(1.0)	6.25(1.0)	4.1(2.0)	4.63
Fusarium oxysporum	0(0.0)	6.25(1.0)	2.0(1.0)	3.13
Rhizopus stolonifer	6·1(2·0)	6·25(1·0)	6·1(3·0)	6·18
Total	100	100	100	100

$$\text{*Combined value} = \frac{\text{No. of times an organism was isolated from markets and barn}}{\text{Total number of isolations from markets and barn}} \times 100$$

and *Rhizopus stolonifer*, had the same frequency of occurrence (6.7%) in the markets. *Rhizopus stolonifer* was the second most frequent organism in the barn (6.1%).

Fusarium moniliforme was the third most frequently occuring fungus in the barn (3.0%). *Aspergillus ochraceus* and *Fusarium oxysporum* were not encountered in the barn. In both the market and barn, *Rhizopus stolonifer* was the second most frequent, after *Botryodiplodia theobromae*. *Aspergillus ochraceus* and *Fusarium oxysporum* had the same frequency of occurrence in both the markets and the barn. *Fusarium moniliforme* was the third most frequently occuring in both the markets and the barn.

4.5 **Pathogenicity of isolates**

All the five fungi isolated from the rotten sweet potato tubers were found to be pathogenic to healthy tubers when inoculated. Fig.14. shows the rots which were caused by the fungi used for the inoculation. In terms of size of necrotic area, the rots were apparently most severe in tubers inoculated with *Aspergillus ochraceus* and *Botryodiplodia theobromae*. The rot caused by *Fusarium moniliforme* was apparently less extensive, than those caused by *Fusarium oxysporum* and *Rhizopus stolonifer* species. Fig.15 shows the transverse sections of the necrotic areas in sweet potato tubers caused by the five fungal species *viz Aspergillus ochraceus, Botryodiplodia theobromae*, *Fusarium moniliforme*, *Fusarium oxysporum*, and *Rhizopus stolonifer* which were used in inoculating "Fante" and "Ayigbe" types of sweet potato. The measured values of these necrotic areas are presented in Table 4. The necrotic spots caused by *Botryodiplodia theobromae*, in the Fante and Ayigbe types of sweet potato were 2.3 cm^2 and 2.5 cm^2 respectively and were therefore not significantly different ($P=0.05$).

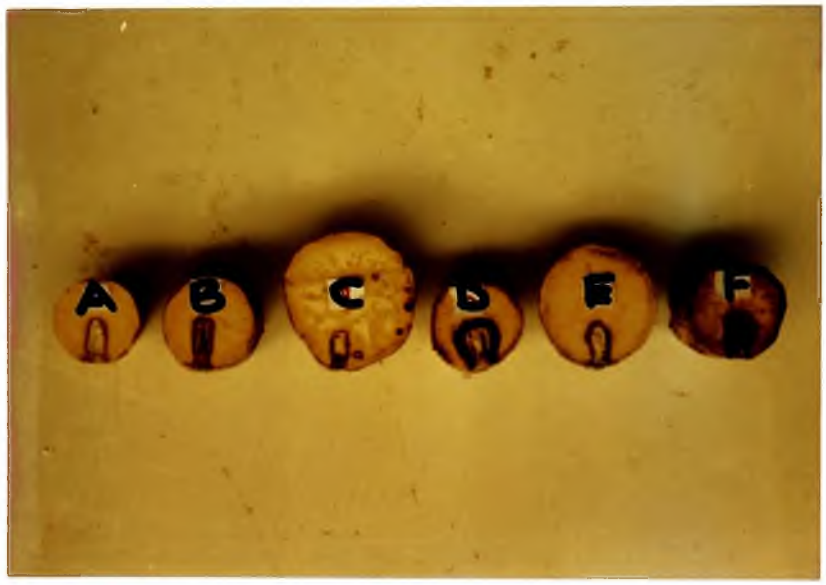


Fig 14 Transverse sections of sweet potato tubers at the points of inoculation with five test fungi inoculated for 10 days at room temperature. A, control (disc of PDA only); B, *Fusarium moniliforme;* C, *Rhizopus stolonifer;* D, *Aspergillus ochraceus;* E, *Fusarium oxysporum*; F, *Botryodiplodia theobromae.*

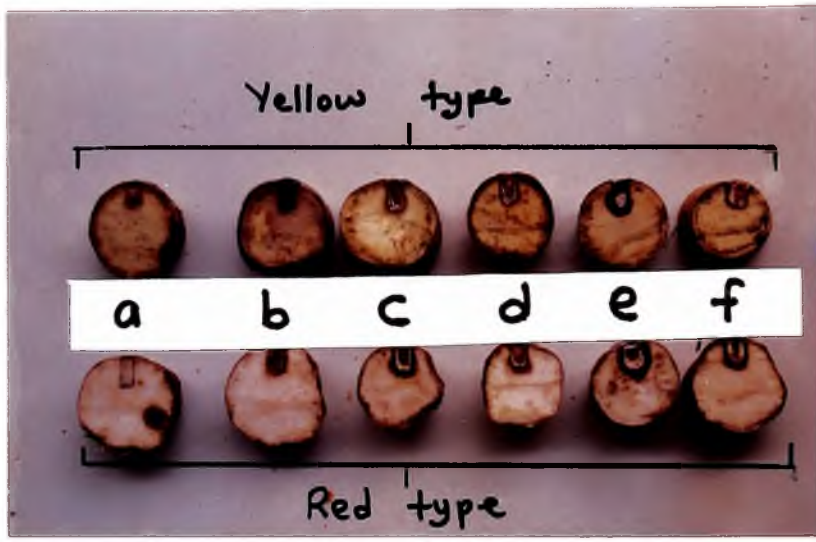


Fig. 15 Transverse sections of sweet potato tubers showing necrotic areas inflicted by five indicated fungal isolates one week after inoculation of (Top) yellow type with yellow flesh, (Bottom) red type with white flesh types of sweet potato.

Key to fungal isolates : a, Control (uninoculated) ; b, *Botryodiplodia theobromae* ; c, *Fusarium oxysporum;* d, *Fusarium moniliforme* ; e, *Aspergillus ochraceus* ; f, *Rhizopus stolonifer.*

Table 4: Necrotic areas caused by the five fungal isolates on two types of sweet potato

Name of fungal isolate used in the inoculation	Type of sweet potato and lesion size (cm^2)	
	Fante	**Ayigbe**
Control	0	0
Aspergillus ochraceus	2.7	5.2
Botryodiplodia theobromae	2.3	2.5
Fusarium moniliforme	2.5	2.7
Fusarium oxysporum	3.2	2.0
Rhizopus stolonifer	2.5	2.6
LSD 5%	1.042	1.071

On the other hand, necrotic spot caused by *Fusarium oxysporum* on the Fante type, (3.2 $cm^{2)}$ was significantly larger (P=0.05) than that in the Ayigbe type (2.0 $cm^{2)}$. For *Fusariun moniliforme* there was no significant difference (P=0.05) between the necrotic area in the Fante, and Ayigbe types of sweet potato which were 2.5 cm^2 and 2.7 cm^2 respectively. Necrotic spots caused by *Aspergillus ochraceus* in the Ayigbe type (5.2 $cm^{2)}$ was significantly higher (P=0.05) than that caused in the Fante type, (2.7 $cm^{2)}$ (Table 4). The necrotic spots caused by *Rhizopus stolonifer* on the Fante and Ayigbe types of sweet potato were not significantly different in size (P=0.05). There were varietal differences in the response of the sweet potato tubers to infection by the five test fungi.

4.6 Evaluation of curing process in terms of periderm formation

When the sweet potato tubers were subjected to the various curing treatments for 4 days, the anatomical studies showed the following thickness and characteristics of the periderm as presented in Table 5. The thickness of all the periderm for the various treatments were significantly different (P = 0.05) from each other. The periderm formed in the unwounded and uncured tubers was significantly thicker (P= 0. 05) than the other wound periderms. There was no periderm formation in wounded and uncured tubers (Table 5). The thickness of the wound periderm from wounded and incubator-cured tubers was second, after the normal periderm from unwounded and uncured tubers followed by that from wounded and polyethylene-cured tubers.

Table 5 Variation in wound-healing capacity of variously treated sweet potato tubers estimated by the thickness (μm) of periderm formed after treatment

Treatment	Periderm thickness in μm	Characteristics
Wounded, incubator-cured	270.5 a *	Wound periderm cells were brick like, thin-wall and arranged one on top of the other without intercellular spaces.
Wounded, polyethylene-cured	232.2 b *	Wound periderm cells were brick-like thin-walled and arranged one on top of the other without intercellular spaces.
Wounded, sun-cured	17.6 c *	Wound periderm was not completely formed and the cells were brick-like, thin-walled and arranged one on top of the other without intercellular spaces.
Wounded, uncured (control)	0.0 d*	Wound periderm was not formed and some of the cells below the wound surface were irregularly shaped while others were roundish
Unwounded, uncured (control)	312.6 e*	Normal periderm cells were brick like, thin-walled and arranged one on top of the otherwithout intercellular spaces.

*The same letters imply no significant difference while different letters imply that there is a significant difference.

Table 6 shows the effect of curing on incidence and severity of rot of stored sweet potato tubers. Wounded and incubator-cured, wounded and polyethene-cured and wounded and sun-cured tubers had their rots coming predominantly from the wounded area with their incidence of rot at the 13th week being 8.9%, 91.0% and 100% respectively. For the two controls, that is wounded, uncured and unwounded, uncured, the rots were predominantly from the stem end with the incidence of rot at the 13th week being 76.7% and 87.4% respectively. At the end of the 13th week, wounded and incubator-cured tubers had the least severity of 45.1cm^2 while wounded and polyethylene-cured tubers had the highest severity of 202.1cm^2. The severity of rots for unwounded and uncured, wounded and uncured and wounded and sun-cured tubers were 142.8cm^2, 167.7cm^2 and 178.1cm^2 respectively. There were significant diferences (P=0.05) in the severity of rot among all the three treatments and the two controls.

Fig. 16 shows a tranverse section of tissue from a wounded and incubator-cured tuber showing wound periderm in the top part. The cells here are brick-like, thin-walled and arranged one on top of the other without intercellular spaces. The thickness of this wound periderm is 270.5μm.

