EFFECT OF PRE- STORAGE TREATMENTS AND STORAGE CONDITIONS ON SOME QUALITY OF STORED YAM TUBERS

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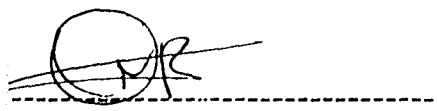
DECLARATION

I, ORHEVBA BOSEDE ADELOLA, hereby declare that this research has been conducted and the thesis written by me. It has never been presented elsewhere for the award of any degree. All the information derived from the works of others was duly acknowledged in the text and listed in the references.



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CERTIFICATION

This thesis titled "Effect of Pre-Storage Treatments and Storage Conditions on Some Quality of Stored Yam Tubers'' by Orhevba Bosede Adelola (M.ENG/S.E.E.T/2003/1000) meets the regulations governing the award of the degree of masters in Engineering (M.ENG) of the Federal University of Technology, Minna, and it is approved for its contribution to Scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to my Late Dad, Prince Michael Folorunsho Aderibigbe. Sleep on beloved Daddy and may your gentle soul continue to rest in perfect peace. Amen.

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All glory, honour and praise to Almighty God, the fountain of all wisdom and knowledge, the giver and sustainer of life, who in his infinite mercy and love has seen me through another milestone achievement in life.

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ABSTRACT

The effects of pre-storage treatments and storage conditions on the quality of stored yam tubers were investigated. Storage conditions used were two traditional yam barns, one with fan and the other without fan. The pre-storage treatments were CIPC solution, CIPC powder and neem tree extracts. Weight loss, rotting, sprouting and nutritional content of the stored yam tubers were determined. The following experiments were under taken: the effect of CIPC solution and powder on sprouting of stored yam tubers, the effects of neem tree extract on weight loss, rotting and sprouting of stored yam tubers and the determination of changes in nutritional content of stored yam tubers: A total of 216 tubers of yam, *"Giwa"* variety *(Discorea rotundata)* with 108 tubers in each barn, were used in the study. Temperature and relative humidity were measured three times a week and four times a day at 0800h, 1200h, 1600h and 2000h using a digital thermohygrometer, *mebus* 4.0. Two types of neem tree extracts were used: these are neem bark extract prepared by soaking neem bark in water and neem leaf slurry prepared by blending neem leaves with small amount of water. For the CIPC solution and powder the experimental design employed was 4x2 factorial design in CRD with 3 replicates. While for the neem extract, the experimental design employed was 3x2 factorial design in CRD with 3 replicates. The results were analyzed using ANOVA and the means analyzed using F-LSD at $P \leq 0.05$. The results showed that the temperature in the barn with fan was slightly lower than that of the barn without fan (4%). While the humidity was also lower by an average of 4% compared to the barn without fan. The CIPC solutions and powder had no significant effect on sprouting of the stored yam tubers at all levels. However the neem bark extract treated tubers had the lowest sprout weights (25g/kg tuber after 5 months of storage) compared to 45g/kg tuber for the control at the same period. This difference is statistically significant ($P \leq 0.05$). This indicates that neem bark extract might have an effect in suppressing sprouting in stored yam tubers. The neem leaf slurry treated tubers also had less sprout weights (33g/kg tuber), however this was not statistically significant. In weight loss the tubers treated with neem leaf slurry had the least weight loss (20%) at the end of storage period compared to 32% in the tuber treated with neem bark extract. None of the treatments (CIPC and neem extracts) had effect in suppressing rotting. The different treatments used, had no significant effect on the nutritional parameters. There were significant reductions in moisture content, crude protein phosphorus and calcium content; carbohydrates also decreased slightly during the period of storage. Tubers stored in the barn with fan had the least sprout weight and least weight loss. The difference in sprout weights between the structures was statistically significant at $P \leq 0.05$. Also, tubers stored in the barn with fan had the least percentage of rotten tubers (1.85% of stored tubers) compared to the tubers stored in the barn without fan (12.03%). From these it can be concluded that intermittent air flow on stored yam tubers reduces sprouting, weight loss and rot development.

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CHAPTER ONE

1.0 INTRODUCTION

Yams (*Dioscorea spp.)* are the most important food crops in West Africa, next to cereals, (Onwueme, 1978), they are wide spread in the humid tropics throughout the world and in a wide variety of species. Yams also form an important food source in other tropical countries like East Africa, the Caribbeans, South America, India and South East Asia. Of particular significance are the white guinea yam *(Dioscorea rotundata poir),* the water yam (*Dioscorea alata),* the yellow yam *(Dioscorea cayensis lam),* and the Chinese yam *(Dioscorea esculenta (lour, burk).*

Economically, the tuber is the most important part of the yam plant, which is extensively used for human consumption (Okonkwo, 1985). Its shape and size can vary greatly from species to species and this makes manual harvesting very difficult, Onwueme (1978), however reported that the shape can be controlled by genetic conditions.

1.1 The Yam Tuber

The outer part of the tuber forms several layers of cork. These layers constitute effective protection from lesions, water loss and against the penetration of pathogens in the soil as well as in storage. The inner part of the tuber is formed by a tissue which is interwoven with vascular channels. Carbohydrates, mainly in the form of starches, are stored in this

tissue. Apart from water and carbohydrates, which are the most important constituents of the tuber, it also contains, fats, vitamins, minerals, protein and lipids (very low, about 1-1.5%).

Yams are often referred to as stem tubers, because they are considered to be modified stem structures, but in fact, they lack the typical characteristics of a modified stem structure, i.e. yam tubers have no pre-formed buds or eyes, no scale leaves, and no equivalent of a terminal bud at the distal end of the tuber (Hahn *et al.*, 1987). Thus, some degree of controversy has centered on the nature of the yam tuber; hence the currently accepted view is that the yam tuber is neither a stem nor a root structure. Rather, it has its origins as a hypocotyl structure (IBPGR, 1980).

1.2 Storage of Yams

Tubers can remain in the ground until needed (Osagie, 1992). Harvested tubers are most often stored in yam barns where they are stalked and tied uniformly to a height of 1 to 2m or piled together in heaps inside the barn (as practiced in the northern part of the country). Loss in flavour and quality of the tubers occurs in storage. Harvested tubers are frequently attacked by several viruses, bacteria, fungi and insects, also rodents, feed on some of the harvested tubers stored in the barns (Onwueme, 1978).

Some cultivars can be stored for 5 to 6 months in dry locations. The storage life of the tuber is ended at the termination of dormancy, when new sprouts develop. Good storage should therefore maintain tubers in their most edible and marketable condition by preventing large moisture losses, spoilage by pathogens, attack by insects and animals, and sprout growth. It should also prevent large accumulation of sugars, which leads to unpleasant sweet taste.

However, in other to obtain a good result after storage (i.e. fresh, edible and marketable yams), the freshly harvested yams to be stored must be clean and undamaged. Also, excessive temperature must be avoided and good aeration provided. Some factors that affect the quality of stored yam tubers are mechanical damage, physiological changes within the plant (respiration, transpiration, dormancy, sprouting e.t.c), infection by decay organisms and pest infestation. The losses caused by these factors may occur throughout all stages of the system; from crop maturity through harvesting, transport and storage. The yam tuber is a living organ hence, metabolic functions continue during dormancy to preserver its viability, this metabolic process is respiration. Respiration results in a steady loss of carbohydrate as carbondioxide and water, while at the same time a respiratory loss of water occurs.

Transpiration is water loss through the skin pores of the tuber. This loss of water contributes largely to total weight loss from freshly harvested yams and adversely affect the quality of the tuber. These respiratory and transpiratory losses result in destruction of edible material. Dormancy is a physiological rest period of the yam tuber during which sprouting is suppressed. The ability of yam tubers to germinate after variable and often prolonged periods of dormancy is a vital quality characteristic which could be manipulated to improve the flexibility of storage duration.

1.3 Objectives

The overall aim of this study is to determine the effect of pre-storage treatments and storage conditions on the quality of stored yam tubers. The specific objectives are:

1. To determine the effect of some sprout suppressing chemicals, CIPC solution and powder on stored yam tubers.
2. To determine the effect of neem tree *(Azadirachta indica juss)* extract on the rotting and sprouting of stored yam tubers.
3. To determine changes in the nutritional content of stored yam tubers during storage.

1.4 Justification

Yam tubers are important source of carbohydrates and are generally preferred to other foodstuffs that are also sources of carbohydrates such as cassava and grains. According to Adesuyi (1975), the present day storage methods are still in a technically underdeveloped state and so enormous losses in weight and quality occur.

Studies by Ibrahim *et al.* (1987); Schmuter *et al.* (1980) and Warthen (1979), indicated that parts of the neem tree have pesticidal properties. It was therefore decided that some parts of the neem tree (specifically, the bark and leaves), and the CIPC (Isopropyl Chlorophenyl Carbamate) chemical be investigated as effective ways of reducing or totally suppressing rotting and sprouting in yam tubers, thereby reducing storage losses. Also Oyeniran and Adesuyi (1979), reported that Chloro Isopropyl Phenyl Carbamate suppressed sprouting in *D.alata* tubers for about three months. In addition, Mozie (1983), reported less significant weight loss than continuous ventilation and no ventilation; also, that intermittent ventilation caused significantly less sprouting than continuous ventilation and no ventilation.

In view of the aforementioned, there was the need to investigate the use of intermittent ventilation (airflow) as a possible means of reducing weight losses and use of CIPC as means of suppressing sprouting in yam

tubers *(Dioscorea rotundata poir)* stored in the conventional barn. Furthermore, the problems of losses in yams during storage appear to lie in lack of adequate ventilation and proper control of physical conditions, such as excessively high temperature and high humidity (Adesuyi, 1971; Ogundana, 1972; Adesuyi, 1975; Oyeniran and Adesuyi, 1983 and Osunde, 2002). It is therefore necessary to carry out further investigation into the storage of yam tubers, in Nigeria, with a view to making recommendations on how best they can be stored with minimum losses.

1.5 Scope

This work is limited to the yam specie known as *Dioscorea rotundata*, (poir), being the most common and most popular of all the yam species in Nigeria.

The nutritional parameters being observed for this work are limited to the following: carbohydrates, crude protein, crude fat, phosphorous, calcium, crude fibre, ash and moisture content therein.

CHAPTER TWO

.0 LITERATURE REVIEW

.1 Yam Storage

Studies on post-harvest technology have so far been mostly concerned with grains and other durable products, which are stored dry, usually at moisture content below 12%. In these products, post harvest deterioration is largely caused by attack of external agents, such as insects, moulds or rodents. Yams are however different, the yam tuber has very high moisture content, usually between 60-70%. Furthermore, the tuber is bulky and awkward to handle. Despite all these, the yams have the greatest potential for storage among all the tropical root crops (Osagie, 1991).

Storage losses of fresh yams are mainly due to physical, physiological, or pathological causes or various combinations of all three. The tubers remain living after being harvested and so have relatively high rates of metabolic activity. This high respiratory activity, needed to sustain metabolism, implies that throughout storage, part of the total mass is continually being converted from starch to carbon dioxide and water, which are lost to the atmosphere, with concomitant weight loss (Osagie, 1991).

Good storage should maintain tubers in their most edible and marketable condition, by preventing large moisture losses, spoilage by pathogens, attack by insects and animals, and sprout growth (Igbeka, 1985). Methods of storage vary from delayed harvesting or storage in simple piles or clamps to storage in buildings, specially designed for the purpose, and application of sophisticated modern techniques.

Osagie (1991), grouped them into three broad headings: Traditional Storage Techniques, Improved Storage Techniques and advanced/Modern Storage techniques. Avoidance of high temperature and the provision of adequate ventilation are of the greatest importance in yam storage. The yam storage practices for yams have been adequately described by Onwueme (1978); Demeaux and Vivier (1984) and Igbeka (1985). The types of storage structures are influenced by various factors, these include climate, purpose of the yam tuber in storage and socio-cultural aspects of storage (FAO, 1990).

2.1.1 Traditional Storage Techniques.

These include: underground storage, heap/platform storage, storage of yam tubers under a conical protective roof (made of maize or millet stalks), Storage of yam tubers in mud huts, storage of yam tubers in yam barn and modified barns (Osunde *et al.*, 2003).

2.1.1.1 *Underground Storage*

This technique is practiced in two forms: Leaving the yam tubers in the ridges after maturity and Storage in trench silos. Some farmers leave the yam tubers in the ground where it was grown and harvest the tubers whenever required. The duration of this type of storage depends on the particular variety of yam and can extend to over 1 to 4 months (Coursey, 1983). This method provides no protection against pests (insects, nematodes and rodents) or rot. Neither does it allow periodic check of the conditions of the stored produce.

In the second form of underground storage, storage in trench silos, a pit is dug and lined with straw or similar material (Nwankiti and Makurdi, 1989). The tubers are then stored on the layer of straw horizontally on top of each other or with the tip vertically downwards, beside each other and are then covered with mulch. The trench silo provides protection from respiration and transpiration weight losses of the tubers but there is lack of ventilation and the direct contact of the tubers causes them to become warm and this promotes the formation of rot (Nwankiti and Makurdi, 1989).

Underground storage technique is simple and in expensive, the moisture in the tuber is also conserved. However, harvesting and collection can at times be difficult e.g. ground often becomes hard baked

during dry season, or flooded during heavy rains. Deterioration of the tuber is speeded up, due to high temperature and high humidity underground.

2.1.1.2 *Heap/Platform Storage*

The yam tubers are piled on a carpet, made of dead yam climbers into a heap. This normally happens under a tree providing shade and the heap is covered with maize or millet stalks or similar materials (F.A.O, 1990). The tubers may also be heaped on the floor in huts or houses (Osagie, 1991). Alternatively, the tubers are arranged on wooden platform and laterals. Storage losses are quite high, since the tubers are accessible to rodents, insects and other pests.

2.1.1.3 Storage of Yam Tubers under a conical Protective roof (made of maize or millet stalks)

This type of storage is often erected under a shade. It consists of a conical protective roof, which can also be lengthened. The tubers lie on top of each other (N'kpenu and Tougnon, 1991). The shady tree makes temperature fluctuations throughout the day milder and the light protective roof allows sufficient ventilation (N'kpenu and Tougnon, 1991). Problems arise with the possible entry of insects, pests and rodents. Also, as the tubers are piled on top of each other and the roof

completely covers the tubers, it prevents regular visual checking of the produce stored.

2.1.1.4 *Storage of Yam Tubers in Mud Huts*

This type of storage is often encountered in the savannah areas of the yam belt i.e. in regions of pronounced dry season (Nwakiti and Makurdi, 1989). They have firm walls erected in the traditional mud style and the roof consists of grass or other plant materials. The yam tubers are piled on top of each other in the hut. The hut provides very good protection from rain and direct sunlight and with the roof made of plant materials and walls of mud, the temperature, inside the hut, gets controlled. However, the lack of ventilation and piling of the yams promotes the formation of rot and the stored yams can only be checked with difficulty. (Nwankiti and Makurdi, 1989)

2.1.1.5 *Storage of Yam Tubers in Yam Barn*

This system of storage is the most wide spread among traditional yam farmers in West Africa. (Nwankiti and Makurdi, 1989). Its construction varies in design and structure, from one yam growing area to another but they all have the same basic features. A yam barn consists of vertical framework to which the tubers are tied. The framework is made from vertical poles, while the cross members are usually of bamboo or raffia palm – leaf midribs (Igbeka, 1985). The live poles usually develop

shades, which are supplemented with palm leaves and thatched roofs to protect the tubers from over wetting by rain and from heat of the sun.

The yam barn is a well-aerated storage system, which is easy to check. Also, germs and rotting tubers are easily removed. This system shows no problems during the dry season, but during the raining season, the high humidity leads to rapid rotting of the tubers (Onwueme, 1978).