Wound periderm formation also occurred in wounded and polyethylene-cured tubers. Fig.17 shows a transverse section of wounded and polyethene-cured tubers containing wound periderm in the top part. The wound periderm cells here are also arranged in the same manner as those in the wounded and incubator-cured tubers. The thickness of this wound periderm is 232.2μm.

Table 6 Influence of the curing process on incidence and severity of rot in sweet potato tubers for 13 weeks

Treatment	Periderm size in µm	* Incidence: Percentage of tubers with rotting from stem end	Percentage of tubers with rotting from wounded area	Severity (cm^2) of rotting**
Wounded, incubator-cured	270.5a	-	35.5	45.1a
Wounded, polyethylene-cured	232.2b	-	94.6	202.1b
Wounded, sun-cured	17.6c	-	100.0	178.1c
Wounded, uncured (Control)	0.0d	76.7	-	167.7 d
Unwounded, uncured (Control)	312.6e	87.4	-	142.8 e

*56 tubers per treatment were used for incidence and severity experiment which was terminated at the 13th week because of weevil infestation of tubers in storage.

- not determined because rots at those points were not prominent. ** area of rotted tissue.

Fig. 16. Tranverse section of sweet potato tuber (yellow variety) showing periderm formation after wounding and curing in an incubator at 29-30 ^{O}C and 85-90% ERH for 4 days.

Top: A. Section of the tuber showing (a) wound periderm region and (b) underlying cells under low power magnification (x 5).

Bottom: B. High power magnification (x400) of wound periderm region shown in (a)

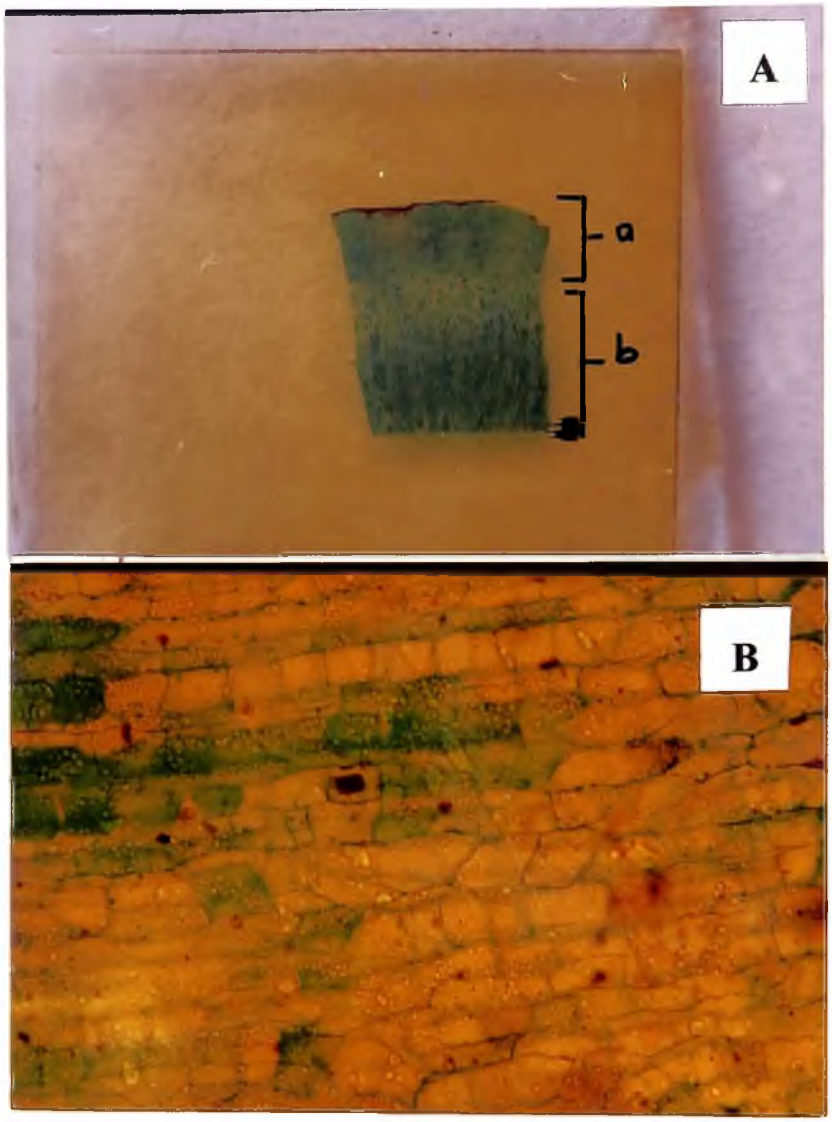
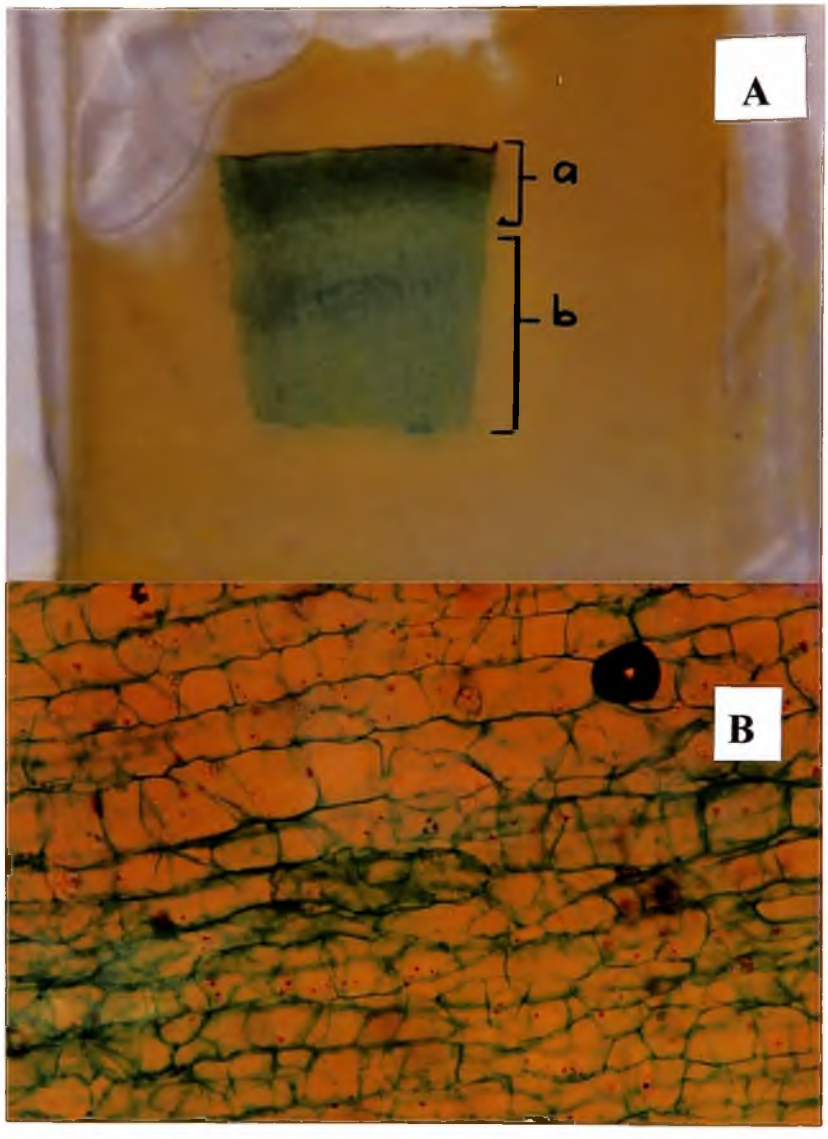


Fig. 17. Transverese section of sweet potato tuber (yellow variety) showing periderm formation after wounding and curing by covering with a transluscent polyethylene sheet at 25-50 ^{o}C and 40-100% ERH for 4 days.

Top: A. Section of tuber showing (a) wound periderm region (b) underlying cells under low power magnification (x4).

Bottom: B. High power magnification (x400) of the wound periderm region shown in (a).



A wound periderm was also formed in tubers which were wounded and sun-cured. Fig.18 shows a section of wounded and sun-cured tubers containing wound periderm in the top part. The wound periderm was however not properly formed. The poor formation of the wound periderm was evidenced by its thickness of 17.6μm, a value significantly smaller (P=0.05) than the thickness of the other wound periderms. Wound periderms of the incubator-cured and polyethylene-cured tubers which had thickness of 270.5μm and 232.2μm respectively, were significantly thicker than this wound periderm.

There was no periderm formation in tubers which were wounded but not cured. The cells below the wound surface were not brick-like. Some of the cells were roundish while others were irregular in shape. Fig.19 shows a section of wounded and uncured tubers containing suberised cells in the top part. The cells were stained red which suggested that suberisation occurred but there was no periderm formation.

When normal periderm was taken from tubers that were neither wounded nor cured, their cells were brick-like, thin-walled and arranged one on top of the other without intercellular spaces. Fig.20 shows a section of unwounded and uncured tubers containing the periderm in the top part. The periderm cells are arranged parallel to the surface of the tuber. The thickness of the normal periderm is 312.6μm. Fig 21 is a composite of Figs 16-20.

Fig. 18. Transverse section of sweet potato tuber (yellow variety) showing periderm formation after wounding and curing in the sun at 22-35 ^{o}C and 20-80% ERH for 4 days.

Top : A. Section of tuber showing (a) wound periderm region and (b) underlying cells under low power magnification (x4).

Bottom: B. High powr magnification (x400) of the wound periderm region shown in (a).