2.1.2 Improved Storage Techniques

Traditional yam storage may be improved by incorporation of several relatively simple kinds of treatments that might extend storage life at fairly low cost and with low risk. These include: curing treatment, use of chemicals, use of germination inhibitors, building of well designed stores, improved modified barns (Osunde *et al.,* 2003) and other storage methods e.g. (wrapping tubers in polythene, waxing, sealed storage).

2.1.2.1 *Curing Treatment*

This is one of the simplest methods of reducing post-harvest infections, and which does not require elaborate apparatus or harmful chemicals. A curing treatment of freshly harvested tubers using temperature between 32 to 40°C and relative humidity between 90 and 95 percent for 1 to 7 days has been shown to improve storage quality of yams (Been *et al.*, 1977; Gonzalez and Colazo de Rivera, 1972; Martin, 1974; Passam *et al.,* 1976 and Ricci *et al.*, 1978).

Basically, subjecting the tubers to a short period of high temperature and humidity encourages natural thickening of the tuber skin and the healing of any surface wounds (Osagie, 1991). It is notable that some local farmers cure their yam tubers, by exposing them to direct sunlight for 1-2 days before putting them away in storage.

.1.2.2 *Use of Chemicals (to reduce microbial damage)*

Infection of yam tubers with microorganisms is a major factor in spoilage during storage. There have been many small-scale operations to control diseases chemically by dips and fumigation (Ogundana, 1972 and Ogundana and Dennis, 1981). Two broad-spectrum fungicides and *Captan, Benomyl thiabedazole* have proved effective in reducing losses in yam tubers (Osagie, 1991).

1.2.3 *Use of Germination Inhibitors*

The growth circle of yams is subject to chemical control and some chemical compounds have been shown to reduce or inhibit sprouting, when applied to yam tubers. For example, gibberellins; when applied by post – harvest immersion, gibberellins exert very widespread effects and extend the dormancy of *D. rotundata, D. esculenta* and *D. rotundata* tubers by as much as 14 weeks, while still fresh in appearance and highly acceptable on the market and the tubers still looking healthy and firm (Osagie, 1991).

Rivera *et al.* (1974), showed that sprouting in *D.alata*, could be inhibited for a short period (1 month) by treatment with Isopropyl Phenyl Carbamate (IPPC) Oyeniran and Adesuyi (1979), also showed that Chloro Isopropyl Phenyl Carbamate suppressed sprouting for less than three months in *D.alata*

2.1.2.4 *Building of Well – Designed Stores*

This involves the erection of special buildings for yam storage. Building can be fully walled or half walled and the walls can be made of mud, concrete, wood or bamboo (Igbeka, 1985). The yam tubers are arranged on shelves inside these buildings, which provide adequate ventilation, and rodents are eliminated. However, the structures are not suitable for long-term storage of yams, (Igbeka, 1985).

2.1.2.5 *Other Storage Methods*

(i) Wrapping the tubers in polythene bags (Thompson *et al.*, 1977). The tubers lost little weight during storage but considerable levels of fungal growth occurred on the surface of the tuber.

(ii) Waxing: Tubers covered with *Epolene* E10 vegetable wax had a very attractive appearance but the treatment had no effect on levels of fungal infections and the effect on weight loss was inconsistent (Thompson *et al.*, 1977).

3 Advanced/Modern Storage Techniques

Modern storage methods involving the use of cold temperatures and ionizing radiation have been tested experimentally with yams. The main problem with these treatments is that they require a high level of technology seldom available to the farmer. These techniques include. Cold storage and Irradiation.

1.3.1 *Cold Storage*

Rivera *et al.* (1974), reported that the storage of yam tubers at a relative humidity of 80% and a temperature of 16°C largely prevents moisture losses and delays sprouting after the tubers are removed from under controlled conditions. In effect, their dormancy period can be extended by 4 additional months. Also, no significant chemical changes were observed during the storage time; their flavour remained unchanged and they lost little weight. Mozie (1988), also showed that white yam (*D. rotundata*) tubers stored at 16°C, resulted in less weight losses than storage at 10°C and 30°C. Temperatures of 12 to 15°C are normally recommended for the cold storage of yams.

Refrigerator storage for periods up to 8 months is costly and subject to problems due to breakdown of equipment or interruption of electrical supply. Adesuyi (1975), reported that, if for any reason during storage there is power failure or a breakdown of the refrigerating unit, for

more than a week, in the store regulated at 15^0C, the yam tubers start sprouting. Scope for the low temperature storage of yams, even if economically feasible, is limited, since yams are susceptible to chilling injury, which causes physiological breakdown and predisposes tissue to microbial decay (Burton, 1970).

2.1.3.2 *Irradiation*

Gamma irradiation has been successfully applied to the storage of yams (Adesiyan, 1977; Adesuyi, 1978; Adesuyi and Mackenzie, 1973; Demeaux *et al.,* 1983 and Rivera *et al.,*1974). The results showed that the optimal gamma irradiation dose required for sprout inhibition varied among eight cultivars of *D. rotundata.*

Complex sprout inhibition, during 8 months of storage with 7.5*krad* was obtained in some cultivars while the other cultivars required 10*krad* or above. They also reported that a dose of between 5 and 20*krad* caused more than 50% reduction in weight loss in all cultivars, in contrast to controls.

Slight damage to internal tissues was observed at and above 20*krad.* It was stated that to ensure acceptability, palatability and complete sprout inhibition without adverse physiological effects, 12.5*krad* proved suitable for all eight cultivars used, and that, tubers should be irradiated as soon as harvest damage has healed. Furthermore, it would appear that, technologically, sprout

inhibition by irradiation is feasible and advantageous, provided healthy well-cured tubers are used, and good handling and storage management are used (Osagie, 1991).

2.2 Factors Affecting Storability of Yams

Deterioration, following the harvesting of fresh yam tubers and the consequent losses are caused by: - mechanical damage, physiological changes within the plant (e.g. respiration, transpiration, dormancy, sprouting etc) and infection by decay organisms and pest infestation. The losses caused by these processes may occur throughout all stages of the system; from crop maturity through harvesting, transport and storage. (Table 2.1)

Diop and Calverly (1998), also reported that pre-harvest factors are largely responsible for significant post-harvest losses. The factors include field pests, infection by disease organisms, and infestation by pests, environmental and cultural practices and also genetic factors. A further complication is the interrelationship and interaction between the different components of production and harvesting. Their effects are greatly influenced by the condition of the product itself, and during storage, the temperature and ambient relative humidity (Diop and Calverly, 1998).

The main causes of storage losses are fully discussed below:

TABLE 2.1 Causes of Losses in Roots and Tubers and Their Effects

Factor	Mechanism	Stage Affected	Resulting Loss
Mechanical	Rupture	Harvest	Moisture loss
	Bruising	Harvest, transport, storage	Access to pests and diseases
Physiological	Transpiration	All storage before processing	Water loss
	Respiration		Dry matter loss
	Sun scorch	In field after lifting	Tissue degradation
	Chilling	Cold storage	Loss of palatability
	Inversion of Starch	End of dormancy	Increased transpiration and respiration.
	Sprouting	Storage	
Pathogenic bacteria and fungi	Necrosis and tissue degradation	Pre-harvest	Partial or complete loss
		Storage	Downgrading
Insect infestation	Chewing	Pre-harvest	Partial loss
		Storage (fresh or processed products)	Access for decay organisms
Rodent and bird damage	Chewing	Pre-harvest	Partial loss
	Pecking	Storage	Access for decay organisms

Source: F.A.O (1981)

2.2.1 Mechanical Damage

Mechanical damage to yam tubers occurs readily during harvesting. Yams are harvested with simple traditional tools, such as hoe and cutlass, which easily cut or abrade the large-seized tubers. The skin

of a matured yam tuber is normally an effective barrier against most potentially invading bacteria and fungi, causing rotting of the tissues. (F.A.O., 1995). Any rupture of this barrier, caused by damage or injury to the skin, will provide an entry point for infection and will also stimulate physiological deterioration and dehydration.

Nwakiti and Makurdi (1989), reported that leaving yam tubers in the ground after maturation is not injurious; however, the soil becomes firmer during the dry months of the year, due to lack of precipitation, and becomes hard, thus, harvesting is carried out with great losses as a result of injury to the yam tubers, most especially, if they are large. Further bruising and abrasion of the tubers may also occur during transportation of the tubers from the farm to the sales point. External injuries in the form of cuts and splits may be fairly obvious, abrasions, which account for a similar proportion of injuries is not obvious, under the coating of soil. Bruising wounds may take some days to develop and even then, can only be seen if the tubers are cut open (Osagie, 1992).

According to Passam *et al.* (1976), the wounds do not remain open but heal, provided the environmental conditions permit. The healing is more rapid and more uniform over clear cuts than over other types of injury. Bruised yam tubers cannot be stored successfully unless the damaged tissue is removed, after which the subsequent normal wound

healing process occurs (Osagie, 1992). Nwadikom (1990), observed that physical properties play a major role in predicting physical damage to yam tubers.

The relationship between tuber diameter, pile height and damage incidence for piles with square and triangular arrangements were given. He concluded by saying that tubers with a moisture content of 70% and above, are more easily damaged and must be placed singly, and also that such tubers should not be allowed to drop from a height above 3cm.

2.2.2 Respiration

The yam tuber is a living organ hence, metabolic functions continue during dormancy to preserve its viability; this major metabolic process taking place in the yam tuber is respiration (Passam and Noon, 1977). The rate is an excellent indicator of metabolic activity of the tissue and thus, a useful guide to the potential storage life of the tuber. The tuber takes the energy essential for this from its store of carbohydrates. Carbohydrates are burned to gain energy during which process; CO_2 and H_2O are emitted as gases.

According to F.A.O (1995), the respiration process results in the oxidation of the starch (a polymer of glucose) contained in the cells of the tuber, which converts it into water, carbon dioxide and heat energy; during this transformation of the starch, the dry matter of the tuber is

reduced The respiration process can be approximately represented by the oxidation of glucose:

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2+6H_2O+energy$..... (1)

For respiration to occur freely a supply of oxygen is needed and the resulting carbon dioxide and heat have to be removed from the product's environment. Respiration rate may be measured as either oxygen consumed or carbon dioxide evolved. A limited supply of oxygen and inadequate removal of carbon dioxide may lead to effective asphyxiation and death of the product tissue (F.A.O, 1995).

2.2.3 Transpiration

Transpiration is water loss through the skin pores of the tuber and is, effectively, evaporation. Loss of water makes a large contribution to total weight loss from freshly harvested yams, which contain from two-thirds to three-quarters water (Osagie, 1992). Diop and Calverly (1998), reported that, because yam tubers are characterized by having high moisture content (depending on the variety, yams have a water content of 60-80%), even in the ambient conditions prevailing in the humid tropics, they will continuously lose water to the surrounding air. During storage, the water content of the fresh tubers reduces continually. This loss depends on the phase of storage (Coursey, 1983). According to him, during the first weeks after harvest, a reduction in the water content of the

tuber is hardly noticeable, in some cases; water content will even rise slightly during this phase. During a storage period of five months, the weight of the tuber falls by up to 20% due to transpiration (Coursey and Walker, 1975). The intensity of transpiration is considerably influenced by the predominant climatic conditions (temperature and relative humidity).

Loss of water due to transpiration can be significant in many ways. Whilst the original nutritional value may not be affected (Onwueme, 1978), a large water loss will adversely affect the quality of the produce, for example a loss greater than 10% will result in a bigger peeling loss because of the shriveled texture of the skin and also, the culinary quality may be affected (Onwueme, 1978).

Furthermore, a greater loss in weight from transpiration is not desired, as due to this, the tubers lose their viability, shrink and become unattractive. As yams are mainly sold accordingly to fresh weight and appearance, a weight loss becomes an economic loss, since the tubers are less attractive to potential buyers. Transpiration may be influenced by the following: temperature, relative humidity, the rate of air movement surrounding the tuber and most significantly, the permeability of the skin and how this may have been effected (F.A.O, 1995).

2.2.4 Dormancy and Sprouting

Coursey (1976), defined dormancy as a physiological rest period of the yam tuber, during which sprouting is suppressed i.e. the inability of the yam tuber to sprout. The ability of yam tubers to germinate after variable and often prolonged periods of dormancy is a vital quality characteristic, which could be manipulated to improve the flexibility of storage duration. A longer shelf life of healthy yam tubers could be achieved with a long dormant period (Orkwor *et al.*, 1998). The inherent length of tuber dormancy varies among the yam species (Table 2.2)

TABLE 2.2: Dormancy Periods of the Major Edible Yams

Yam Species	Locality	Length of Dormancy (Weeks)
D. alata	Caribbean	14-16
	West Africa	14-18
D. rotundata	West Africa	12-14
D. cayenensis	West Africa	4-8
D. esculenta	West Africa	12-18
	Caribbean	4-8
D. trifida	Caribbean	4

Source: Passam (1982)

Most known cultivars of *D. rotundata* and *D. cayensis* exhibit an approximate 3-month dormancy period (IITA, 1971). Martin and Sadik (1977) noted that the tuber storage life of *D. rotundata* is slightly longer

and more variable than that of *D. cayensis.* It has been suggested that differences in length of tuber dormancy among the species are due to the ecological environment in which they evolved (Passam, 1982).

In view of the fact that the tuber is the economically useful part of the yam plant, more attention ought to be devoted to the mechanism of sprouting as this limits the storage life of the yam tuber (Passam and Noon, 1977); according to Passam (1982), the duration of dormancy can be influenced to a certain extent, by temperature and relative humidity. Low temperatures and low relative humidity rates prolong dormancy (Table 2.2).

The possibilities of changing the temperature and relative humidity to influence dormancy are limited, as the tuber tissue is destroyed when the temperature falls below 15^0C, also, relative humidity which is too low hinders storage quality, as early drying of the tuber is induced by this (Passam, 1982).

Adesuyi (1982), also reported that lower storage temperatures are widely practiced as a technique for reducing the metabolic activity of roots and tubers and prolonging their dormancy. Temperatures of 16^0C to 17^0C have been used to prolong the storage period for *D. alata* tubers for up to four months. (Table 2.3)

TABLE 2.3: Cumulative Percentage of Sprouting of Yam Tubers Stored at Different Temperatures.

Storage Period (Months)	15^0C	20^0C	25^0C	Yam Storage Barn (Ambient)
0	0	0	0	0
1	0	14	0	0
2	0	40	28	30
3	0	54	94	88
4	0	54	100	100
5	0	56	100	100

Source: Adesuyi (1982).

While yam tubers remain dormant, they can be stored satisfactorily, (provided they are undamaged and free from disease). As soon as dormancy is broken and sprouting begins, the rate of dry matter loss increases dramatically, since the formation of sprouts required energy, which is drawn from the tuber's carbohydrate reserves (F.A.O, 1995). The rate of water loss also increases and if this becomes excessive, the tubers dry out, allowing pathogens to penetrate the tuber, potentially causing severe damage, if not total loss, making continued storage quite impracticable.

2.2.5 Pathological Factors

All living organisms are subject to invasion by microorganisms; fungi, bacteria and viruses, which constitutes the most serious cause of direct post-harvest loss in tropical root crops. These disease organisms are widely distributed in the air and soil and on dead and decaying plant

material. The time of infection may be while the crops are in the field before harvest or at any time, afterwards. Since many post-harvest pathogens are introduced through wounds, one of the major factors governing the incidence and magnitude of losses due to pathogenic microorganism is the physical condition of the produce. The cork layer surrounding the yam tuber is intended to serve as a barrier against bacterial and fungi attack. When this protective barrier is damaged, the plant is predisposed to pathogenic infection (F.A.O, 1995).

.2.5.1 *Sources of Infection*

The infection may start; before harvest, through natural pore above and below ground parts of plants, due to injuries caused after harvest by careless handling, by insect or other animal damage, and by direct penetration of the intact skin of the plant. Pre-harvest field infection does not necessarily become apparent until after harvest but can occur at any time between the field and storage period.

2.2.6 Attacks by Pests

Post-harvest and storage losses are caused by pests, which include, insects, nematodes and animals.

2.2.6.1 *Insects*

According to investigations carried out by Sauphanor and Ratnadass (1985), it can be assumed that the pressure of pests will

become regionally more important, due to pests, which are introduced accidentally. Insects damage the yam tubers in two ways: by boring holes in the tubers, reducing the quantity and quality of the produce and sometimes, the germination capacity and they damage the epidermis, providing entry for moulds and bacteria to penetrate the tuber, thereby causing secondary damage.

The yam beetle (*Heteroligus spp*), according to details stated by Onwueme (1978), is the insect, which causes the most damage to yams in West Africa. It attacks the tuber during the growth phase, which then only rarely dies. The epidermis is destroyed during eating, leaving the way open for secondary infections leading to mould, which can cause high storage losses. Other extensively widespread pests, which infest the yam tuber, during storage, are mealy bugs and yam mealy bugs (*Aspidiella hartii and Planococcus discorea*). These form whitish colonies, which can cover the whole tuber. The insects suck the juice out of the tuber, leading to a certain loss in weight.

However, what is more significant is that the tubers which are infested are not suitable for sale and the mealy bugs have a negative effect on germination capacity (Sauphanor and Ratnadass, 1985). In recent years, there has been a significant increase in insect attacks on yam tubers in storage (Osagie, 1991). In several cases this has led to the

destruction of 50% of the harvest, after several months of storage. These losses are essentially, due to the larva of two *Lepidoptera*: *Euzopherodes* rapidella (Sauphanor and Ratnadass, 1985) and *Dasyses rugosella* (Dina, 1977).

2.6.2 *Nematodes*

Nematodes occur on yams as root and tuber parasites. They mostly infest the plant during the vegetation period and remain in the tubers after the harvest. They damage not only the tubers, but create entries for other pests, in particular, mould fungi; for this reason, infestation by nematodes is often accompanied by tuber rot which mostly causes greater economic damage than infestation only by nematodes. Many species of nematodes affect root and tuber crops. Among these *scutellonema* bradys, *pratylenchus coffeae* and *melloidogyne* spp are alleged to be the most significant, particularly on yams (Bridge, 1980).

2.6.3 *Rodents, Birds and Other Animals*

Rodents are the most important pests for stored yam tubers. In the region of West Africa, most damage is caused particularly by the giant rat (*Crictomys*) and the common rat (*Rattus*) (Onwueme, 1978). Stored yam tubers are also popular with birds, monkeys and warth dogs, as well as with domestic animals like goats and sheep.

2.3 Anatomy of the Sprouting Process

Osagie (1991), reported that knowledge of cellular events occurring during tuber germination is critical, both for successful storage of ware tubers as well as for production of viable tuber setts for yam cultivation. Precise information on developmental processes associated with the yam sprout was not available until the report of Onwueme (1973). He described *de novo* genesis of adventitious buds during tuber germination of *D. alata and D. rotundata* from within a bulging amorphous mass of cells, generated by activity of a discontinuous meristem in the outer cortex of the tuber.

Wickham *et al.* (1981), described the origin of roots, shoots and the organ of renewed growth (i.e. primary nodal complex or PNC) during tuber germination in *D. alata, D. esculenta, D. rotundata and D. trifida.* They concluded that the sequence of events taking place during tuber germination was remarkably similar in the four species.

The first external indication of renewed growth is the development of small protuberances on the tuber surface. These are the sites of developing roots. Primary shoots emerge from protective scale leaves or *calyptrae* (Burkill, 1970), which encloses developing adventitious buds. Secondary shoots develop from axillaries buds formed early in development, in the axils of *calyptrae* or first formed leaves of the

primary shoot. Shoot genesis is initiated by cell divisions in the inner cortex of *D. alata* tubers and in the primary thickening meristem of other species. Further activity of the primary thickening meristem results in a multi-layered meristematic zone of up to thirty cells thick, which was designated, the tuber germinating meristem (Wickham *et al.*, 1981) to emphasize its different role from the primary thickening meristem. Thus, contrary to the role of this latter meristem in producing storage parenchyma and cortical tissues during tuber development as well as tuber-roots during tuber germination, the tuber germination meristem gives rise to adventitious buds, the PNC initial and the PNC meristem. This latter meristem is the major source of cells in the PNC initial, later to differentiate into a distinct organ by formation of parenchyma cells and scattered vascular bundles (Osagie, 1991).

In contrast to the report of Onwueme (1973), that adventitious buds were differentiated within a bulging amorphous mass of cells. Wickham *et al.* (1981), observed that such buds were always first formed on the outer tangential surface of the tuber germinating meristem and that PNC development followed bud formation. They further suggested that the normal growth cycle of the primary nodal complex might be under a rythmical hormone-induced control. Osagie (1991), concluded by saying that, dormancy is broken by the resumption of meristematicity in the primary thickening meristem, that it

was not clear what determines the exact point on the tuber surface where the sprouting locus will arise.

2.4 Effect of Chemical Treatments on the Storage Life of Yam Tubers

Definite dormant period imposes a physiological limitation to year round planting and the production of off-season crops (Osagie, 1991). Season gluts can be prevented and market prices stabilized, if a simple technique to break dormancy is available. Research studies on preserving the yam tubers include studies by Akinnusi *et al.* (1984), in which the comparative effectiveness of three rot preventing chemicals was investigated; these chemicals, include, RE. 49 dust (a halophen base chemical) RE 49 liquid and locally brewed gin (Ogogoro).

Other studies include the use of chemicals such as Benlate and Thiabendazole (Ogundana, 1972) RE 49 (Halophen, 5% dust) and (CIPC (Chloro-Isoprophyl phenyl carbamate, 1% dust) (Oyeniran and Adesuyi, 1983). In a further study Rivera *et al.* (1974), showed that sprouting in D.alata could be inhibited for a short period by treatment with Isopropyl Phenyl Carbamate (IPPC) in Dinafog form. Olorunda *et al.* (1974), also reported that Isopropyl phenyl Carbamate inhibited sprouting of de-sprouted tubers. After 7 months of storage, tubers treated with CIPC (Isopropyl-N-3-Chlorophenyl) carbamate in aerosol or fog form remained sprout free for an additional twenty days as compared to controls. Tubers

treated with 7-10 *krad* gamma rays remained sprout-free for an additional 60 days; thus, they concluded that, controlled storage and pre-storage treatments could extend yam storage for up to 9 -10 months, almost sufficient to provide fresh yam year round. Franklin combined the use of gibberellic acid and wax, as treatments for the suppression of sprouting. Akalusi *et al.* (1986), found that lime and local gin (app. 62% alcohol) prolonged the shelf life of *D. rotundata*, mainly by reducing decay. Other chemicals used are summarized in Table 2.4.

Also, due to the need to discover simple, effective and inexpensive methods of controlling rotting and sprouting in yams, studies had been going on, and also personal communication with farmers indicate that many herbs are used for the purposes of storage of many crops. Such studies indicated that parts of the neem tree have pesticidal properties (Ibrahim *et al.*, 1987; Schmutter *et al.*, 1980 and Warthen, 1979).

TABLE 2.4: The Effect of Applied Chemicals on the Storage Life of Yam Tubers.

Source	Applied Chemical	Effects
Adesuyi, (1973)	Maleic hydrazide	No apparent effect
	Tetrachloronitrobenzene	No apparent effect
	B-Naphtaleneacetic acid	No apparent effect
Rivera *et al.*, (1974)	Isopropylphenyl-carbamate	Phytotoxic + 1 month storage *(D.alata)*
Olorunda *et al.*, (1974)	Isopropylphenyl carbamate	Inhibited sprouting of desprouted tubers
Martin, (1977)	Gibberellic acid	+ 1 month storage
Passam, (1977)	Gibberellic acid	No apparent effect
	2,6-Dichlorophenoxy acetic acid	Inhibited dormancy
Oyeniran and Adesuyi, (1979)	Choloro Isopropyl Phenyl Carbamate	Suppressed sprouting in less than 3 months *(D.alata)*
Passam *et al.*, (1982)	Ethanol	Promoted sprouting
Ramanujam and Nair, (1982)	Maleic hydrazide (1000ppm)	Controlled sprouting
Wickham *et al.*, (1984)	Maleic hydrazide	Delayed sprouting
	Gibberellic acid	Marked extension of dormant period. Extends storage life.
Ireland and Passam, (1985)	Gibberellic acid	Prolongs dormancy
Mozie (1987)	2,4-Dichlorophenoxy acetic acid	Inhibition of sprouting

Source: Osagie (1991).

2.5 Effect of Air Flow on Weight Losses and Sprouting of White Yam Tubers (*Dioscorea Rotundata Poir*) Stored in the Conventional Barn.

Not many significant advances have been made in recent years with respect to the technological aspect of yam storage. As a result, the rate of sprouting and weight loss during storage in the conventional barn continues to pose serious problems. Previous studies (Coursey, 1972), have revealed that relationship exist between sprouting of yam tubers and the level of weight losses that occur during storage in the conventional barn.

However, controlled environmental factors such as rate of air flow, humidity and temperature of the conventional barn were not evaluated in terms of their effects on either rate of sprouting or weight loss. In his study, Mozie (1983), observed that throughout the storage period of 44 weeks (11 months) there was significant difference in the percentage sprouting rate and the rate of weight losses of yam tubers stored in the conventional barn when supplied with air flow intermittently, continuously or none at all (i.e. no airflow).

He reported that intermittent ventilation (airflow) allowed significant less weight loss than continuous ventilation and no ventilation (no airflow) also, that intermittent ventilation caused significant less sprouting than continuous ventilation and no ventilation.

2.6 Nutritional Changes during Post Harvest Storage.

Osagie (1991), reported that yam tubers, under storage conditions, exhibit considerable physiological activity: respiratory, enzymic and biosynthetic; the physiological changes affect the internal composition of the tuber. Respiration results in a steady loss of carbohydrate as carbondioxide and water, while at the same time, a respiratory loss of water occurs. These respiratory and transpiratory losses result in a destruction of edible material, which under normal storage conditions can often reach 10% after 3 months, and up to 25% after 5 months (Passam *et al.,* 1978).

Relatively little change occurs in the actual nutritional value of the material remaining after this metabolic loss takes place (Gonzalez and Collazo de Rivera, 1972). According to experiments by Martin and Ruberte (1976), quality begins to deteriorate very early in harvested yams, usually by rotting from harvest wounds. If rotting is avoided, other forms of deterioration occur and increase with time, including shriveling, associated with water loss. All forms of visible deterioration reduce the appeal of the tuber. Other notable changes affect flavour (Gramshaw and Osinowo, 1985) and taste. Stored tubers taste drier than fresh tubers. It is evident that the main factors affecting yam tuber quality during storage have not been identified and more studies are required in this area. The

dry matter portion of yam tubers is mostly composed of carbohydrates, which exist primarily in the form of starch and sugars. Ikediobi and Oti (1983), attributed the steady decline in starch, which they observed in stored *D. rotundata* tubers to the respiratory loss of sugar as carbon dioxide.

CHAPTER THREE

3.0 MATERIALS AND METHODS OF EXPERIMENTS

This work involves evaluation of the effect of different pre-storage treatments on yams stored in two different storage conditions

3.1. Description of Storage Barn without Fan.

The yam barn was erected in the open air, where sufficient shade and ventilation was available. The frame of the barn consisted of vertically erected wooden poles of 2m in height, set at a distance of 1m to each other. These poles were stabilized by attaching horizontal poles to them. The dimension of the barn were 2.5m, 3.5m and 2m, width, length and height respectively, locally knitted thatch made of dried plant stalks were wound round the frame and the top. These served as the roof and the wall. There was a slight opening between the roof and wall to allow for ventilation and a reduction in ambient temperature of the barn.

Figure 1 shows the different parts and dimensions of the storage barn., while plate 1 shows the interior of the barn without fan.

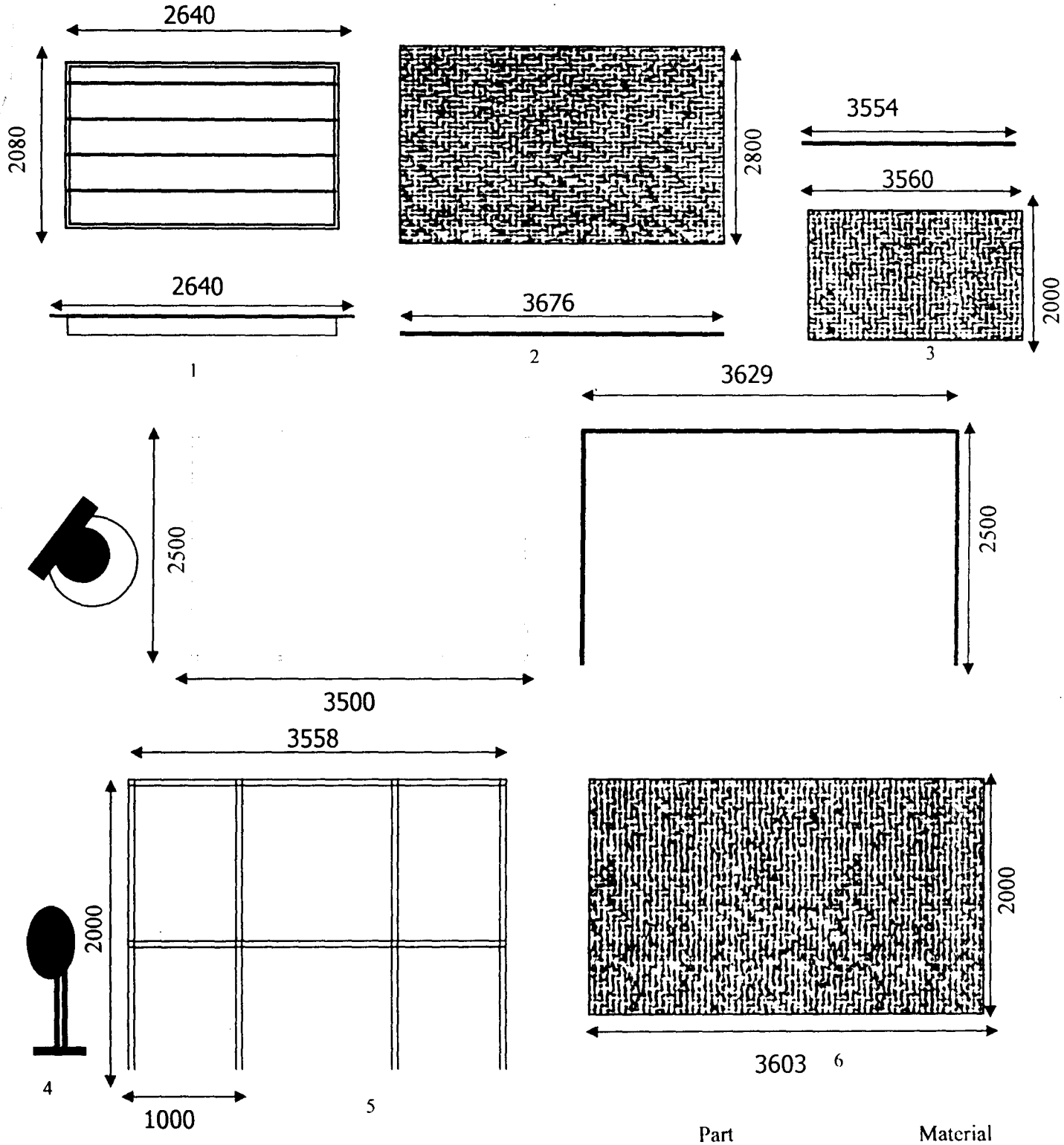

FIG 1: PARTS OF THE STORAGE BARN

Part	Material
1. Raised Platform	Plywood
2. Barn Roof	Thatch
3. Barn Door	Thatch
4. Fan	Metal/Plastic
5. Barn Frame	Wood
6. Barn Walls	Thatch

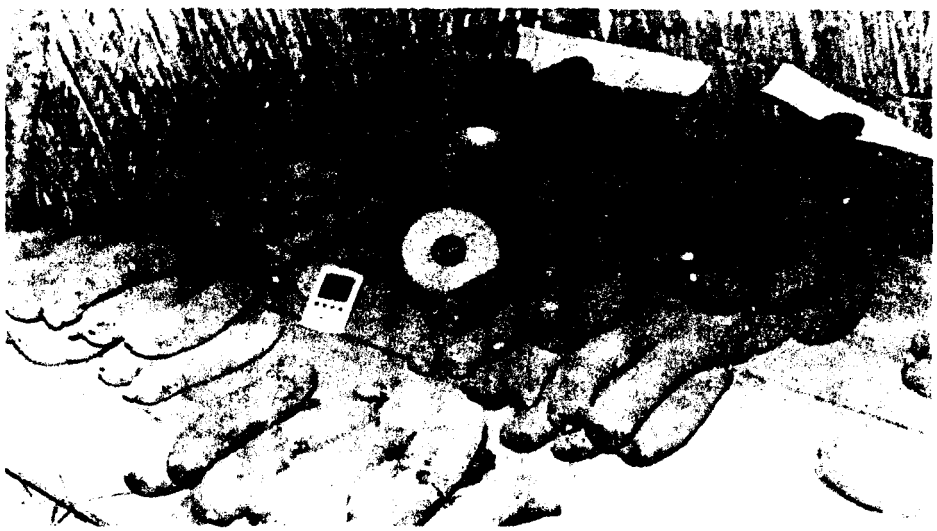

Plate 1: The barn without fan.