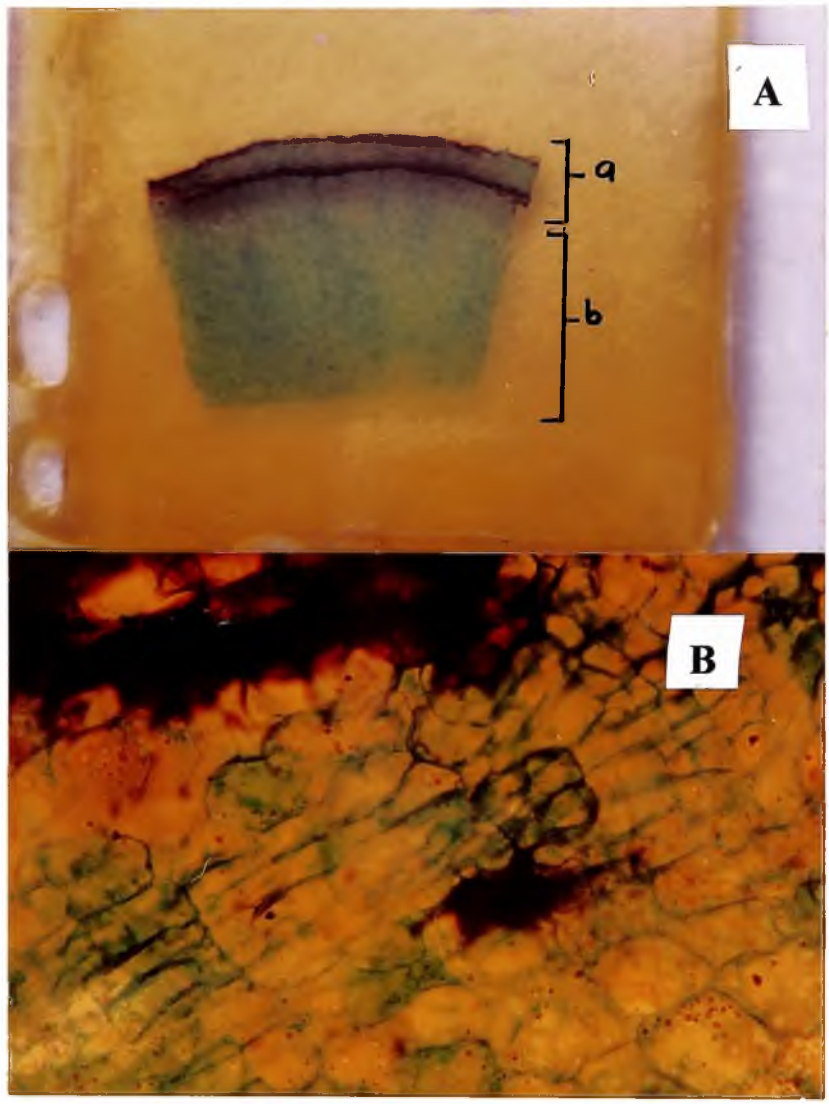


Fig. 19. Tranverse section of sweet potato tuber (yellow variety) after wounding and not curing.

Top: A. Section of the tuber showing (a) cells immediately below wound surface and (b) underlying cells under low power magnification (x5).

Bottom: B. High power magnification (x400) of cells immediately below wound surface shown in (a).

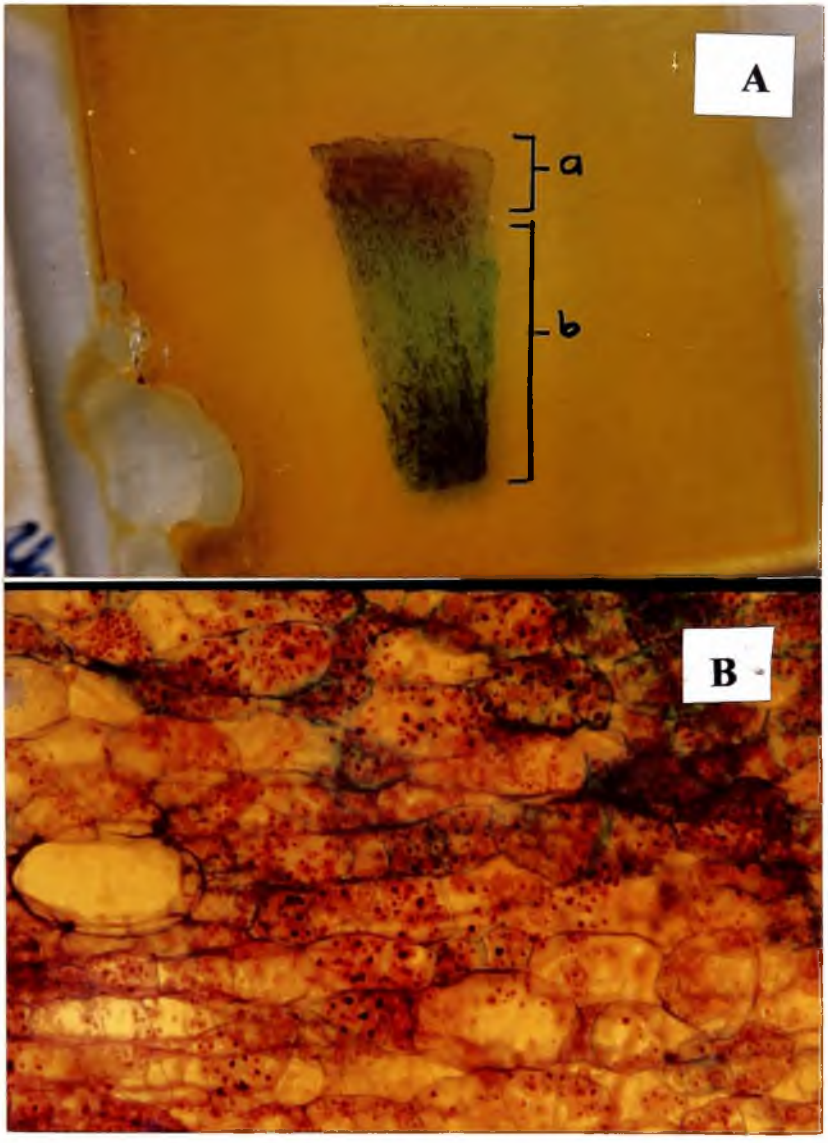
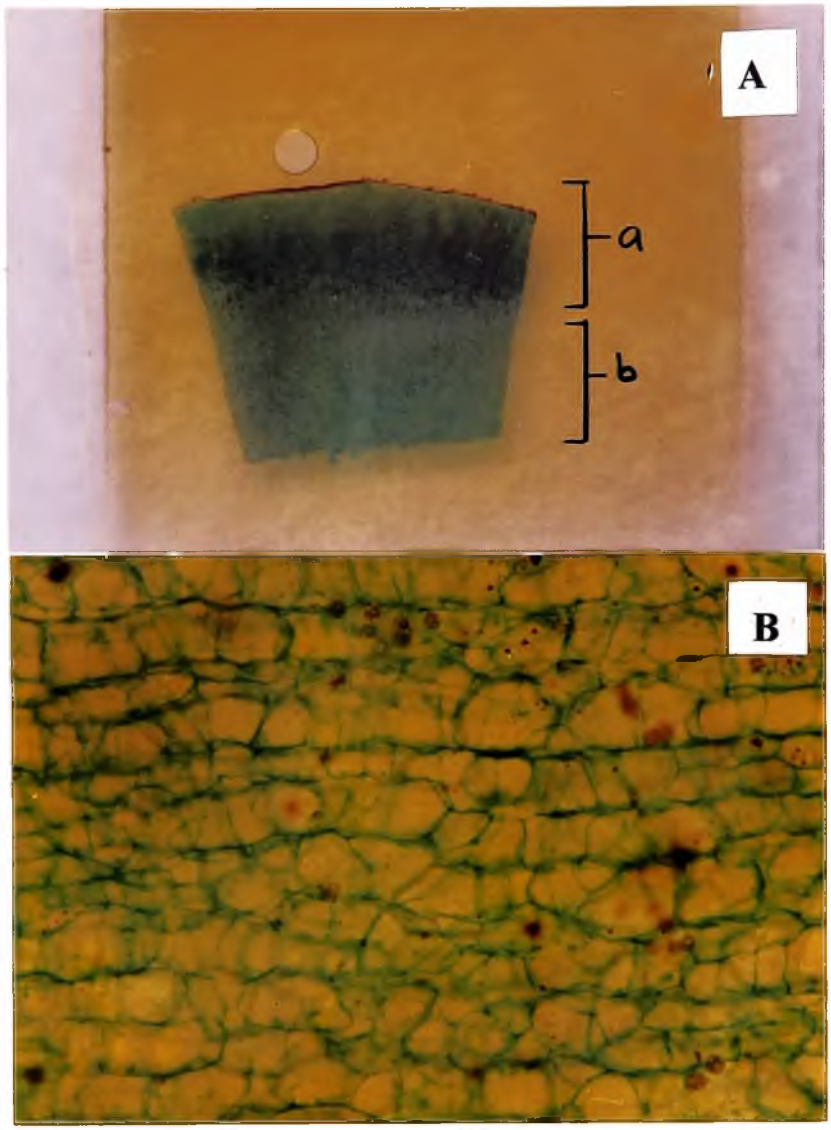


Fig. 20. Transverse section showing periderm from unwounded and uncured sweet potato tuber (yellow variety).

Top: A. Section of tuber showing (a) normal periderm and (b) underlying cells under low power magnification (x4).

Bottom: B. High power magnification (x400) of the normal periderm region shown in (a).



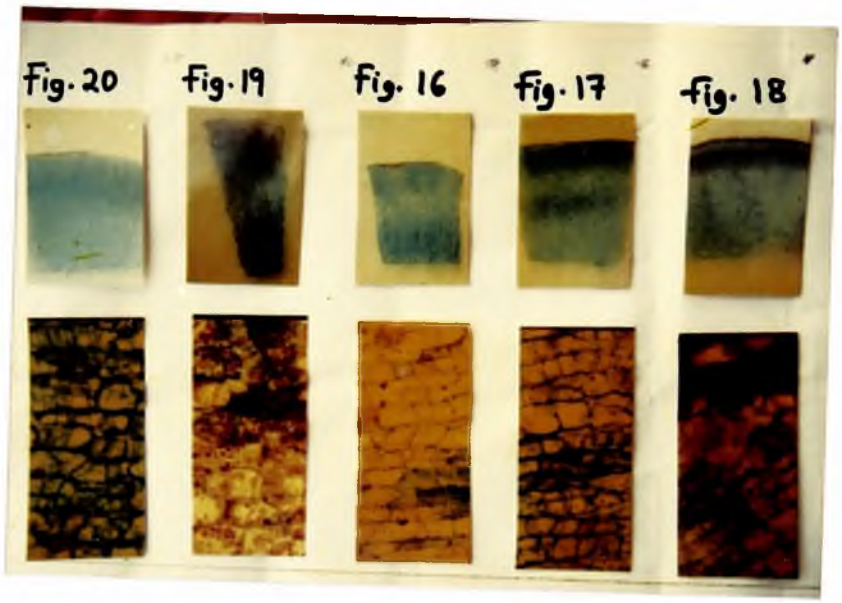


Fig. 21. Composite photograph of Figs. 16-20

4.7 Effect of curing on shelf-life of sweet potatoes

4.7.1 Incidence of rot

The incidence of rotting in tubers which were subjected to different curing treatments are shown in Fig. 22. Appendix 2 also shows the data on rotting in sweet potato tubers. Rotting was highest in wounded and sun-cured tubers. By the 4th week , the percentage rot was about 90% totally rotting after 7 weeks.

Wounded and polyethene-cured tubers had the second highest incidence of rot. By the 6th week of storage, the percentage rot was over 80% reaching above 90% after 18 weeks.

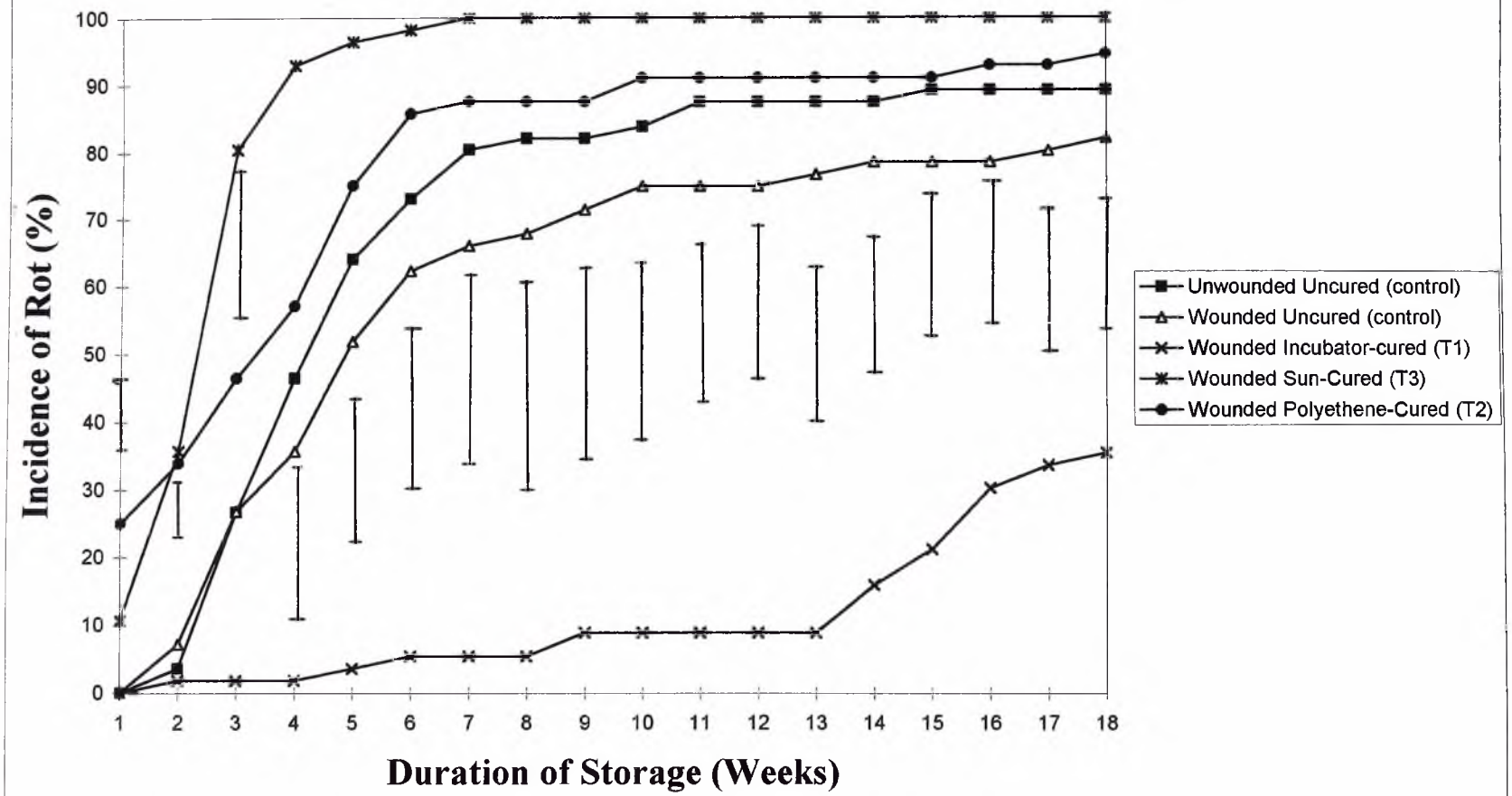
Unwounded and uncured tubers had an intact periderm and were therefore expected to store well but they recorded a significantly high (P=0.05) incidence of rot. By the 7th week about 80% of the tubers were rotten reaching over 90% in the 18th week.

Wounded and uncured tubers also had a significantly high (P=0.05) incidence of rot. By the 6th week over 60% of the tubers were rotten, reaching a little above 80% by the 18th week.

Wounded and incubator-cured tubers recorded the lowest incidence of rot throughout the storage period which was significantly different (P=0.05) from the rest. From the 1st to the 13th week, the percentage rot was less than 10% reaching about 35% in the 18th week.

There was a general increase in the incidence of rot among tubers belonging to the three treatments and the two controls, throughout the storage period.

Fig. 22 Effect of Different Curing Methods on Incidence of Rotting in Sweet Potato Tubers (Yellow Variety)



By the 18th week, less than 40% of tubers cured in the incubator were rotten while between 70-100% of tubers belonging to the rest of the treatments including the controls were rotten. There was no significant difference (P=0.05) in incidence of rot between unwounded and uncured and wounded and uncured tubers from the 3rd to the 18th week of storage. During the same period, there were significant differences (P=0.05) in incidence of rot among incubator-cured and polyethylene-cured tubers. At the end of the storage period, the percentage rot of incubator-cured tubers which was 35.5% was significantly lower (P=0.05) than those of the remaining treatments.

The normal periderm performed worse in terms of rot than the wound periderms. Also wounded and uncured tubers fared better than unwounded and uncured, wounded and polyethylene-cured and wounded and sun-cured tubers.

The rotting in unwounded and uncured tubers were found mostly at the stem end of the tuber while rotting tubers from the other treatments were observed from the stem end as well as the wounded area. Rotting in incubator-cured tubers originated mostly from holes made by the sweet potato weevil, *Cylas* sp. The weevils made holes into the tubers which facilitated the entry of rot-causing fungi (Fig.23A). Longitudinal section through the holes showed regions of necrosis around the holes (Fig.23B). Fig. 23C shows the sweet potato weevil, *Cylas* sp. The weevil damage resulted in the termination of the experiment after 18 weeks of storage.

Fig. 23 Damage caused by sweet potato weevil, *Cylas* sp. to sweet potato tubers (yellow variety) in storage.

(A) Holes made on sweet potato tubers by sweet potato weevil (seen as black spots) .

(B) Necrotic region around holes made by sweet potato weevil (arrowed).

(C) Sweet potato weevil, *Cylas* sp (x4.0).

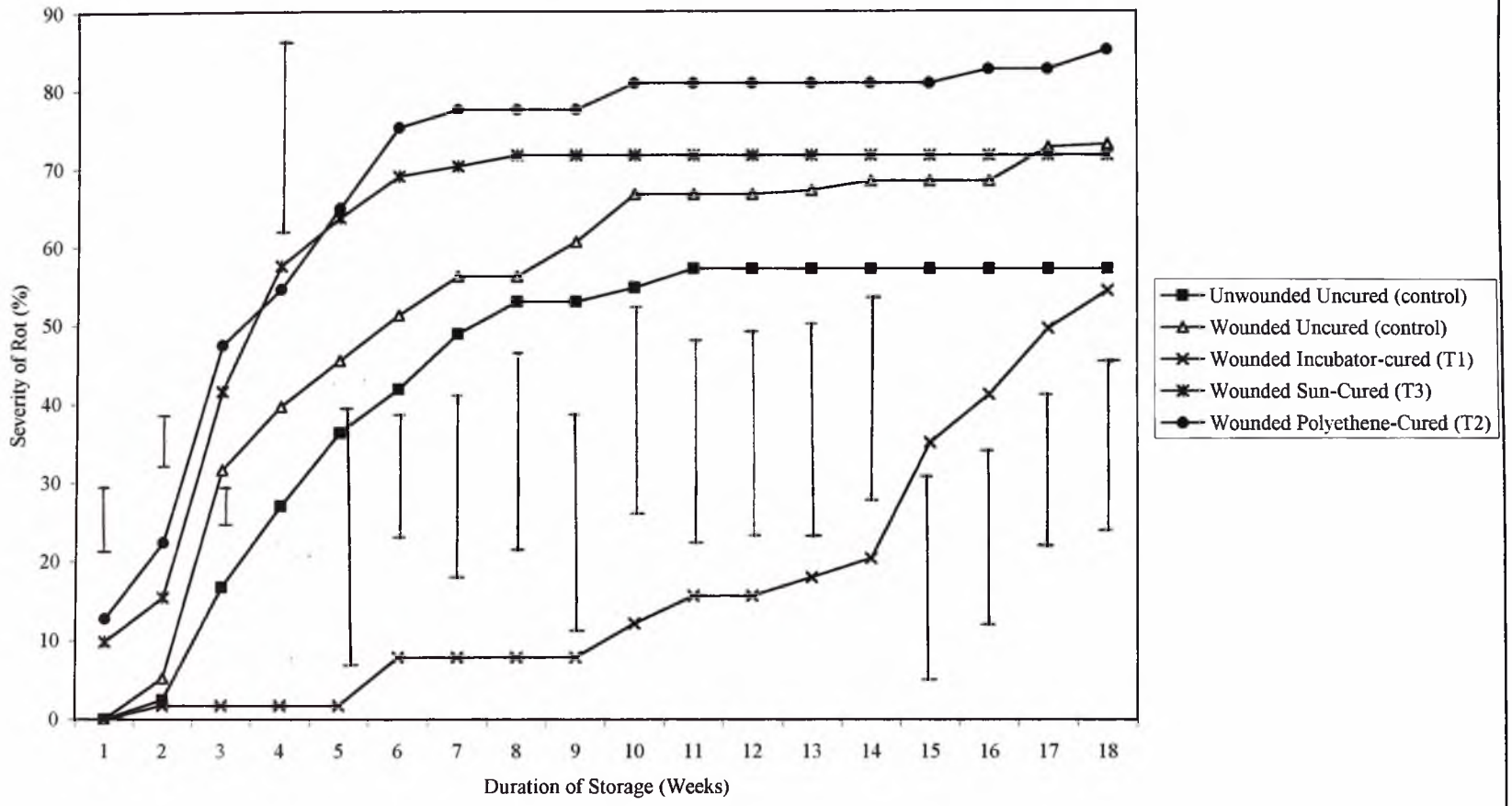
4.7.2. **Severity of rot**

Fig.24 shows the severity of rot in tubers subjected to different curing treatments. Rotting was highest in the samples of sweet potato wounded and polyethylene-cured. By the 6th week the severity was about 75% reaching above 80% by the 18th week. Wounded and sun-cured tubers had the second highest severity of rot. By the 8th week the severity was 70% and remained so until the 18th week when the experiment was terminated. Wounded and uncured tubers had the third highest severity of rot. By the 7th week, the severity was about 50% reaching a little above 75% in the 18th week.