3.2. Description of Storage Barn with Fan.

The barn with fan was constructed exactly the same way the barn without fan was constructed, with the same dimension, materials and at the same location. The only difference was the presence of a standing fan to aid air circulation in the storage barn with fan. Plate 2 shows the interior of the barn with fan and plate 3 show the back view of the barn with fan.

Plate 2: The barn with fan.

Plate 3: Back view of the yam barn.

3.3. Experimental Procedure.

Two traditional yam storage barns were constructed and used for the storage of *cv. Giwa* yam tubers at the Department of Agricultural Engineering Federal University of Technology, Minna, Nigeria. One of the barns had a fan that operated at 27.24m/s speed and rotated at 180^0, this is to enable all the tubers to be evenly ventilated. 108 freshly harvested tubers obtained from a farm in Garatu, Niger State, Nigeria were stored in each barn and used for the study. The tubers in each barn were divided into nine sub groups of 12 tubers and labeled.

The tubers were arranged on a wooden platform that was placed on the floor of the barn in order to reduce bruising and facilitate ventilation, weighing and observation. The tubers were pre-treated before storage using CIPC solution and powder in 3 levels and neem extracts (neem bark extract and neem leaf slurry). Parameters monitored during storage were temperature and relative humidity of the air inside the barns. The quality

of stored yams were determined from the loss in weight, rate of sprouting, rot development and some nutritional parameters such as carbohydrates, calcium, phosphorus, crude protein, crude fat, crude fibre, ash content and moisture content were analyzed. The tubers were stored for 6 months between January and June, 2006. The following investigations were undertaken:

1. The effect of some sprouts suppressing chemicals CIPC solution and powder on stored yam tubers.
2. The effect of neem tree extract on the rooting and sprouting of stored yam tubers.
3. Determine changes in the nutritional content of stored yam tubers during storage.

3.4 The Effect of CIPC Solution and Powder on Stored Yam Tubers.

This was accomplished in two different experiments. The first experiment was the effect of CIPC solution on stored yam tubers and the second was the effect of CIPC powder on stored yam tubers.

3.4.1 The Effect of CIPC Solution on Stored Yam Tubers.

A 4x2 factorial experiment in CRD with 3 replicates was used in this study. The 4 levels of treatment of CIPC solutions per kg of tuber were: 1.5ml, 3.0ml, 4.5ml and control. The 3ml CIPC solution /1kg of tubers is the dosage used for successfully controlling sprouting in stored potatoes.

The two storage factors were a barn with fan and the other without fan. The yam storage parameter measured was sprouting. The results were analyzed using ANOVA and the means analyzed using F-LSD at $P \leq 0.05$.

3.4.2 The Effect of CIPC Powder on Stored Yam Tubers.

A 4x2 factorial experiment in CRD with 3 replicates was used in this study. The 4 levels of treatment of CIPC powder per kg of tuber were: 1g, 2g, 3g and control. The 2g of CIPC powder/1kg tuber is the dosage used for successfully controlling sprouting in stored potatoes. The two storage structures were a barn with fan and the other without fan. The yam storage parameter measured was sprouting. The results were analyzed using ANOVA and the means analyzed using F-LSD at $P \leq 0.05$.

3.4.3 The Effect of Neem Extract on Sprouting, Rotting and Weight Loss in Stored Yam Tubers.

A 3x2 factorial experiment in CRD with 3 replicates was used in this study. The three treatments were neem bark extract, neem leaf slurry and control. Neem tree extracts gave favourable results in reducing sprouting, weight loss and rotting during storage of yam tubers, in previous studies. The two storage factors were a barn with fan and the other without fan. The yam storage parameter measured were sprouting, rotting and weight loss in stored yam tubers.

3.4.4 Determination of Changes in the Nutritional Content of the Stored Yam Tubers.

Nutritional analysis of the stored yam tubers was under taken during the 6 months storage period. This was done at the beginning of storage, after 90 days and after 180 days of storage. The nutritional parameters analyzed were moisture content, ash content, crude protein, crude fat and calcium and carbohydrate. 12 tubers were randomly selected from each barn and these were in 3 replicates.

3.5 Measurement of Temperature and Relative Humidity.

The temperature and relative humidity were measured for 26 weeks. Readings were taken three times a week, at 0800h, 1200h, 1600h and 2000h, in order to have an even distribution of measurements in a day. A digital thermohygrometer (Mebus 4.0) was used to measure the air temperature and humidity. The weekly, biweekly and monthly averages for all readings were computed.

3.6. Determination of Yam Quality.

The quality of the stored yams was determined from the loss in weight, rate of sprouting and rots development.

3.6.1 Determination of Sprouting.

De-sprouting was carried out manually, by snapping off sprouts from the head of the tubers. This was done, once in two weeks during the 6 months study period. The sprouts, which were removed, were weighed, using the top loading electronic weighing balance (0.01g accuracy).

Yam tubers to be de-sprouted were selected based on length of sprouts, tubers with sprouts, longer than 2cm were de-sprouted. Almost all the tubers, irrespective of the treatments used had sprouted and had to be de-sprouted before the end of the study period.

3.6.2 Determination of Weight Loss.

All the 108 yam tubers in each barn were weighed before storage. These tubers were weighed every 30 days during storage by use of a weighing balance with 1.0g accuracy and their respective weights recorded based on the treatments used on them.

3.6.3 Determination of Rotting.

Observation for rotting was always carried out whenever the tubers were weighed or de-sprouted. Rotten tubers were detected by both visual examination and by exerting slight pressure on the yam tubers with the fingers. Yams were regarded as rotten when they were soft to touch and lost coherence when felt (soft rot) or by being too hard to touch (dry rot) as well as visual observation of internal streaks of discolouration when

cut open. All the tubers were always examined at every time of observation.

3.7. Determination of Nutritional Parameters.

The nutritional parameters analyzed were: moisture content, ash content, crude protein, crude fat and crude fibre. Others were phosphorus, calcium and carbohydrate.

3.7.1 Determination of Moisture Content

The moisture content was determined using the oven method as given by Association of Official Analytical Chemists (A.O.A.C, 1980). The apparatus and materials used are Oven, electronic weighing balance. (top loading 0.0 1g accuracy), desiccators, crucible and grinder (mill)

Procedure:

5g of the fresh yam sample was weighed into a moisture can. The can and the sample were weighed and then transferred into an oven, and the sample oven dried initially at 80^{O}C for 3 hours and then at 105^{O}C for the next 12 hours. The sample was allowed to cool in a dessicator and the oven dried sample was weighed. The percentage moisture content was then calculated as:

$$\% \text{ Moisture} = \frac{W_2 - W_1}{W_3 - W_1} \times \frac{100}{1}$$

Where: W_1 = Weight of can

W_2 = Weight of can + fresh sample

W_3 = Weight of can + Oven dried sample

3.7.2 Determination of Ash Content

The ash content was determined using a method as given by Obigbesan, (1984). The apparatus and materials used are Furnace, top loading electronic weighing balance (0.01g accuracy) and crucible.

Procedure

1g of the oven dried ground sample was weighed into a crucible with a known weight, and the weight of the crucible + sample was obtained. The sample was placed in a furnace and ashed at a temperature of 550^{o}C for six hours. The ashed sample was allowed to cool in a dessicator and weighed.

The percentage of ash in the sample was calculated as given by Obigbesan, (1984):

$$\% \text{ Ash} = \frac{W_2 - W_1}{W_3 - W_1} \times \frac{100}{1}$$

Where: W_1 = Weight of crucible

W_2 = Weight of crucible + sample

W_3 = Weight of crucible + ashed sample

3.7.3 Determination of Crude Protein

Crude Protein was determined by the universal Kjeldahl method. The apparatus and materials used for this method are Kjeldahl digestion block, Kjeldahl distillation unit, burette, pipette and standard flask (100ml). While the Reagents used are concentrated sulphuric acid, Kjeldahl catalyst tablets, boric acid crystals, 40% sodium hydroxide, boric acid mixed indicator, 0.01M HCI and distilled water

Procedure

0.5g of the oven-dried sample was weighed into the kjeldahl digestion tube, 20ml of conc. Sulphuric was added, two tablets of the kjeldahl catalyst tablets were also added and the sample digested, using the kjeldahl digestion block, for 5 hours at a temperature of 450^{o}C. When a clear digest was obtained, the digested sample was allowed to cool and then transferred quantitatively into a 100ml standard flask. An aliquot of 10ml was used to carry out the Nitrogen distillation. The distillate was titrated to obtain the titre value of the various samples. Nitrogen was then calculated as follows:

$$\% N = (A - B) X 0.01 X 0.014 x df x \frac{100}{W}$$

Where: A = titre value of the sample

B = titre blank

0.01 = molarity of acid used for titration

0.014 = nitrogen conversion factor.

df = dilution factor.

W = weight of sample.

100 = percentage conversion.

To determine the crude protein in the tissue sample, the percentage nitrogen was multiplied by the factor, 6.25, which converted the % nitrogen to crude protein. The factor, 6.25, owes its origin to the assumption that all feed protein contains 16% nitrogen, and that all nitrogen in a feed is present as protein.

(Anderson and Ingram, 1989).

3.7.4 Determination of Crude Fat

Fat content in the yam tissue was determined by soxhlet extraction, using petroleum ether. This is known as soxhlet extraction method. The apparatus used are Soxhlet extraction unit, extraction thimble and electronic weighing balance (Top loading). Petroleum ether was the reagent used for the extraction.

Procedure

1g of the ground tissue sample was weighed into the extraction thimble. The thimble was then placed into the soxhlet extraction unit. Petroleum ether was placed in a round bottomed flask which was coupled with the extraction unit. The unit was then heated using the heating mantle.

Extraction was continued for 12 hours during which time all the oil was extracted. The flask containing the petroleum ether was dismantled and the petroleum ether allowed to evaporate. The flask was weighed to obtain the quantity of oil extracted and the % Lipid extracted was then also calculated. (Obigbesan, 1984).

3.7.5 Determination of Crude Fibre

Crude fibre was determined using the method as given by Obigbesan, (1984). The apparatus and materials used are Beaker (600ml), round bottomed flask condenser unit, buchner funnel, crucible and silica with porous base. While the reagents used are (0.25N) sulphuric acid solution, qq(0.25N) sodium hydroxide solution, ethyl alcohol and hydrochloric acid –1% V/V.

Procedure

2g of the dried, fat free sample was weighed into 600ml beaker.20ml of hot H_2SO_4 was added and then brought to boil for 30 minutes. Distilled water was used to maintain the volume and to wash down particles adhering to the sides. This was filtered through a buchner funnel and washed properly with boiling water. .

The residue was transferred back to the beaker and 200ml of hot sodium hydroxide solution added to it, this was brought to boil. After boiling for 30minutes, it was filtered through porous crucible and washed twice with alcohol. This was allowed to dry in an oven, overnight, at $100^{O}C$. The dried sample was cooled, weighed and ashed at $500^{O}C$ for 3 hours. After ashing, the resulting sample was allowed to cool and then weighed. The weight of the fibre was calculated as follows:

$$\% \text{ Crude fibre} = \frac{\text{Wt of crucible + dried sample} - \text{Wt of crucible + residue}}{\text{Wt of Sample}} \times \frac{100}{1}$$

(Obigbesan, 1984).

3.7.6 Determination of Phosphorus

Phosphorus was determined using the method as given by Association of Official Analytical Chemists (A.O.A.C, 1980). The apparatus used are electrophotometer and volumetric flask (100ml). The reagents used are vanado – molybdate reagent, phosphorus standard

solution, stock, 100ppm p, phosphorus standard solution, 25ppm p and Distilled water.

Procedure

5ml of sample solution (obtained from ashing) was pipetted into 100ml volumetric flask and 45ml distilled water was added within 5 minutes, 20ml of vanado-molybdate reagent was added and diluted to volume, this was mixed and allowed to standard for 10 minutes. % transmittance at 400ml was determined

A standard curve for phosphorus was obtained after pipetting 0, 2, 4, 5, 10, 15 and 20ml of the 25ppm phosphorus standard solution into a series of 100ml volumetric flasks and the colour was developed according to the same procedure stated earlier. Optical density (O.D) was then plotted against concentration and % phosphorus content calculated in the sample.

3.7.7 Determination of Calcium Content

The Calcium content was determined using the method given by the Association of Official Analytical Chemists (A.O.A.C, 1980). The apparatus and materials used are porcelain dishes, volumetric flasks, beakers, quantitative filter paper, funnel and burette. Reagents used are HCl, HNO_3 (70% dilute), methyl red indicator, ammonium oxalate, Conc. H_2SO_4, permanganate solution (0.05M).

Procedure

25ml of the sample was pipetted and diluted to 100ml by addition of 75ml H_2O. Two drops each of methyl indicator and conc. HCl were added, which gave a pink colour. This was then diluted with 50ml H_2O and boiled for 30 minutes. While boiling, 10ml of 4.2% ammonium oxalate solution was added. The precipitate was allowed to settle out and filtered. The precipitate was washed out with ammonium hydroxide solution (dil.). The filter paper and precipitate were put back in a beaker and a mixture of 125ml H_2O and 5ml H_2SO_4 was added and heated to $70^{o}C$; this was then titrated while hot, against 0.25 KM_nO_7 (standard permanganate solution). % Calcium was calculated as follows:

$$\% \text{ Calcium} = \frac{\text{ml permanganate solution} \times \text{aliquot used} \times 0.1}{\text{Weight of sample} \qquad 250}$$

3.7.8 Determination of Soluble Carbohydrate (nitrogen – free extractive)

Although the Nitrogen – Free Extractive (N.F.E) is often referred to as soluble carbohydrates, it cannot be directly determined. Instead, it must be obtained by subtracting the sum of the ash, crude protein, crude fat and crude fibre, which were obtained and discussed earlier, from 100.

i.e. N.F.E = 100 – (% ash + % crude fat + % crude fibre)

(Obigbesan,1984).