Unwounded and uncured tubers had the fourth highest severity. By the 8th week, the severity was a little above 50% reaching almost 60% in the 18th week. The wounded and incubator-cured tubers had the least severity of rot. By the 13th week the severity was above 15%. From the 14th week, the severity increased, reaching about 55% in the 18th week mainly due to weevil infestation.

There was a general increase in severity of rot for all tubers belonging to the three treaments and the two controls throughout the storage period.

Fig. 24. Effect of Different Curing Methods on Severity of Rot in Sweet Potato Tubers (Yellow Variety)



4.7.3. Weight loss of sweet potato tubers during storage at 23-33 ^{o}C and 45-82% RH

Results of weight loss are presented in Fig.25 (See appendix 4). There was a steady increase in the loss of fresh weight in all treatments as well as the controls, throughout the 8-week period. Weight loss was least in incubator-cured tubers while the sun-cured tubers recorded the highest rate of weight loss.

Fresh weight loss in incubator-cured tubers was significantly lower ($P = 0.05$) than those of the other treatments. At the end of the 8th week, incubator-cured tubers had lost 10.38% fresh weight which was significantly lower ($P=0.05$) than the value of 22.69% in the sun-cured tubers. By the 8th week all wounded and sun-cured tubers were rotten.

4.7.4. Sprouting of sweet potato tubers

Sprouting of tubers which were subjected to different curing treatments is shown in Fig. 26 (See Appendix 6) During the 1st week of storage, about 40% of incubator-cured tubers had sprouted. At the end of the 8th week when the experiment was terminated, the percentage sprout of incubator-cured tubers was 98.1% which was significantly higher ($P =0.05$) than the values for the other treatments *viz* 5% for sun-cured tubers and 10% for polyethylene-cured tubers. Fig.27 shows sprouted tubers from incubator-cured tubers immediately after 4 days following curing of tubers.

Fig. 25 Effect of Different Curing Methods on PercentageWeight Loss by Sweet Potato Tubers (Yellow Variety)

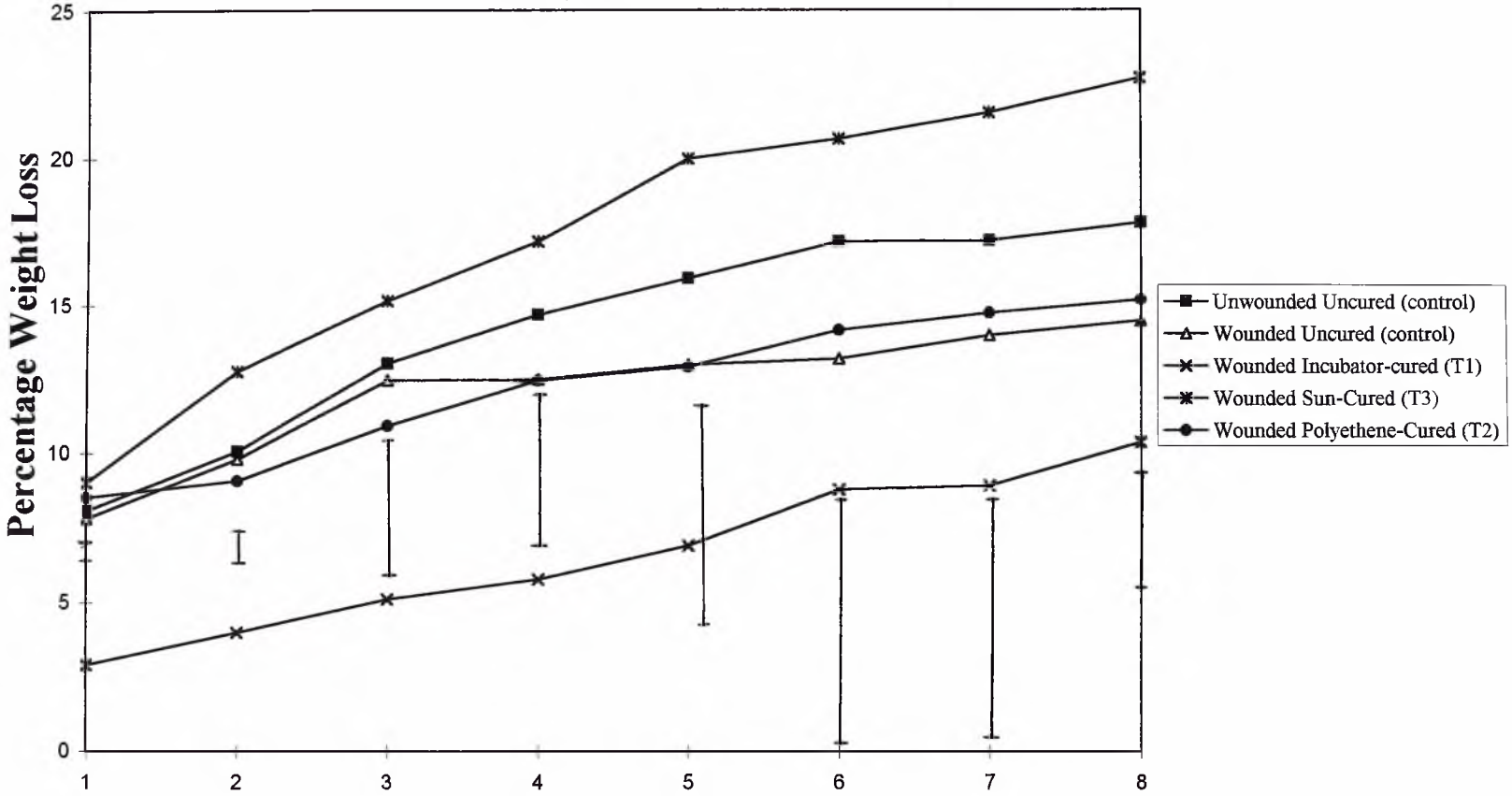


Fig. 26 Effect of Different Curing Methods on Percentage Sprouting of Sweet Potato Tubers (Yellow Variety)

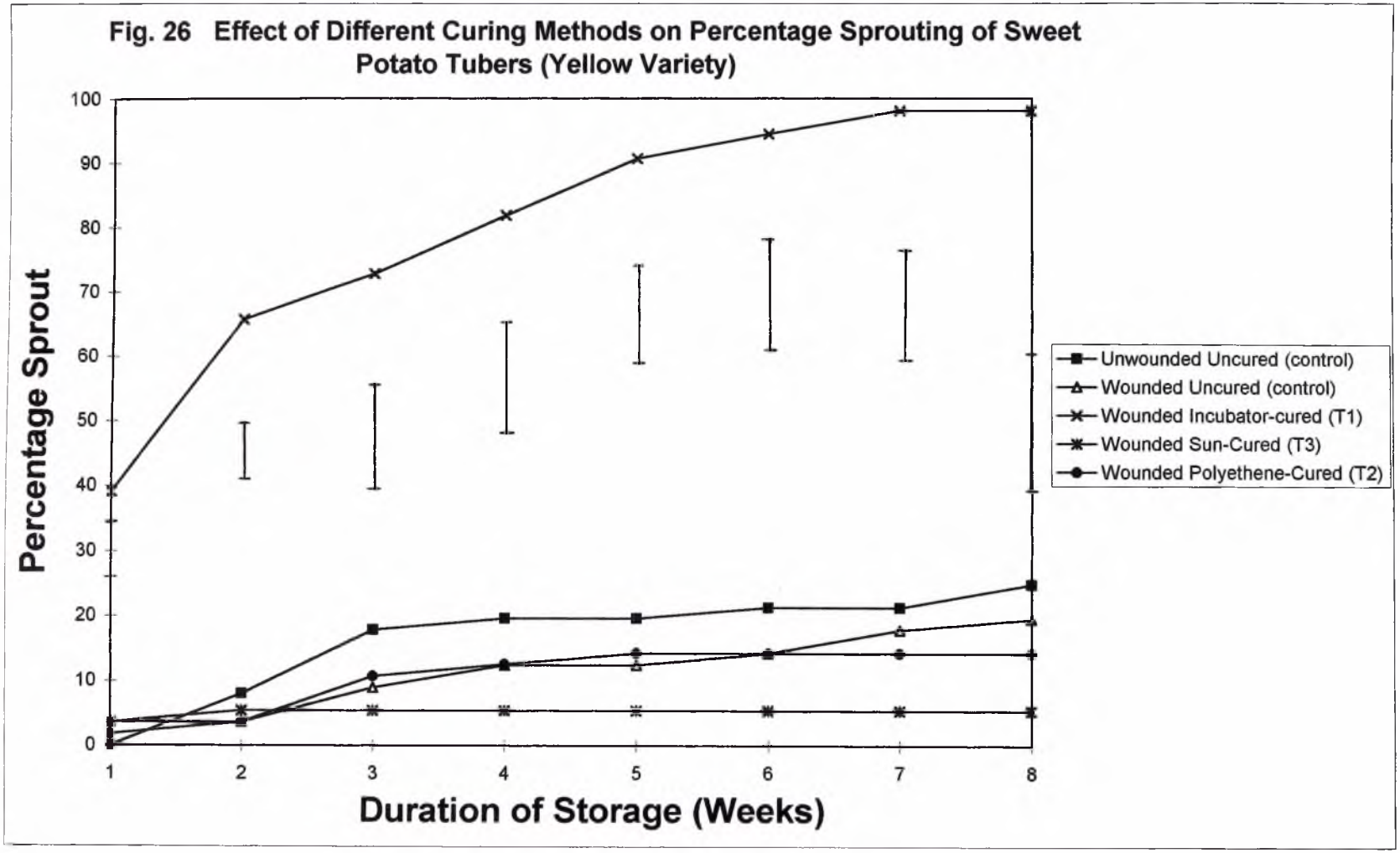


Fig. 27 Sprouted sweet potato tubers (yellow variety) stored at 23-33 ^{o}C and 45-82% RH for 8 weeks (x 0.25)

CHAPTER FIVE

DISCUSSION

Four types of sweet potato based on skin and flesh colour were encountered in the survey. These are the yellow skin with yellow flesh, yellow skin with white flesh, red skin with red flesh and red skin with white flesh. The yellow skin with yellow flesh type also known as "Fante" happened to be the most preferred among consumers, because the quality of the flesh resembles that of yam and also it has a relatively low sugar content.