Thus, the figure for N.F.E is affected by any chemical error occurring during the analysis of all the separate factions listed earlier; thus, extra care is taker in the determination of the various factions.

Furthermore, N.F.E. does not constitute a particular substance or group of substances, but instead consists of all the starches and sugars, some semi cellulose and varying proportions of lignin (Obigbesan, 1984).

3.8. Preparation of Neem Leaf Slurry.

Neem (*Azidarachta indica Juss*) leaves were obtained from the neem tree. 1000g of the leaves were weighed and blended with 2 litres of water, resulted in slurry. The slurry was then divided into two. The tubers meant for this treatment, 12 tubers in each barn, were then coated with the slurry. Equal quantity of slurry was used for each tuber. The tuber where then placed carefully on the wooden platform in the barns.

3.9 Preparation of Neem Bark Extract.

Some samples of neem bark were obtained from the neem tree 5kg of neem bark was weighed and soaked in 15 litres of water, this was allowed to stand over night (12 hours). This extract was obtained by filtering with a fine meshed sieve. The resulting extract was divided into two equal halves, one for each barn, and the tubers in each barn, meant for this treatment were individually soaked in the solution for about five minutes and then placed carefully on the wooden platforms.

3.10 Preparation of Chloro Isopropyl Phenyl Carbamate Powder.

CIPC powder was weighed into three different weights, representing three levels for each barn: level 1:1g of CIPC powder/kg tuber, Level 2: 2g of CIPC powder/1kg tuber (as used in the storage of potatoes), Level 3: 3g of CIPC powder/1kg tuber.

Each of these levels had 3 replicates i.e. the 12 tubers were divided into three replicates with four tubers in each. It was properly ensured that the yams were thoroughly coated with the CIPC powder.

3.11 Preparation of Chloro Isopropyl Phenyl Carbamate Solution.

The CIPC solution was measured into three different volumes; 1.5ml, 3ml and 4.5ml, these were diluted with equal quantity of water (100ml) for varying degrees of concentration. Correct measurements were obtained with the use of a syringe. Thus the resulting solutions for each level were: Level 1: 1.5ml CIPC solution/1kg tuber, Level 2: 3ml CIPC solution/1kg tuber, Level 3: 4.5ml CIPC solution/1kg tuber. The prepared solution was sprayed on 12 tubers in each barn: i.e three replicates with four tubers in each. The tubers were evenly sprayed and all surfaces of the tubers were properly covered.

3.12 Analysis of Results

The monthly average values for temperature and relative humidity at 0800h, 1200h, 1600h and 2000h were computed. These values for the entire storage period (6 months) were presented using the line chart.

The average values of sprouting and weight loss for the replicates were computed and subjected to analysis of variance. The means were separated by LSD to determine the effects of the treatments on the tubers. These mean values and analysis of variance were presented on a table. The percentage and number of rotten tubers were also presented on a table.

The average of the 3 replicates for the nutritional values analysed were computed and presented on a table.

CHAPTER FOUR

.0 RESULTS AND DISCUSSION

The results obtained from the experiments carried out are discussed below.

.1 Temperature in the Barns

The Summary of the average temperature in the two barns is as presented in Table 4.1

Table 4.1 Summary of Average Temperature in the Two Barns.

	Barn with fan	Barn without fan
Time (h)	Temp (0^{o}C)	Temp (0^{o}C)
0800	27.08	29.92
1200	30.83	33.58
1600	33.5	35.5
2000	29.75	31.5

The temperature in the barn with fan fluctuated between 27.08 and 33.5^{0}C with an average of 29^{0}C while that in the barn without fan fluctuated between 29.92 and 35.5^{0}C, with an average of 33^{0}C over the storage period. The average temperature in the barn with fan was 4^{0}C less than in the barn without fan.

Figure 2 shows that the barn without fan had the highest temperature (35.5^{0}C) at 1600h while the barn with fan had a temperature of (33.5^{0}C) at the same period. The barn with fan had the lowest temperature (27.08^{0}C) at 0800h while that of barn without fan was 29.92^{0}C during the same period.

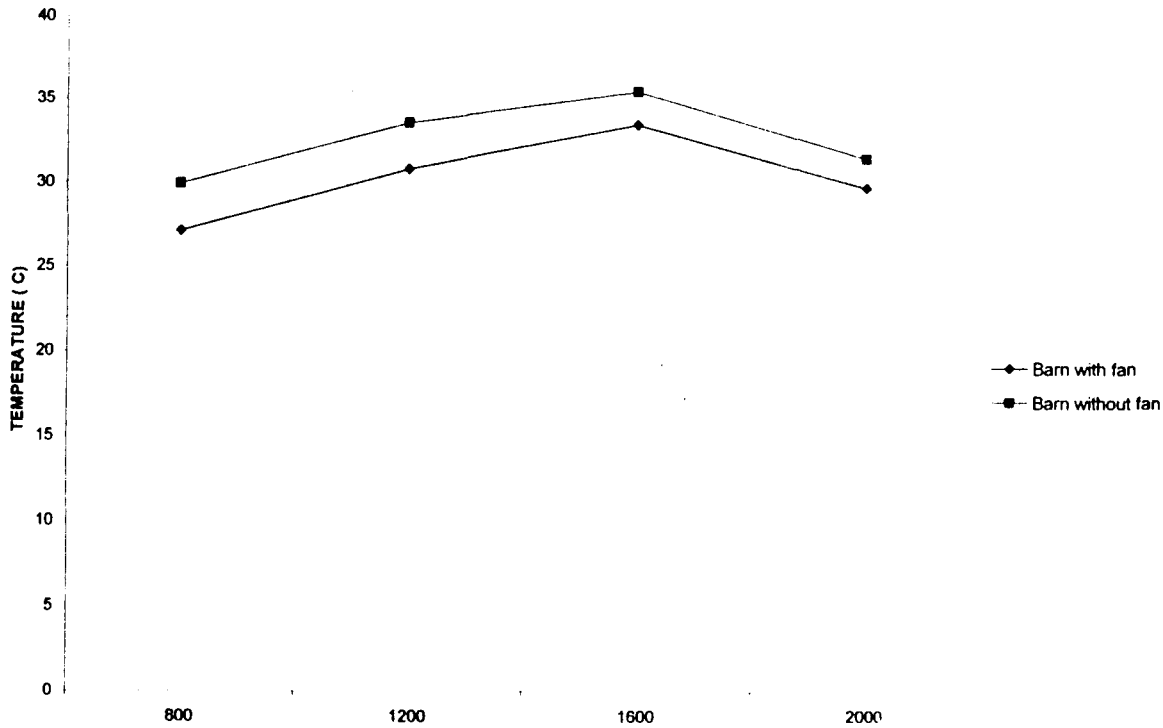

FIG 2: AVERAGE TEMPERATURE IN THE TWO BARNS

The difference in temperature between the two barns may be attributed to the presence of fan which helped to improve airflow and this may have led to the slight decrease observed in the temperature inside the barn with fan as compared with barn without fan.

4.2. Relative Humidity in the Barns

The Summary of the average relative humidity in the two barns is as presented in Table 4.2

Table 4.2 Summary of Average Relative Humidity in the Two Barns.

	Barn with fan	Barn without fan
Time (h)	R.H (%)	R.H (%)
0800	45.58	48.18
1200	37.33	40.92
1600	33.67	37.83
2000	36.92	40.12

The relative humidity in the barn with fan ranged between 33.67 and 45.58% with an average of 39% while that in the barn without fan ranged between 37.83 and 48.18% with an average of 43% over the storage period. The average relative humidity in the barn with fan was 4% less than in the barn without fan.

Figure 3 shows that the barn with fan had the lowest relative humidity (33.67%) at 1600H while the barn without fan had 37.83% during the same period.

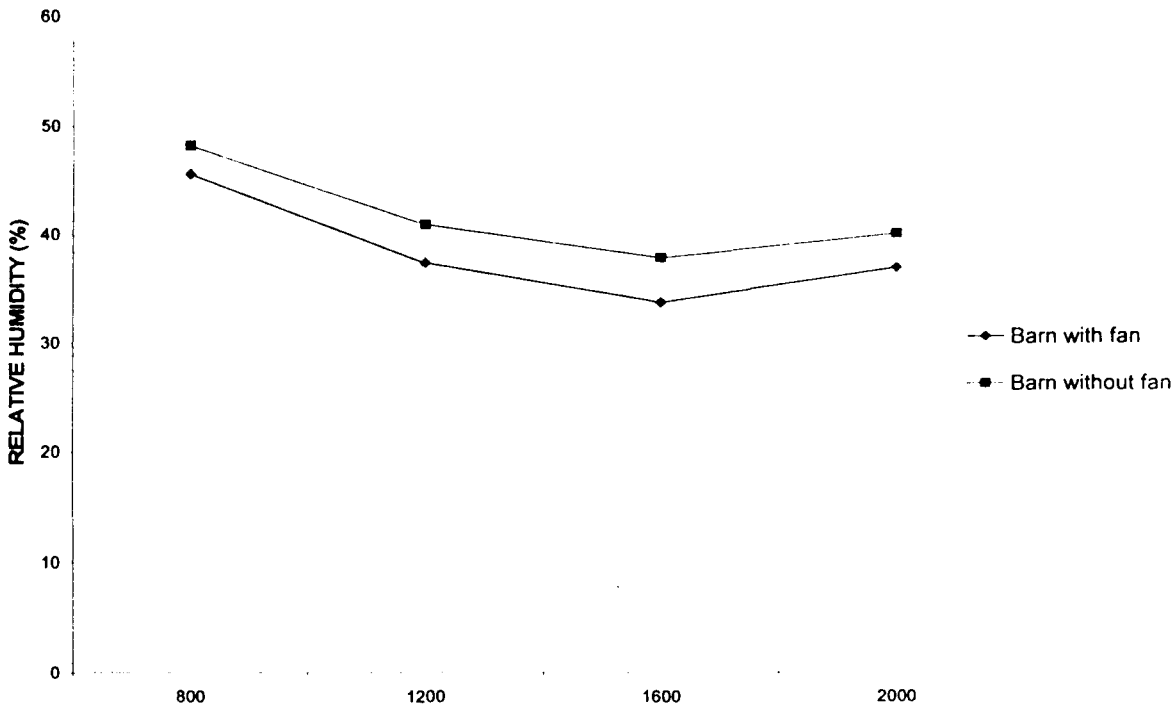

FIG 3: AVERAGE RELATIVE HUMIDITY IN THE TWO BARNS

The difference of 4% relative humidity noticed between the two barns may be attributed to the presence of fan in the barn with fan which helped

in the dispersion of accumulated hot air on and around the surface of the yam tubers.

4.3. Effect of CIPC Solution on Sprouting of Stored Yam Tubers.

The summary of average sprout weights of yam tubers treated with CIPC solution is as presented in Table 4.3

Table 4.3 Summary of Average Sprout Weights of Yam Tubers Treated with CIPC Solution.

	CIPC Solution			
	1.5ml	3ml	4.5ml	Control
Barn with fan	7.65	16.49	13.61	19.73
Barn without fan	18.02	21.12	30.05	27.17

Figure 4 shows the sprout weights of tubers treated with CIPC solution at three levels and the control in barn with fan. At the beginning of the storage period, specifically, the first 3 months (January, February and March) there was no particular difference in the sprout growth of the tubers, but from the 4th month (April), it was observed that the control had the highest sprout weights. In June there were no sprout growths, this could be as a result of the regular removal of sprouts as Mozie (1983), reported that regular removal of sprouts subsequently leads to inability of the tubers to sprout any longer.

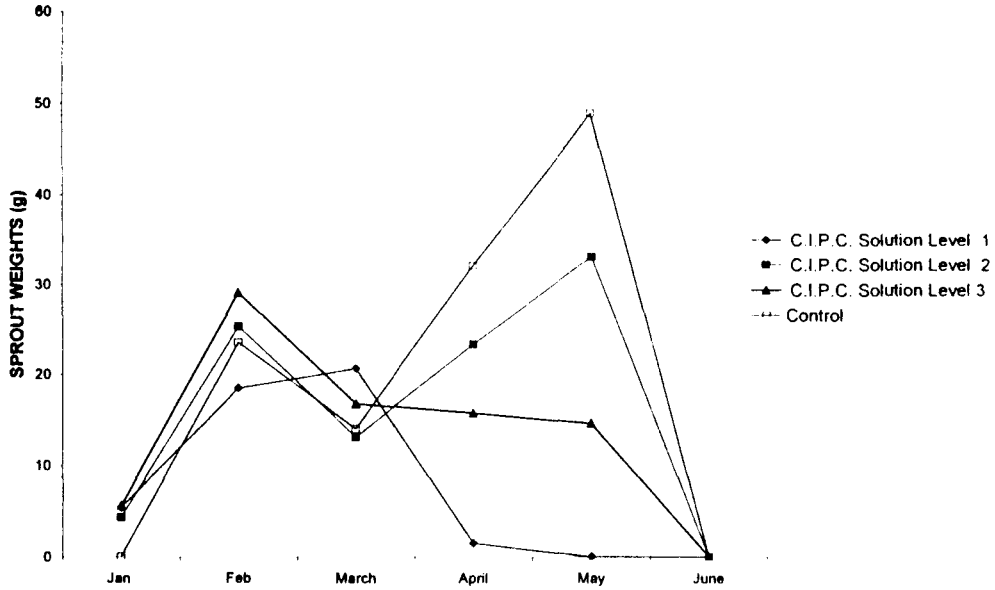

FIG 4: MONTHLY AVERAGE SPROUT WEIGHTS OF TUBERS TREATED WITH CIPC SOLUTION (BARN WITH FAN)

Figure 5 shows the rate of sprouting of tubers treated with CIPC solution at three levels and the control in barn without fan. No distinct pattern of sprout growth could be observed among the various levels of treatments used throughout the period of storage. It could be deduced from the figure, that the CIPC solution had no effect on sprout suppressing in stored yam tubers *(Dioscorea Rotundata).* The lack of sprouting in June could be as a result of the drop in temperature at that period (May/June) due to the on set of the rains, since high temperature predisposes tubers to sprouting and vice versa (Mozie,1988).

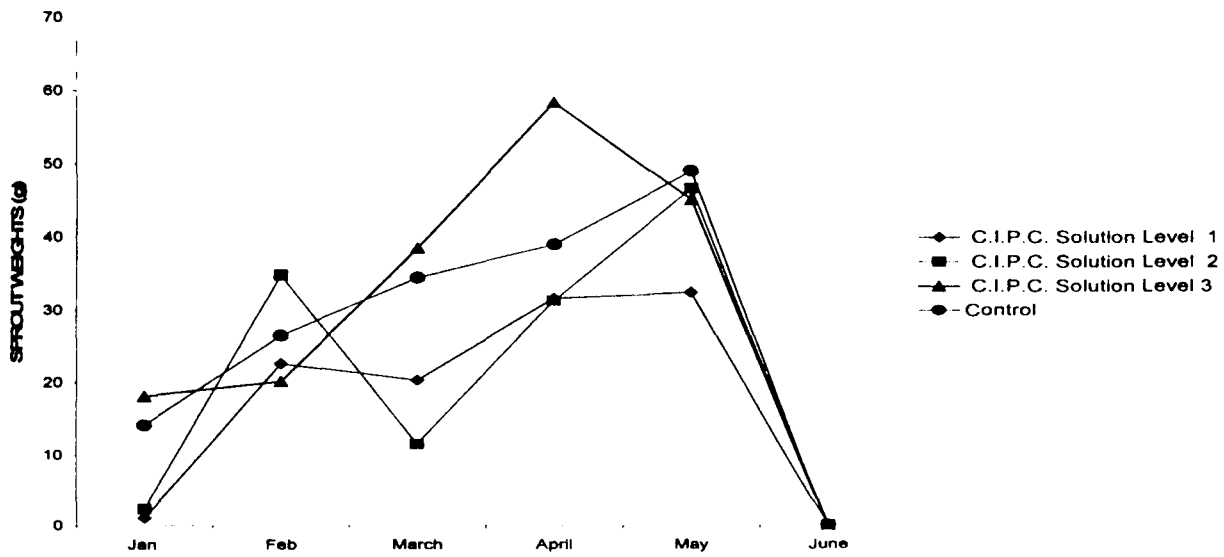

FIG 5: MONTHLY AVERAGE SPROUT WEIGHTS OF TUBERS TREATED WITH CIPC SOLUTION (BARN WITHOUT FAN)

Table 4.4 shows the 4x2 factorial experiment in a completely randomized design with three replicates for the experiment.

Table 4.4 Effect of CIPC Solution on Sprouting of Stored Yam Tubers.

		CIPC Solution					
orage ondition	**Replication**	**1.5ml**	**3ml**	**4.5ml**	**Control**	**Total**	**Mean**
	1	10.63	19.10	13.16	18.09	58.98	14.75
	2	2.09	25.06	9.76	3.63	40.53	10.13
B1	3	20.24	7.3	17.94	28.38	73.86	18.47
	Total	**32.96**	**49.46**	**409.85**	**50.11**	**173.35**	**43.34**
	Mean	10.99	16.49	13.62	16.7	57.8	
	1	19.75	22.26	15.19	10.81	68.01	17.00
B2	2	16.97	31.41	30.32	31.81	110.51	27.63
	3	17.35	9.74	44.65	24.86	96.6	24.15
	Total	**54.07**	**63.4**	**90.16**	**67.48**	**275.12**	
	Mean	18.02	21.14	30.05	22.49	91.71	
	Total	**57.03**	**112.87**	**131.01**	**117.59**	**448.5 =Y**	
	Means	14.51	18.81	21.84	19.60		

B1 = Barn with fan B2 = Barn without fan

The analysis of variance for the effect of CIPC solution on sprouting of the stored yam tubers is shown in Table 4.5

Table 4.5 ANOVA of the Effect of CIPC Solution on Sprouting of Stored Yam Tubers.

ɔurces of Variation	**df**	**ss**	**ms**	**Fcal**	**Ftab**	**Remarks**
·eatment Combinations	8 - 1= 7	230.77	328.824	0.0335	2.66	ns
ıctor A (CIPC Solution)	4 – 1 = 3	42920.9219	14306.98	1.44585	3.21	ns
ıctor B (Barn type)	2 – 1 = 1	97,370.295	97,370.295	9.926	4.49	*
ıteraction AB	3 x 1 = 3	18957.8128	6319.27	0.644	3.21	ns
rror	4x2(3-1)=16	156,947.2597	9809.204			
otal	(4x2x3)-1=23					

ns = not significant * = Significant

Since Fcal<Ftab for treatment combinations, CIPC solution (factor A) and interaction, AB, it implies that the treatment combination, CIPC solution (factor A) and interaction of factors, AB, had no significant effect on sprouting of the stored yam tubers. The table shows that Fcal>Ftab for barn type (factor B), this implies that the barn type has a significant effect on sprouting of the stored yam tubers.

It can therefore be concluded that the CIPC solution (factor A) had no significant effect on sprouting of the stored yam tubers; even though it is being used to suppress sprouting in potatoes, and was also used to delay sprouting in *D.alata* tubers (Osagie, 1992); this may be due to the chemical, genetical and Physiological composition of the yam *(Dioscorea rotundata)* tuber and also the environmental conditions, as potatoes are stored at 4^0C and 65 – 75% relative humidity.

4.4 Effect of CIPC Powder on Sprouting of Stored Yam Tubers.

The summary of average sprout weights of yam tubers treated with CIPC powder is as presented in Table 4.6

Table 4.6 Summary of Average Sprout Weights of Yam Tubers Treated with CIPC Powder.

	CIPC Powder			
	1g	2g	3g	Control
Barn with fan	12.18	15.55	20.33	19.58
Barn without fan	15.16	27.81	17.24	27.17

Figure 6 shows the sprout weights of tubers treated with CIPC powder at three levels and the control in barn with fan. At the first and second months of storage (January and February) there was no remarkable difference in the sprout weights of the tubers irrespective of levels of treatments. However, by March, the CIPC powder (level 3) tubers had the highest sprout weights while the control had the lowest at that particular time. In May the control had the highest sprout weight while the CIPC powder (level 1) tubers had the lowest sprout weights.

There were no sprout growths in June, this lack of sprouting could be as a result of the drop in temperature at that period (May/June) due to the on set of the rains, since high temperature predisposes tubers to sprouting and vice versa (Mozie,1988).

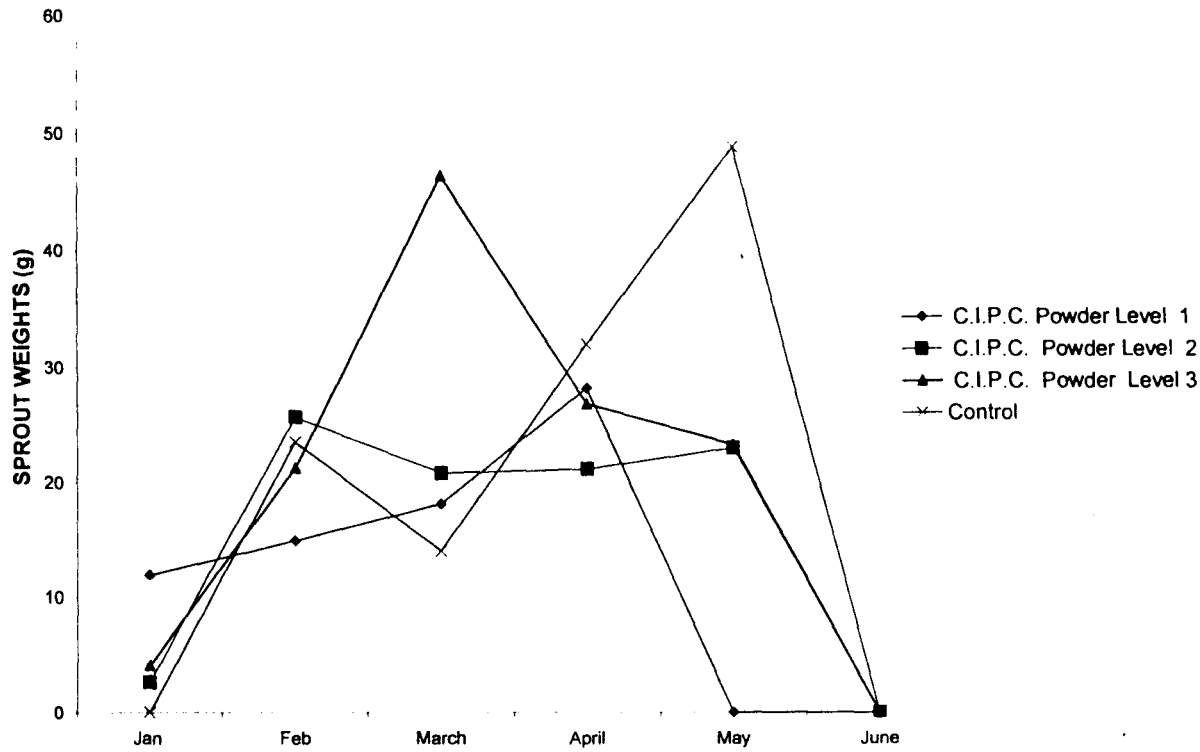

FIG 6: MONTHLY AVERAGE SPROUT WEIGHTS OF TUBERS TREATED WITH CIPC POWDER (BARN WITH FAN)

Figure 7 shows the sprout weights of tubers treated with CIPC powder at three levels and the control in barn without fan. From the figure, CIPC powder (Levels 1 and 3) showed low sprout weight throughout the storage period while CIPC powder (level 2) and the control had the highest level of sprout weights.

In June there were no sprout growths, this could be as a result of the regular removal of sprouts as Mozie (1983), reported that regular removal of sprouts subsequently leads to inability of the tubers to sprout any longer.

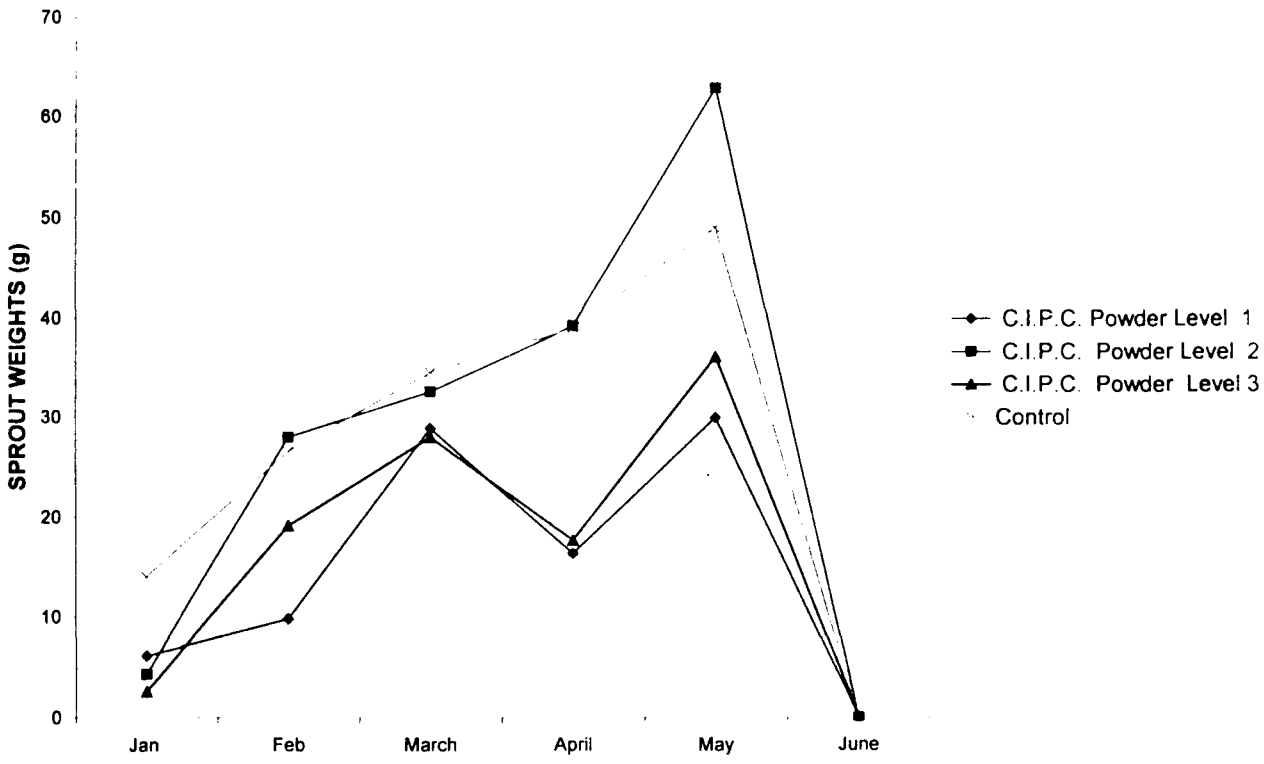

FIG 7: MONTHLY AVERAGE SPROUT WEIGHTS OF TUBERS TREATED WITH CIPC POWDER (BARN WITHOUT FAN)

Table 4.7 Shows the 4x2 factorial experiment in a completely randomized design (CRD) with three replicates for the experiment.

ıble 4.7 Effect of CIPC Powder on Sprouting of Stored Yam Tubers.

		CIPC Powder					
rage Condition	**Replication**	**1g**	**2g**	**3g**	**Control**	**Total**	**Mean**
	1	15.06	21.02	21.57	18.09	75.74	18.94
	2	14.72	11.16	14.36	3.63	43.87	10.97
B1	3	6.88	14.46	25.05	28.38	74.77	18.70
	Total	36.66	**46.64**	**60.98**	**50.1**	**194.38**	**48.61**
	Mean	12.22	15.55	20.33	16.7	64.79	16.2
	1	20.82	25.5	21.55	10.81	78.68	19.67
B2	2	13.18	22.07	17.12	31.81	84.18	21.05
	3	11.48	35.87	13.9	24.86	86.11	21.53
	Total	**45.48**	**83.44**	**52.57**	**67.48**	**248.97**	**62.24**
	Mean	15.16	27.81	17.52	22.49	82.98	20.75
	Total	**82.14**	**130.08**	**113.55**	**117.58**	**443.35=Y**	
	Mean	13.69	21.68	18.93	19.60	73.90	

B1 = Barn with fan B2 = Barn without fan

The analysis of variance for the effect of CIPC powder on sprouting of the stored yam tubers is shown in Table 4.8

Table 4.8 ANOVA of the Effect of CIPC Powder on Sprouting of Stored Yam Tubers

ɔurces of Variation	**df**	**ss**	**ms**	**Fcal**	**F tab**	**Remarks**
ːeatment Combinations	7	1381.576	197.368	0.0210	2.66	ns
actor A (CIPC Solution)	3	42196.45	14065.492	1.4973	3.21	ns
actor B (Barn type)	1	91579.68	91579.68	**9.7490**	4.49	*
ıteraction AB	3	17905.665	5968.555	0.6354	3.21	ns
ırror	16	150300.2439	9393.765			
ʾotal	23					

ns = not significant * = significant

Since Fcal<Ftab for treatment combinations, CIPC powder (factor A) and interaction, AB, it implies that the treatment combination, CIPC powder (factor A) and interaction of factors, AB, had no significant effect on sprouting of the tubers. On the other hand, the table indicates that Fcal>Ftab for barn type (factor B), this implies that the barn type has a significant effect on sprouting of the stored yam tubers.

Therefore, it can be concluded that the CIPC powder (factor A), had no significant effect on sprouting of the stored yam tubers. Thus, it is seen that the CIPC solution and powder had no effect on sprouting in the yam (*Dioscorea rotundata*).

4.5. Effect of Neem Extract on Weight Loss of Stored Yam Tubers

The summary of average weights loss of yam tubers treated with neem extract is as presented in Table 4.9

Table 4.9 Summary of Average Weights loss of Yam Tubers Treated with Neem Extract

	Neem Extract		
	Bark Extract	Leaf Slurry	Control
Barn with fan	18.12	12.78	15.22
Barn without fan	23.02	11.0	16.52

Figure 8 shows the percentage weight loss of tubers treated with neem tree extract in barn with fan while Figure 9 shows that of the barn without fan. Fig. 8 indicates that the neem bark extract tubers had the highest weight loss throughout the six months period of storage while those treated with neem leaf slurry had the lowest weight loss generally; similar observation was made in the barn without fan (Fig 9) The neem bark extract tubers had the highest weight loss generally while the neem leaf slurry tubers recorded the lowest weight loss through out the storage period.