It was observed that sweet potatoes are transported mainly by road to the marketing centers in jute sacks. The delicate nature of the skin requires that tubers be handled with utmost care. This is supported by the report made by the National Academy of Science (1978) that injury of sweet potato tubers can occur at almost any point in the postharvest system which arises from poor handling and packaging, from transportation and storage conditions or from damage from the market place. Edmond (1971) also reported that unless proper precautions are taken and recommended practices are followed, the tubers are likely to rot before they reach the consumer or at best arrive in the retail store in an unattractive condition. To solve this problem Booth (1974) suggested the use of boxes or cartons which according to him are far more suitable than large sacks for handling and transportation of root crops in the tropics. Booth's suggestion of the use of boxes or cartons for handling and transportation of root crops in the tropics may be impracticable because of the high cost of the packaging material. In view of this, baskets made from raphia and other relatively cheap material could be used in place of

cartons and boxes since such containers allow proper convectional circulation of air around the tubers. The baskets could be lined with some soft material like leaves or dry grass to avoid bruising. This method of handling should be evaluated for efficacy vis-a-vis the use of cartons and boxes for the same purpose.

Nine different methods of sweet potato storage were encountered during the survey. Storage of tubers in sacks in open places was the most frequently used method. This form of storage probably predisposes the tubers to physiological damage resulting from the accumulated heat within the sacks. The situation is accentuated by the direct exposure of the sacks containing the tubers to direct sunlight. Improper storage therefore accounts for the high post harvest losses often recorded. Coursey and Booth (1972) estimated that 23% of the total production of root crops is lost due to an inadequate understanding of conditions required for prolonging the shelf-life of the produce . All respondents indicated that there was rotting of tubers which was probably due to the improper application of handling and storage methods. An evaluation of the various methods of storage will therefore be necessary, so that the best method can be recommended to farmers, sellers and users.

In spite of the high incidence of rot reported by respondents, majority of them (83.3%) did not take any preventive measures against sweet potato tuber rot; indicative of the fact that chemical and physical methods for controlling sweet potato tuber rot, not excepting the most current pre-storage treatment of curing were not employed. It is therefore not surprising that respondents did not practice deliberate curing methods like solar-curing, pit-curing, curing by covering with dry grass and curing by covering with jute sacks. Kushman and Wright (1969) reported that one of the most effective and simple means of reducing postharvest water and

physiological losses is curing. Curing is a wound healing process during which general skin strengthening also occurs. It is effective in reducing water loss and acts as a barrier against infection (Booth, 1974) . Curing should be adopted to reduce postharvest losses and therefore improve upon sweet production in Ghana.

Respondents indicated that they can detect rotten sweet potato tubers with little or no external evidence. This is done by (i) applying pressure on the tuber; (ii) looking for dark colouration on the external surface; (iii) detection of peculiar scent and (iv) pus emanating from the tubers. These methods of detecting rot are used in sorting out rotting tubers during packaging, handling and transportation from producing areas. This helps in removing infected tubers from healthy tubers. Tubers in storage can also be inspected periodically using the techniques mentioned above.

Sweet potato weevil, *Cylas sp.* was found to be the most important pest associated with sweet potato storage in Ghana. Shelf-life studies also confirmed that sweet potato weevil, *Cylas* sp. was the major pest associated with sweet potato storage. This finding agrees with the report of Danquah and Lamptey (1998) that the attack of the sweet potato weevil is a major constraint associated with sweet potato production. Rats and mice, the minor pests were not encountered in the barn due to the fact that the barn was protected from rodents by surrounding it with a wire mesh.

Post harvest control of tuber rot of sweet potato in Ghana has been given very little attention. The Ministry of Food and Agriculture in Ghana has no information on recent production figures of sweet potatoes (Boateng-Siriboe, Personal communication, MOFA, 1999). In 1993

NARP reported that almost no work on sweet potato was being carried out, let alone written and disseminated. This is a confirmation of how much the crop had been neglected over the years until recently, when it attracted the attention of researchers in this country.

Five different fungi have been shown to cause rotting of tubers in sweet potato. These were *Aspergillus ochraceus, Botryodiplodia theobromae, Fusarium moniliforme, Fusarium oxysporum* and *Rhizopus stolonifer. Botryodiplodia theobromae* had the highest frequency of occurrence in both the markets and in the barn samples. Like the other fungi this pathogen sporulates naturally on sweet potato tubers and the spores can be dispersed by air currents. The high frequency observed in the barn for this pathogen requires further investigation. Edmond (1971) reported that *Botryodiplodia theobromae* could be widespread in almost all sweet potato producing areas and this could partly explain its frequent occurence in the barn. Java black rot caused by *Botryodiplodia theobromae* is one of the most important postharvest diseases of sweet potato in the tropics (Lo and Clark, 1988). Edmond (1971) reported that Java black rot was present in practically all sweet potato producing districts throughout the world. The causal fungus is called *Botryodiplodia theobromae* although other species of *Botryodiplodia* have produced Java black rot in the fleshy tuber (Harter, 1916). *Botryodiplodia theobromae* has also been reported as a tuber rot organism by Sciven *et al.* (1988), Ray (1994) and Coursey and Booth (1972). In this study *Botryodiplodia theobromae* was isolated from rotten sweet potato tubers collected from different markets and its pathogenicity was established by inoculating into healthy tubers.

Aspergillus ochraceus and *Fusarium oxysporum* were isolated only from the markets and not the barn. This implies that these pathogens do not occur in the atmosphere of the barn. Their

presence in rotten market tubers indicates the possibility of their being prevalent in the sweet potato growing areas from which retailers make their purchases for sale.

Cook (1953) and Harter and Weimer (1919) reported that *Fusarium oxysporum* causes surface rot of sweet potato. Moyer (1982) also reported that *Fusarium solani* causes tuber rot in sweet potatoes. *Fusarium oxysporum* was also isolated in this study and found to be pathogenic to sweet potatoe tubers.

Ray *et al.* (1994) in India isolated *Rhizopus oryzae* from rotting sweet potato tubers. Arene and Nwankiti (1978) in Nigeria also isolated *Rhizopus stolonifer* from rotten sweet potato tubers. *Rhizopus nigricans* is also a causal agent of soft rot in sweet potatoes (MOA, 1988 and Cook, 1953). *Rhizopus stolonifer* has also been reported by Onwueme (1982) and Danquah and Lamptey (1998) as the cause of tuber rot in sweet potato. *Rhizopus stolonifer* which was isolated from rotting sweet potato in this study and found to be pathogenic.

Aspergillus sp. has been reported as causing rotting of sweet potato in storage. *Aspergillus ochraceus* is being recorded for the first time in Ghana as causing rotting of sweet potato tubers in storage. Cornelius (1998) found *Aspergillus flavus* Link, *Aspergillus niger* van Tieghem, and *Aspergillus oryzae* (Alhburg) Cohn as causing rotting in yam although none of the above species was isolated in this study from sweet potato tubers.

The virulence of the five fungal isolates on two types of sweet potato encountered in the survey, that is "Fante" and "Ayigbe" was tested. Apart from *Aspergillus ochraceus* and *Fusarium oxysporum*, there was no significant difference (P=0.05) in the virulence of the other

isolates on the two types of sweet potato. *Aspergillus ochraceus* was more virulent in the "Ayigbe" type than in the "Fante". On the other hand, *Fusarium oxysporum* was more virulent in the "Fante" type than in the "Ayigbe" type. The different levels of virulence indicates that even though rot-causing micro-organisms may produce necrotic areas on sweet potato tubers, the extent of the rot will depend on the type of sweet potato.

There was a general increase in the incidence of rot among incubator-cured, polyethylene-cured and sun-cured tubers as well as unwounded, uncured and wounded, uncured tubers that is the controls throughout the storage period. Presence of rot in a tuber implies that the periderm is probably not intact. The unwounded and uncured tubers had an intact periderm and were therefore expected to store well but they recorded a high incidence of rot. This could be attributed to wounds created at the stem end of the tuber during harvesting which served as entry points for the rot-causing fungi. Rot-causing fungi could have entered through the small rootlets which were damaged during harvesting (Cook, 1953). Rot in wounded and uncured tubers was due to the malformation of a wound periderm on wounded areas, which facilitated the entry of rot-causing organisms . This is supported by the findings of Booth (1974) that the development of a wound periderm is effective in retarding water loss and acts as a barrier against infection invading mycoflora.

Wounded and polyethylene-cured tubers and wounded and incubator-cured tubers were expected to be more resilient to infection but this was not the case. By the 18th week of storage, the rot incidence in wounded and incubator-cured and wounded and polyethylene-cured tubers were 40% and 90% respectively. Since the wound periderms in wounded and incubator-cured and wounded and polyethylene-cured tubers were relatively well formed, with

a thickness of 270.5µm and 232.5µm respectively, the higher incidence of rot in these tubers could be due to some other factor, which requires further investigation. The high incidence of rot in polyethylene-cured tubers is probably due to heat from sunlight which may have been trapped under the polyethylene leading to physiological damage of the tubers and subsequently rot. The high humidity under the polyethylene could also be a factor conducive for germination and vegetative growth of fungal propagules.

The incidence of rot among wounded and sun-cured tubers attained 100 % by the 8th week of storage. This can be partly attributed to the improper formation of the wound periderm in wounded and sun-cured tubers.