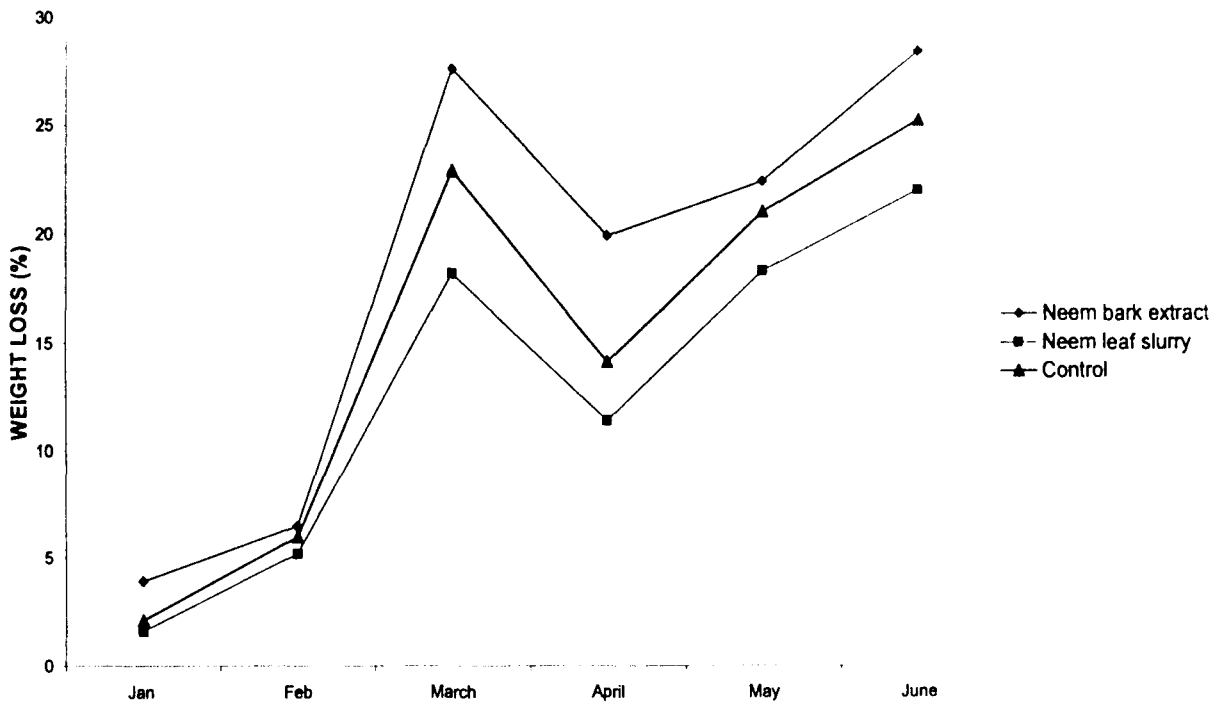

FIG 8: MONTHLY AVERAGE PERCENTAGE WEIGHT LOSS OF YAM TUBERS TREATED WITH NEEM TREE EXTRACTS (BARN WITH FAN)

It can be seen from the table, that the mean difference computed for bark extract and leaf slurry is greater than the LSD values at 0.05% level of significance, this was also the case, for leaf slurry and control, thus, the means for bark extract and leaf slurry and that of leaf slurry and control are significantly different.

The mean difference computed for bark extract and control less is less than the LSD values at 0.05% level of significance, thus, the means is not significantly different. It can therefore be concluded from the above that the leaf slurry had a greater significant effect on weight loss of the stored yam tubers. The satisfactory result showed by the effect of the neem leaf slurry agrees with the findings by Ibrahim *et al.*,1987; Schmutter *et al.*, 1980 and Warthem, 1979.

4.6. Effect of Neem Extract on Sprouting of Stored Yam Tubers.

The summary of average sprout weights of yam tubers treated with neem extract is as presented in Table 4.13

Table 4.13 Summary of Average Sprout Weights of yam Tubers Treated with Neem Extract

	Bark Extract	Leaf Slurry	Control
Barn with fan	9.15	12.68	19.73
Barn without fan	19.13	16.45	27.18

Figure 10 shows the sprouting rate of yam tubers treated with neem tree extract in barn with fan. Sprouting was high in the control as compared with the neem tree extract tubers. The neem bark extract tubers generally had the lowest sprout weights (lowest rate of sprouting), followed by the neem leaf slurry tubers

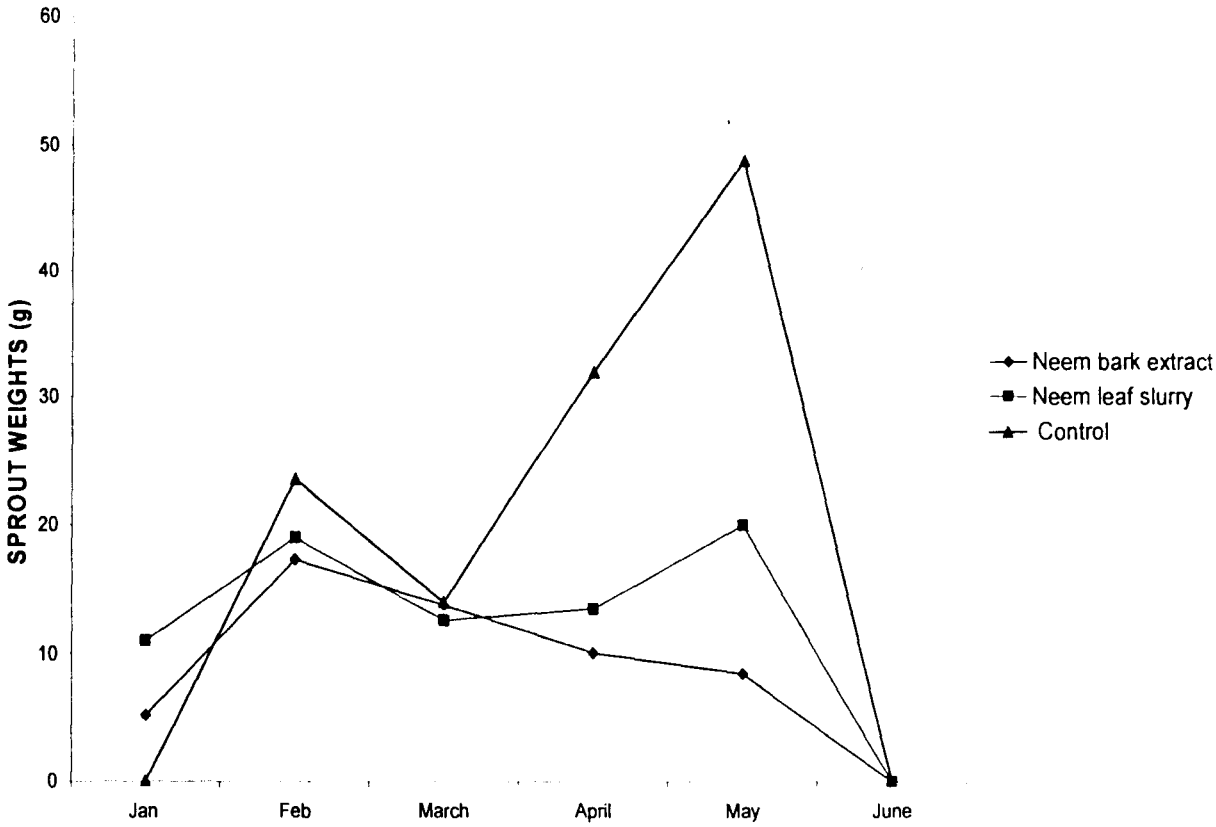

FIG 10: MONTHLY AVERAGE SPROUT WEIGHTS OF TUBERS TREATED WITH NEEM TREE EXTRACTS (BARN WITH FAN)

Sprouting started at the end of January and was highest at the end of March for the neem tree extract tubers; the control recorded the highest sprout weight at the end of the storage period. The rate of sprouting reduced and eventually tapered off completely at the sixth month of

storage (June), this could be due to temperature change (i.e. decrease in temperature as a result of the rains) and the regular removal of sprouts.

Figure 11 shows the rate of sprouting of neem tree extract tubers in the barn without fan. As with what obtained in the barn with fan, the control had the highest sprout weights, averagely, however there was no district or remarkable difference between the tubers treated with the neem leaf slurry and neem bark extract, as both treatments showed low sprout weights. Ibrahim *et al.* (1987), reported that neem tree extract treatment have favourable effect on sprouting as they were able to suppress sprouting for five months in stored yam tubers *(Dioscorea Roundata).*

The lack of sprouting observed in June could be due to temperature change (i.e. decrease in temperature as a result of rains) and the regular removal of sprouts.

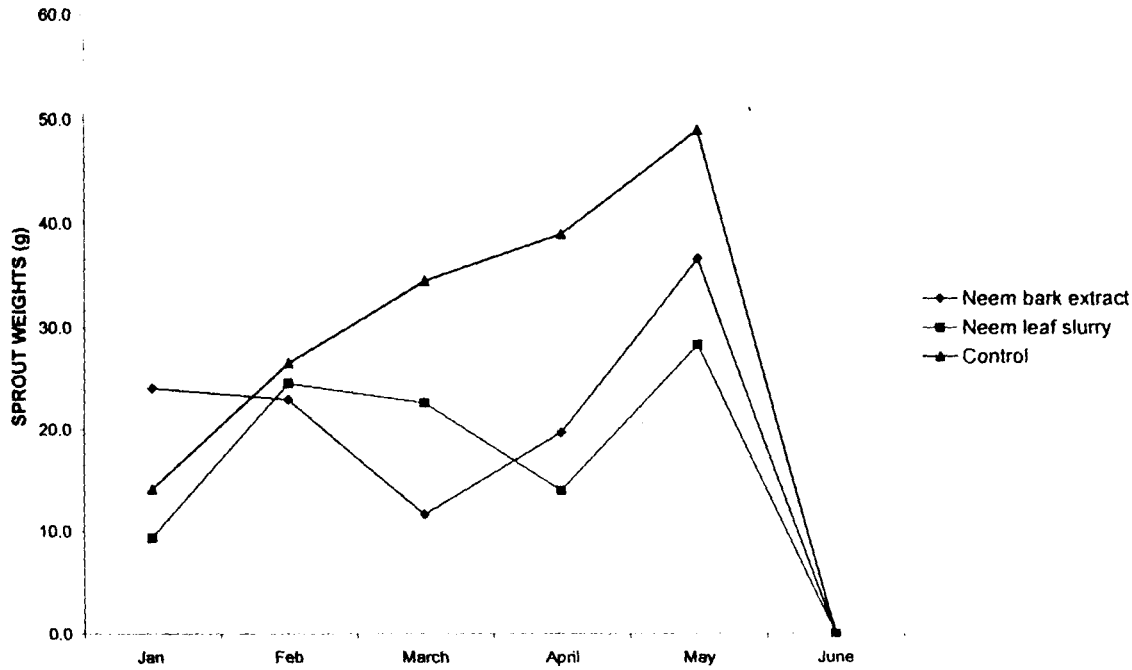

FIG 11: MONTHLY AVERAGE SPROUT WEIGHTS OF TUBERS TREATED WITH NEEM TREE EXTRACT (BARN WITHOUT FAN)

Table 4.14 shows the 3x2 factorial experiment in a completely randomized design (CRD) with 3 replicates for the experiment.

Table 4.14 Effect of Neem Extract on Weight loss of Stored Yam Tubers

		Neem Extract				
Storage Condition	**Replication**	**Bark Extract**	**Leaf Slurry**	**Control**	**Total**	**Mean**
	1	11.31	15.18	18.09	44.58	14.86
	2	12.16	15.16	3.63	30.95	10.32
B1	3	10.76	9.33	28.39	48.48	16.16
	Total	**34.23**	**39.67**	**50.11**	**124.01**	
	Mean	11.41	13.22	16.70	41.34	
	1	20.48	7.38	10.81	38.67	12.89
B2	2	29.60	9.69	31.81	71.1	23.7
	3	14.39	14.43	24.86	53.68	17.89
	Total	**64.47**	**31.50**	**67.48**	**163.45**	**54.4**
	Mean	21.49	10.50	22.49	287.46 = Y	
	Total	98.7	**71.17**	**117.59**	**47.91**	
	Means	**16.45**	11.86	19.60		

B1 = Barn with fan B2 = Barn without fan

The analysis of variance for the effect of neem extract on sprouting of stored yam tubers is shown on Table 4.15

Table 4.15 ANOVA of the Effect of Neem Extract on Weight Loss of Stored Yam Tubers

Sources of Variation	**df**	**ss**	**ms**	**Fcal**	**Ftab**	**Remarks**
Treatment Combinations	7	1100.54	157.22	0.0379	2.66	ns
Factor A (Neen Extract)	3	24043.53	18014.51	**4.346**	3.21	*
Factor B (Barn type)	1	37503.64	27503.64	**9.047**	4.49	*
Interaction AB	3	58881.78	1960.59	0.473	3.21	ns
Error	16	66,328.41	4145.52			
Total	23					

ns = not significant * = significant

The table shows that Fcal<Ftab for treatment combinations and interaction of factors, AB, this implies that the treatment combination and interaction of factors, AB, have no significant effect on sprouting of the stored yam tubers. On the other hand, Fcal>Ftab for neem extract (factor A) and barn type (factor B), this implies that the neem extract (factor A) and the barn type (factor B) both have significant effect on sprouting of stored yam tubers. Thus, their means were separated by LSD to determine which of the neem extract (bark extract and leaf slurry) had greater effect on sprouting of the stored yam tubers. The analysis of variance table for the LSD method is as presented on table 4.16

Table 4.16 Analysis of Variance Table for Neem extract on Sprouting using F – LSD Method.

Sources of variation	Sum of Squares	Degree of Freedom	Mean Differences	LSD Values at 0.05% Variances	Remarks
Between Bark Extract and Leaf Slurry	6090.3	2	13.76	20.44	ns
Between Bark Extract and Control	9468.8	2	9.45	19.78	ns
Between Leaf slurry and Control	7403.6	2	23.20	22.92	*

ns = not significant * = significant

It can be seen from the table, that the mean difference computed for leaf slurry and control is greater than the LSD values at 0.05% level of significance. This means that the means for leaf slurry and control are significantly different. The mean difference computed for bark extract and leaf slurry , and that of bark extract and control were less than the LSD values at 0.05% level of significance, thus, they are not significantly different.

It can therefore be concluded that leaf slurry had a greater significant effect on sprouting of the stored yam tubers. The observations of the effect of the neem tree extract treatments on yam sprouting suggest that there are some factors in the different neem preparations which affected the rate of sprouting and thus led to the reduced rate of sprouting observed in these neem tree extract tubers.

4.7 Effect of Neem Extract on Rotting of Stored Yam Tubers.

Table 4.17 is the summary of rotten tubers in each barn, for neem extract treatments.

Table 4.17 Effects of Neem extract on Rotting.

	Neem Bark Extracts	Neem Leaf Slurry	Control
Barn with fan	1 (0.93%)	Nil	Nil
Barn without fan	2 (1.85%)	2 (1.85%)	Nil
Total	3 (2.7%)	2 (1.85%)	Nil

From the table, it is observed that the neem extract had 5(4.63%) rotten tubers, while the control had none. The leaf slurry had fewer numbers of rotten tubers, 2(1.85%) than the bark extract, 3(2.78%). Ibrahim *et al.(*1987), reported that there may be some factors in the different neem preparations that predisposes the tubers to rotting, since the active compounds of neem being natural substance may decompose rapidly especially under tropical conditions.

However Williams and Akano (1985), reported that yam tubers coated with ash slurry did not rot throughout the storage period; but in this study, the neem extract treatment showed little effect in rot prevention, but this could be improved by providing adequate ventilation to prevent the accumulation of unwanted heat around, or on the yam tubers, which could predispose them to rotting.