After 13 weeks of storage, there was an increase in the incidence of rot among wounded and incubator-cured tubers. This can partly be attributed to the weevil damage which set in during the 13th week of storage and became serious by the 18th week. The holes made by the weevils facilitated the entry of rot-causing fungi. This confirms the findings of Onwueme (1982) that the activities of the adult weevil and their larvae in the tuber promote the spread of rots and infection by rot fungi.

There was no significant difference (P=0.05) in incidence of rot between unwounded and uncured and wounded and uncured tubers from the 3rd to the 18th week of storage (Fig.22). From casual observation, rotting in unwounded and uncured tubers originated from the stem end of the tubers. The wounds at the stem end and those made artificially on the tubers are possibly the cause of rotting in unwounded, uncured and wounded, uncured tubers, which were not significantly different in terms of rot incidence. It is necessary to determine the areas

from which rots occur in wounded, cured and wounded, uncured tubers.

Wounded and uncured tubers which were expected to perform worse than tubers from the three treatments, rather fared better than the wounded and polyethylene-cured and wounded and sun-cured tubers. The possible reasons for this trend are the improper formation of the wound periderm in wounded and sun-cured tubers as well as the possible physiological damage of the wounded and polyethylene-cured tubers due probably to the trapping of heat from sunlight under the polyethylene.

At the end of the storage period, 35% of the wounded and incubator-cured tubers were rotten which was significantly lower (P=0.05) than the incidence of rot recorded in unwounded and uncured, wounded and uncured, wounded and sun-cured and wounded and polyethylene-cured tubers which were respectively, 89.2%, 82.1%, 100% and 94.6% (Fig. 22). The shelf-life of cured tubers was extended appreciably. At the end of the storage period of 18 weeks, about 65% of wounded and incubator-cured tubers were healthy. This implies that properly cured tubers can be stored for as long as 18 weeks. The weevil damage further decreased the shelf-life of the properly cured tubers by accentuating the rot damage. Since cured tubers were not stored at a temperature of 13 ^{o} to 15 ^{o}C, it is not possible to tell whether they would have remained wholesome for at least 6 months without deterioration as reported by Doku (1987, Personal communication), MOA (1988) and Booth (1974). From these studies it can be concluded that the maximum time for farmers to store sweet potato is one month.

Since incubators may not be available to farmers, sellers and users, tubers could be cured after harvesting by covering with polyethylene but exposure to intense sunlight should be avoided

as much as possible to prevent the accumulation of heat within the polyethylene sheet.

From week 1 to week 6, there was an increase in the severity of rot for tubers belonging to all the treatments and the controls except those which were cured in the incubator (Fig. 24). This shows that tubers which were so treated were more susceptible to the tuber rot fungi than those which were cured in the incubator. Over 60% of the incubator-cured tubers remained healthy at the end of the storage period. This underscores the fact that incubator-cured tubers were properly cured and the periderm was presumably thick enough to prevent the entry of rot-causing fungi.

There was a steady increase in the loss of fresh weight in all treatments as well as the controls throughout the 8-week period (Fig. 25). The steady weight loss could be attributed to biological processes like respiration and transpiration, sprouting and microbial activity which were reported by Winarno (1982) as responsible for weight losses in stored tubers. Booth (1974) reported that loss in weight in sweet potato after 113 days of storage was 17% in the cured sample and 42% in the uncured one. Similarly, the weight loss in properly cured tubers i.e. the incubator-cured samples was about 10% while that in the wounded uncured ones was about 17% after 8 weeks of storage. The weight loss values for the cured and uncured samples in this study were lower than those obtained by Booth (1974) due probably to the fact that, he stored the tubers for 113 days while those used in this study were stored for 56 days. There may also be varietal differences between the potato tubers used by Booth (1974) and those used in this present study. Weight loss data could not be taken beyond the 8th week, because all the wounded and sun-cured tubers were completely rotten by the 8th week. No meaningful comparison of the treatments could therefore be made beyond this point.

At the end of the first week of storage about 40% of wounded and incubator-cured tubers had sprouted and this was significantly higher (P = 0.05) than the percentage sprout in the other treatments and the two controls (Fig. 26). It is possible that much of the sprouting occurred during the curing period.

In contrast with the report of Passam and Noon (1977) that once dormancy is broken and sprouting begins, tubers undergo senescence, pathogenic invasion occurs and effective storage of yams is no longer possible, the early termination of dormancy in wounded and incubator-cured tubers of sweet potato did not result in a concomitant increase in senescence and pathogenic invasion as evidenced by the long shelf-life. It is possible that curing increases the resistance of sweet potato tubers to pathogenic invasion, following the termination of dormancy, due to some biochemical and anatomical changes which occur in the tubers during curing. Further investigation on the effect of curing on the anatomical and biochemical changes of sweet potato tubers in relation to dormancy is necessary.

Sweet potato has no state of dormancy, that is, it can sprout in spite of an unfavourable environment (Pantastico, *et al.* 1975). This could probably partly explain why the tubers from all the treatments including the controls sprouted, with higher percentage sprouting in the wounded and incubator-cured tubers. The significantly higher (P=0.05) percentage sprouting found in the wounded and incubator-cured tubers could mean that the conditions under which the curing was carried out, are also favourable for promoting sprouting of sweet potato. Production of planting material can therefore be enhanced by subjecting sweet potato tubers to the conditions under which the tubers were cured (29-32 ^{o}C and 85-90%). This will help in the production of planting material without the use of chemicals like ethephon, a growth

regulator, dimethyl sulphoxide (DMSO) or carbon dioxide gas to induce sprouting.

From this work, proper curing leading to the formation of a thick periderm is important to prolong the shelf-life of sweet potatoes, provided measures are taken to prevent weevil damage.

The following are recommendations based on this study:-

1. Storage methods identified in the survey can be evaluated to determine the most effective one.
2. A more extensive survey can be carried out in other sweet potato growing areas in Ghana so that the post harvest problems prevailing there and remedies (if any) adopted by producers in those areas can be identified.
3. A study can be conducted on the biochemical and anatomical changes which occur during curing and how these affect the shelf-life of the sweet potatoes.
4. An investigation can be carried out to find out whether there is any correlation between periderm thickness and weight loss in stored sweet potatoes.

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APPENDIX 1

SURVEY ON EXTENT OF ROT, DIFFERENCES OF SWEET POTATO TYPES WITH RESPECT TO ROTTING, CURING AND METHODS OF STORAGE OF SWEET POTATOES IN GHANA.

QUESTIONNAIRE FOR SWEET POTATO SELLERS/FARMERS/USERS

1. Name ..... Farmer/seller/user.
2. Location .....Date .....

   Enumerator .....

   Sex : Male: Female:

A. TYPES OF SWEET POTATOES AND THEIR LOCAL TRANSPORTATION

3. a.1 For how long have you been selling sweet potatoes? Since 19 .....

4 a. 2. How many sweet potato types do you know?

1. One
2. Two
3. Three
4. More than three

5. a. 3. Name the sweet potato types you know

1.

2.

3.

4.

6. a.4 What types do you sell?

1

2

3

4

7. a.5 When are the different types available for sale?

1.

2.

3.

4.

8. a.6 Where is your source of supply?

1. Village market
2. Buy at farm gate
3. My farm
4. Urban/City market
5. Other (specify)

9. a.7. If it is from the market can you tell how long they have been stored after harvest?

a. Yes b. No

10. a.8 Do you consider duration of storage before buying?

a. Yes b. No

11 a.9 What is the duration of storage of sweet potatoes?

1. One week
2. Two week
3. Three weeks
4. One month
5. Two months
6. Three months
7. More than three months

12. a.10 How are the sweet potatoes transported to the market?

1. Road 2. Rail 3. Air 4. Boat 5. Other (specify)

13. a11. How long does it take to transport sweet potatoes to the market?

1. 1-2 days
2. 3-4 days
3. 5-7 days
4. 4-10 days
5. 11-14 days
6. 3 weeks
7. 1 month
8. I do not know

B. CURING

14. b1. Do you expose the tubers to sunlight for some time before storing?

1. Yes 2. No

15. b2. If yes, for how long are tubers exposed to sunlight?

1. A few hours
2. One day
3. Two days
4. Three days
5. Four days
6. More than four days

16. b3. Do you place tubers in a soil pit for a given period?

1. Yes 2. No

17. b4. If yes for how long?

1. A few hours
2. One day
3. Two days
4. Three days
5. Four days
6. More than four days

18. b5. Do you cover tubers with dry grass, tarpauline or some other material for a given period?

1. Yes
2. No

19. b6. If you say yes for long?

1. A few hours
2. One day
3. Two days
4. Three days
5. Four days
6. More than four days

20. b7 Do you place tubers horizontally over each other and cover with jute sacks?

1. Yes
2. No

21. b8. If yes for how long?

1. A few hours
2. One day
3. Two days
4. Three days
5. Four days
6. More than four days

C. STORAGE

24. c1. Where do you store your sweet potatoes?

1. Roofed and open-sided storage sheds?
2. Heaped in airy place and covered
3. Pit covered with soil

4. Enclosed room

5. No storage

6. Baskets

7. Other (specify)

25 c2. Do you inspect your sweet potatoes periodically when they are in storage?

1. Yes 2. No

26. c3. Do you experience sprouting?

1. Yes 2. No

27. c4. Which type sprouts fastest?

1.

2.

3.

4.

28. c5. Do you experience problems of pests in your sweet potatoes store?

1. Yes 2. No

29. c6. If yes, name them :

1. Rats 3. Sweet potato weevil

2. Mice 4. Other (specify).

D. SWEET POTATO ROT

30. d1. Have you ever experienced sweet potato rot?

1. Yes 2. No

31. d2. When?

1. All the time 2. During rainy season

3. During dry season 4. Others (specify)

32. d3. Are there differences in degree of rot between different sweet potato types?

1. Yes 2. No 3. I do not know

33. d4 If yes which type rots fastest?

34. d5 Which type rots slowest?

35. d6. Is there any sweet potato type that does not rot?

1. Yes 2. No 3. I do not know

36. d7. If yes then name it.....

d8. How do you prevent your sweet potatoes from rot?

1. Pre-storage curing treatment
2. Apply wood ash to bruised portions of tubers
3. Apply line wash to bruised portions of tubers
4. No preventive measure taken
5. Other (specify) .....

37. d9. If yes how do you do it?

1. Apply pressure on the tuber surface using the fingers
2. Other (specify)

38. d11. What quantity of sweet potatoes normally get rotten out of each consignment?

39. d12. How many consignment do you sell in a year?

APPENDIX 2

TUBER ROT (%) IN SWEET POTATO STORED AT 23-32^{0}C AND 46-82 R.H.
STORAGE DURATION (WEEKS)

	1	2	3	4	5	6	7	8	9	10	12	11	13	14	15	16	17	18
Unwounded Uncured (Control)	0a	3.6a	26.7a	46.4a	64.0a	73.0a	80.3a	82.0[a]	82.0a	83.8a	87.4a	87.4a	87.4a	87.4a	89.2a	89.2a	89.2a	89.2a
Wounded uncured (Control)	0a	7.2a	26.8a	35.7a	51.8a	62.3a	66.0a	67.8ab	71.4a	74.9ab	74.9ab	74.9ab	76.7a	78.5ab	78.5ab	78.5ab	78.5ab	82.1a
Wounded Incubator Cured (T_1)	0a	1.8a	1.8b	1.8b	3.6b	5.4b	5.4b	5.4c	8.9b	8.9c	8.9c	8.9c	8.9b	15.9c	21.3c	30.3b	30.3b	35.5b
Wounded Sun-Cured (T_3)	10.7b	35.7b	80.4c	92.9c	96.4c	98.2b	98.2a	100ad	100a	100ad	100ad	100ad	100ad	100ad	100ad	100ad	100ad	100ad
Wounded Polyethene Cured (T_2)	25.0c	33.9b	46.4a	57.1a	75.0a	85.7a	87.5a	87.5a	87.5a	91.0a	91.0a	91.0a	91.0a	91.0a	91.0a	91.0a	92.9a	94.6a

Means followed by the same letter in a column are significantly different at 5% level os L S D
(All tubers belonging to treatment 1 had rotted by the 8th Week)

APPENDIX 3

ANALYSIS OF VARIANCE FOR PERCENTAGE (%) ROT

Analysis of variance

Week 1

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.03049	0.01016	0.91	
Treatment	4	0.43799	0.10950	9.78	<.001
Error	12	0.13437	0.01120		
Total	19	0.60285			

Week 2

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.08019	0.02673	1.54	
Treatment	4	0.85694	0.21423	12.34	<.001
Error	12	0.20835	0.01736		
Total	19	1.14548			

Week 3

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.05037	0.01679	0.55	
Treatment	4	1.93071	0.48268	15.86	<.001
Error	12	0.36516	0.03043		
Total	19	2.34624			

Week 4

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.01525	0.00508	0.28	
Treatment	4	2.68258	0.67064	36.50	<.001
Error	12	0.22049	0.01837		
Total	19	2.91832			

Week 5

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.03059	0.01020	0.30	
Treatment	4	3.14171	0.78543	23.07	<.001
Error	12	0.40856	0.03405		
Total	19	3.58085			

Week 6

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.03690	0.01230	0.40	
Treatment	4	3.18712	0.79678	25.87	<.001
Error	12	0.36960	0.03080		
Total	19	3.59362			

Week 7

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.09646	0.03215	0.91	
Treatment	4	3.29957	0.82489	23.42	<.001
Error	12	0.42272	0.03523		
Total	19	3.81875			

Week 8

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.06505	0.02168	0.65	
Treatment	4	3.43353	0.85838	25.70	<.001
Error	12	0.40076	0.03340		
Total	19	3.89933			

Week 9

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.05706	0.01902	0.55	
Treatment	4	3.43253	0.85813	24.82	<.001
Error	12	0.41489	0.03457		
Total	19	3.90448			

Week 10

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.04751	0.01584	0.43	
Treatment	4	3.24500	0.81125	22.00	<.001
Error	12	0.44243	0.03687		
Total	19	3.73494			

Week 11

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.03949	0.01316	0.33	
Treatment	4	3.31763	0.82941	20.90	<.001
Error	12	0.47632	0.03969		
Total	19	3.83344			

Week 12

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.03949	0.01316	0.33	
Treatment	4	3.31763	0.82941	20.90	<.001
Error	12	0.47632	0.03969		
Total	19	3.83344			

Week 13

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.02878	0.00959	0.23	
Treatment	4	3.11190	0.77798	18.79	<.001
Error	12	0.49674	0.04139		
Total	19	3.63742			

Week 14

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.05202	0.01734	0.54	
Treatment	4	2.68470	0.67117	20.72	<.001
Error	12	0.38875	0.03240		
Total	19	3.12547			

Week 15

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.04298	0.01433	0.46	
Treatment	4	2.26818	0.56704	18.21	<.001
Error	12	0.37370	0.03114		
Total	19	2.68485			

Week 16

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.07450	0.02483	0.86	
Treatment	4	1.81406	0.45352	15.62	<.001
Error	12	0.34841	0.02903		
Total	19	2.23697			

Week 17

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.07276	0.02425	0.78	
Treatment	4	1.64750	0.41187	13.32	<.001
Error	12	0.37107	0.03092		
Total	19	2.09132			

Week 18

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.05431	0.01810	0.55	
Treatment	4	1.58436	0.39609	12.02	<.001
Error	12	0.39546	0.03295		
Total	19	2.03412			

APPENDIX 4

TUBER WEIGHT LOSS (%) IN SWEET POTATO STORED AT 23-32^{0}C AND 46-82 R.H.

STORAGE DURATION (WEEKS)

	1	2	3	4	5	6	7	8
Unwounded Uncured (Control)	8.08a	10.06a	13.02a	14.68[a]	15.92[a]	17.16a	17.21a	17.81a
Wounded uncured (Control)	7.81a	9,80a	12.48a	12.50[a]	13.0[a]	13.2a	14.0a	14.5a
Wounded Incubator Cured (T_1)	2.90b	3.99b	5.10b	5.78b	6.92b	8.80ab	8.94b	10.38ab
Wounded Sun-Cured (T_3)	9.02a	12.75c	15.15[a]	17.17a	19.97[a]	20.63a	21.51c	22.69c
Wounded Polyethene Cured (T_2)	8.53a	9.08a	10.92a	12.45a	12.92[a]	14.16a	14.75a	15.20a

Means followed by the same letter in a column are not significantly different at 5% level of L S D
(All tubers belonging to treatment 1 were completely rotten by the 8th week).

APPENDIX 5

ANALYSIS OF VARIANCE FOR PERCENTAGE WEIGHT LOSS

Week 1

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.0043714	0.0014571	2.00	
Treatment	4	0.0481033	0.0120258	16.52	<.001
Error	12	0.0087345	0.0007279		
Total	19	0.0612092			

Week 2

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.0018061	0.0006020	1.05	
Treatment	4	0.0593444	0.0148361	25.96	<.001
Error	12	0.0068577	0.0005715		
Total	19	0.0680082			

Week 3

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.0017027	0.0005676	0.70	
Treatment	4	0.0818200	0.0204550	25.52	<.001
Error	12	0.0097225	0.0008102		
Total	19	0.0932452			

Week 4

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.004317	0.001439	0.99	
Treatment	4	0.076429	0.019107	13.08	<.001
Error	12	0.017530	0.001461		
Total	19	0.098275			

Week 5

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.011208	0.003736	1.56	
Treatment	4	0.084793	0.021198	8.87	0.001
Error	12	0.124669	0.002389		
Total	19	3.90448			

Week 6

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.001387	0.000462	0.19	
Treatment	4	0.052436	0.013109	5.39	0.010
Error	12	0.029164	0.00243		
Total	19	0.082988			

Week 7

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.001343	0.000448	0.17	
Treatment	4	0.056769	0.014192	5.44	0.010
Error	12	0.031306	0.002609		
Total	19	0.089418			

Week 8

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.002933	0.000978	0.54	
Treatment	4	0.046585	0.011646	6.49	0.005
Error	12	0.021549	0.001796		
Total	19	0.071067			

APPENDIX 6

TUBER SPROUT (%) IN SWEET POTATO STORED AT 23-320C AND 46-82 R.H.

STORAGE DURATION (WEEKS)

	1	2	3	4	5	6	7	8
Unwounded Uncured (Control)	0a	8.0a	17.8a	19.6a	19.6a	21.3a	21.3a	24.9a
Wounded uncured (Control)	3.6a	3.6a	8.9a	12.4a	12.4a	13.2a	14.0a	14.5a
Wounded Incubator Cured (T_1)	39.1b	65.7b	72.8b	81.8b	90.7b	94.5b	98.1b	98.1b
Wounded Sun-Cured (T_3)	3.6a	5.4a	5.4a	5.4[a]	5.4[a]	5.4ac	5.4ac	5.4ac
Wounded Polyethene Cured (T_2)	1.8a	3.6a	10.7a	12.5a	14.2a	14.2a	14.2a	14.2d

Means followed by the same letter in a column are not significantly different at 5% level of L S D

APPENDIX 7

ANALYSIS OF VARIANCE FOR PERCENTAGE SPROUT

Week 1

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.088604	0.029535	4.12	
Treatment	4	0.792666	0.198167	27.66	<.001
Error	12	0.085985	0.007165		
Total	19	0.967256			

Week 2

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.02406	0.00802	0.31	
Treatment	4	1.71202	0.42801	16.77	<.001
Error	12	0.30630	0.02553		
Total	19	2.04238			

Week 3

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.03869	0.01290	0.41	
Treatment	4	1.76920	0.44230	14.22	<.001
Error	12	0.37328	0.03111		
Total	19	2.18117			

Week 4

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.07270	0.02423	0.82	
Treatment	4	2.21806	0.55451	18.68	<.001
Error	12	0.35615	0.02968		
Total	19	2.64691			

Week 5

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.09205	0.03068	1.27	
Treatment	4	2.86195	0.71549	29.72	<.001
Error	12	0.28892	0.02408		
Total	19	3.24292			

Week 6

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.15836	0.05279	2.29	
Treatment	4	3.26568	0.81642	35.40	<.001
Error	12	0.27677	0.02306		
Total	19	3.70081			

Week 7

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.14693	0.04898	1.99	
Treatment	4	3.52920	0.88230	35.91	<.001
Error	12	0.29485	0.02457		
Total	19	3.97099			

Week 8

Source of Variation	Degree of Freedom	Sum of Squares	Mean Squares	Frequency Values	Probabilities
Replication	3	0.17542	0.05847	2.20	
Treatment	4	3.49122	0.87280	32.88	<.001
Error	12	0.31853	0.02654		
Total	19	3.98516			