4.8. Effect of Treatments on the Nutritional Composition of the Stored Yam tubers.

Tables 4.18 and 4.19 show the nutritional composition of the tubers before storage, after three months and after six months of storage in the two barns. It was observed that the values of the nutritional content in the yam tubers changed over the period of storage in both barns. From the tables, it can be observed that the different treatments used, had no effect

on the nutritional content of the tubers. Significant reductions in moisture, crude protein, phosphorus and calcium content occurred throughout the period of storage in both barns. Mozie (1984), and Onayemi and Idowu (1988), observed decreased moisture and protein levels in stored yam tubers.

Generally, carbohydrate decreased slightly during the period of storage in both barns. Osunde *et al.* (2003), reported that the carbohydrate content of yam tuber decreases during storage due to conversion of starch to sugar, and respiratory losses of sugar as carbondioxide. Differences were observed in moisture, ash, crude protein, phosphorus and calcium content between the two barns.

Table 4.18 Nutritional Composition of fresh and stored yam tubers (Barn with fan)

Period	Before storage	3 months after storage.					Six months after storage				
		Neem bark extract	Neem leaf slurry	CIPC Solution	CIPC powder	Control	Neem bark extract	Neem leaf slurry	CIPC Solution	CIPC Powder	Control
Constituents											
Moisture %	71	68.51	67.64	66.0	65.74	66.39	59.87	55.43	52.64	59.05	56.03
Carbohydrate (g)	24.6	23.82	22.15	23.14	24.77	24.78	20.74	21.85	20.62	20.83	21.4
Ash (g)	1.2	1.13	1.29	1.18	1.3	1.02	1.33	1.19	1.07	1.41	1.37
Crude Protein (g)	2.6	2.52	2.36	1.94	1.38	1.28	2.12	1.95	1.42	1.07	0.94
Phosphorus (mg)	18	8.42	6.08	6.26	6.65	6.15	9.34	6.21	6.82.	5.99	5.77
Calcium (mg)	12.2	4.99	5.02	5.18	5.16	4.31	4.58	5.11	5.22	5.41	4.23
Crude fibre %	0.95	1.47	1.26	0.89	1.08	1.31	1.24	1.02	0.93	1.04	1.13
Crude Fat (g)	0.27	0.20	0.15	0.23	0.20	0.30	0.19	0.11	0.17	0.14	0.27

Table 4.19 Nutritional Composition of fresh and stored yam tubers (Barn without fan)

		3 months after storage.					Six months after storage				
Period	Before storage	Neem bark extract	Neem leaf slurry	CIPC Solution	CIPC powder	Control	Neem bark extract	Neem leaf slurry	CIPC Solution	CIPC Powder	Control
Constituents											
Moisture %	71	67.26	67.80	62.49	62.36	61.97	55.19	55.13	52.49	55.98	51.49
Carbohydrate (g)	24.6	23.43	22.9	23.9	25.63	24.18	23.31	20.86	21.75	22.61	21.7
Ash (g)	1.2	0.65	0.94	0.71	0.83	0.55	1.19	1.26	1.83	1.33	1.32
Crude Protein (g)	2.6	2.32	1.94	1.87	1.29	1.01	1.62	1.38	1.28	1.01	1.0
Phosphorus (mg)	18	5.92	5.55	6.13	6.37	6.12	7.06	6.14	6.78	6.46	6.05
Calcium (mg)	12.2	1.21	0.98	1.23	1.20	1.97	4.93	4.08	5.37	4.21	5.05
Crude fibre %	0.95	1.53	1.36	1.45	1.94	2.31	1.32	1.25	1.18	1.07	1.15
Crude Fat (g)	0.27	0.15	0.10	0.2	0.18	0.15	0.20	0.15	0.22	0.2	02

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study was carried out to determine the effects of different pre-storage treatments and storage conditions on stored yam tubers. The results showed that the CIPC solution and powder did not have any effect on suppressing sprouting in *D. rotundata* tubers. The neem tree extract had significant effect on weight loss and sprouting of the stored yam tubers; with the leaf slurry having a greater influence than the bark extract. Weight loss of the yam tubers was more influenced than sprouting. The neem extracts had little effect on rotting, since they did not prevent rotting of the stored yam tubers.

From the study, it can be observed that the different treatment used had no significant effect on the nutritional parameters. There were significant reductions in moisture, crude protein, phosphorus and calcium content throughout the period of storage, also, carbohydrate decreased slightly during the storage period.

5.2 RECOMMENDATIONS

Based on the work done, the following recommendations are made:

1. The use of Chloro Isopropyl Phenyl Carbamate (CIPC) chemical in combination with low temperature and high relative humidity as used in the successful storage of potatoes; need to be further investigated for use in the storage of other varieties of yam tubers.
2. The precise quantity, concentration and application rate of Neem tree extract that would give excellent preservation of yam tubers should be further investigated.
3. Cost effectiveness of bi-weekly or monthly sprout removal during storage should be investigated.
4. Farmers should be encouraged and sensitized on the effectiveness of bark extracts on sprout suppressing and weight loss reduction.
5. Neem extract should be used where adequate ventilation is provided to reduce or prevent rotting of the yam tubers. It is recommended that the storage structures be built in a shady, cool and well ventilated area, also they should be built in such a way that they are well aerated and away from heat.

6. Further work may be carried out to find out the effect of different rates of air flow on the quality of stored yam tubers.

REFERENCES.

Adesiyan, S. O. (1977). Studies on the Effect of Gamma Radiation (from Cobalt 60 source) on Storage life of white yam (*Discorea rotundata* Var. efon) Infected with *scutellonema bradys Ann. App.l Biol* 86, 213 – 218.

Adesuyi, S. A. (1971). Curing Techniques for Reducing the Incidence of Rot in Yams during Storage. Rep. Nig. Stored products Research Inst. (1973) Pp 57 – 63

Adesuyi, S. A. (1973). Advances in Yam Storage Research in Nigeria. 3rd International Symposium. Tropical Root Crops. Ibadan, Nigeria. Pp 51 – 60.

Adesuyi, S. A. and Mackenzie, J. A. (1973). The Inhibition of Sprouting in Stored Yams, *Discorea rotundata* poir, by Gamma Radiation and Chemicals.

Adesuyi, S. A. (1975). Investigations in the Storage Physiology of Yam Tubers *(Discorea rotundata* Poir) with Special Reference to the Control of Sprouting. Ph.D Thesis, University of Ibadan, Nigeria. Pp 317.

Adesuyi, S.A. (1978). Effectiveness of Gamma Radiation for Inhibition of sprouting in stored yam tubers (*D. rotundata* poir) Rep. Nigerian stored Prod. Res. Inst. 1975/ 76 Tech. Rep. No. 6 pp 39- 44

Adesuyi, S. A (1979). The Effect of Different Environmental Conditions on the Respiration Patterns of Stored Yam Tubers (*Discorea rotundata* poir) Rep. Nigerian Stored Prod. Res. Inst. (1976 – 77).

Adesuyi, S. A. (1982). The Application of Advanced Technology to the Improvement of Yam Storage. Yams: *Ignames* (Miege, J. and Lyonga, S. N, eds), Pp. 312 – 319. Oxford: Oxford University Press, 411 Pp.

Akalusi, D.O., Opadokun, J.S., Ogali, E.I. and Okobi, A.O. (1986). Chemical Trials on the Storage of White Yam (*Discorea rotundata)* Tubers Rep. Nigerian Stored Prod. Res. Inst. 1, 2-37.

Akinnusi, O. A., Oyeniran, J.O. and Sowunmi, O. (1984). Effect of Chemical Treatment on Yams Stored in an Improved Yam Barn. Rep. Nigerian Stored Prod. Res. Inst. (1981). 69 -77.

Anderson, J. M and Igram, J. S. I (1989). A Handbook of Methods of Analysis. C. A. B International Pp 39.

Association of Official Analytical Chemists (AOAC) (1980). Official Methods of Analysis. Ed. 11, Washington, D.C.S

Been, B. O., Perkins, C., and Thompson, A. K. (1977). Yam Curing for Storage. Acta Hortic 62, 311 – 316.

Bridge, J. (1982). Nematodes of Yams. Yams: *ignames* (Miege, J. and Lyonga, S. N; eds) Pp 253 – 264. Oxford: Oxford University press Pp 441.

Burkil, I. H (1970). The Organography and the Evolution of *Dioscoreceae*, the Family of the Yams. J. Linn. Soc. (Bot) 56, 319 – 420.

Burton, W. G. (1978). Post – Harvest Behaviour and Storage of Potatoes. Applied Biology Vol. 111 (T. H. Coaker eds). Academic Press, London Pp. 86 – 228.

Carter, S. E; Fresco, L.O., Jones, P. G. and Faibairn, J. N. (1992). An Atlas of Cassava in Africa. Historical, Agroecological and Demographic Aspects of Crop Distribution. C. I. A. T, Cali, Columbia. Pp 86.

Coursey, D. G. and Walker, H. M. (1975). A study of the Origins of Weight Losses in Stored Yams. Rep. Nigerian Stored Prod. Res. Inst. Tech. Rep. No 17, 61 – 64.

Coursey, D. G. (1976). The Origin and Domestication of Yams in Africa. World Anthropology. (Harlan, J.R., Wet, M..J. and Stemler, A. B. L., eds). Pp 385 – 408.

Coursey, D. G (1976). Yams. In "Evolution of Crop Plants" (N. W. Simmonde, ed.) London, Longinans, Pp 70 – 74.

Coursey, D. G (1983). Yams. In Handbook of Tropical Foods. (H. V. Chan, ed.) Marcel Dekker, Inc. New York and Basel. Pp 555 – 601. Demeaux, M. and Viver, P. (1984) Methods Modernes dc Conservation des Ignames. L' Agronomie Tropicale 39, 186 – 191.

Diehl, L. (1981). Small Holder Farming Systems with Yams in the Southern Guinea Savannah of Nigeria. Eschbon, GTZ (Gesellschaft fur Technische Zusammenarbeit).

Dina, S. O. (1977). Occurrence of *Dasyes rugosella stainton* (Lepiodoptera: Tineidae) on Stored Yam Tubers in Nigeria. Trop. Sci. 19, 113 – 116.

Diop, A. G and Calverly, D. J. (1998). Food and Agriculture Organisation of the United Nations, Agro – Industries and Post–Harvest Management Service, Agriculture Support System Division.

Ene, L.S.O and Okoli, O.O (1985). Yam Improvement Genetic Consideration and Problems. Biochemical Society of Nigeria in Collaboration with Anambra State University of Technology, Enugu. Pp 45 -347.

F A O, (1981). Food and Agriculture Organization of the United Nations, Rome.

FAO, (1990). Production Year Book. Food and Agriculture Organization of the United Nations, Rome. Vol 59.

F A O (1995). Food and Agriculture Organization of the United Nations, Agro – Industries and Post – Harvest Management Service, Agriculture Support System Division.

Ferguson, T. U. (1977). Tuber Development in Yams; Physiological and Agronomic Implications. Proceedings of the 3rd Symposium of the International Society for Tropical Root Crops (Nigeria, 1973) (Leakey, C. L. A., ed.), Pp 72 -77.

Franklin, W. M. (1977). Prolonging the Storage Life of Yams by Removal of Shoots and by Treatment with Gibberelic Acid and Waxes. Tropical Root and Tuber Crops Newsletter No 10, Pp 39 – 44.

Gonzales, M. A., and Collazo de Rivera, A. (1972). Storage of Fresh Yams (*Discorea alata* L.) under Controlled Conditions. Jour. Agric. Univ. Puerto Rico 56: 46 – 55.

Granshaw, J. W. and Oshinowo, A. (1985). Volatile Components of Cooked Tubers of the Water Yam (*Discorea alata*). J. of Science. Food Agric. 33, 71 – 80

Green, K. R and Florini, D.A (1996). Pests and Pathogens of Yams in Storage. African Journal of Root and Tuber Crops 1 (2).

Hahn, S. K, Osiru, D. S. O, Akoroda, M.O. and Otoo, J. A. (1987). Yam Production and its Future Prospects. Outlook on Agriculture 16. Pp 105 – 110.

IBPGR (International Board for Plant Genetic Resources) (1980). Directory of Geraplasm Collection for Root and Tuber Crops. Regional Committee for South East Asia. Descriptors for Yam (Discorea Spp). IBPGR Secretariat, Rome. Pp 19.

Ibrahim, M. H., Williams, J.O., Abiodun, M.O. (1987). Assessment of Parts of Neem Tree for Yam Tuber Storage. Rep. Nig. Stored Prod. Res. Inst. 4, 37 – 41.

Igbeka, J. C. (1985) Storage Practices for Yam in Nigeria, Agriculture Mechanization in Asia, Africa and Latin America. 16, 55 – 58.

IITA (International Institute of Tropical Agriculture) (1971).

Ikediobi, C.O. and Oti, E. (1983). Some Biochemical Changes Associated with Post-Harvest Storage of White Yam (*Discorea rotundata*) tubers. J. Sci. Food Agric. 34, 1123 – 1129.

Ireland C.R. and passam, H.C. (1985). Effect of Exogenous *batatasin, batatasin* ,and Gibberellins on the Dormancy of Stored Yam Tubers.Trop Agric 62,41-46.

Ketiku, A.O. and Oyenuga, V.A. (1973). Changes in Carbohydrate Constituents of Yam Tuber (*Dioscorea rotundata,* poir) during Growth. J.Sci. Food and Agric, 24, 367 – 373.

Lagemann, J. (1977). Traditional African Farming Systems in Eastern Nigeria. Muenchen, Weltforum, Verlag.

Martin, F. W. (1974). Curing Yams before Storage. I. wound types, Species and Humidity Effects. J. Agric. Univ. Puerto – Rico. 58, 211 – 218.

Martin, F. W. and Ruberte, R. (1976). Changes in the Quality of Yams (*Discorea alata*), in storage. Tropical Root and Tuber Crops Newsletter 9, 40 – 51.

Martin, F. W. and Sadik, S. (1977). Tropical Yams and their Potential. 4. *Discorea rotundata* and *Discorea cayenensis*. Agriculture Handbook USDA, No 502, 36.

Martin, F. W (1977). Prolonging the Storage Life of Yams by Removal of Shoots and by Treatment with Gibberellic Acid and Waxes. *Trop. Root Tuber Newsletter* 10, 39.

Mozie, O. (1983). Effect of Air Flow on Weight Losses and Sprouting of White Yam Tubers Stored in the Conventional Barn. Tropical Root and Tuber Crops News Letter No13 pp 32-37

Mozie, O. (1987). The Effect of 2, 4 – D and other Plant Growth Regulators on Sprout Formation in *D. rotundata* poir. (White Yams) in Storage. Tropical Sci. 27, 229 – 232.

Mozie, O. (1988). Effect of Storage Temperature on Storage Weight Losses in White Yam (*Discorea rotundata* poir.) Tubers. Tropical Science 28, 273 – 275

N'kpenu, J.O. and Tougnon, I.D. (1991). Post-Harvest Protection of Root Tuber Crops for Small Farmholders. (edi) (1991) hamburg, pp 1-26.

Nwandikom, G. I. (1990). Yam Tuber Resistance to Mechanical Damage. Agricultural Mechanization in Asia, Africa and Latin America. 21, 33 – 36.

Nwakiti, A. O and Makurdi, D. (1989). Traditional and some Improved Storage Methods for Root and Tuber Crops in Nigeria. In: Deutsche Stiftung Fur Internationale Entwicklung (DSE) (edi): Roots, Tubers and legumes, Bonn, Pp 51-67.

Obigbesan, G. O (1984). Lecture notes. Department of Agronomy, University of Ibadan, Nigeria.

Ogundana, S. K. (1972). The Control of Soft Rot of Yams in Nigeria. International Bidtn Bulletin. 8 (2) Pp 75 – 78.

Ogundana, S. K. and Dennis, C. (1981). Assessment of Fungicides for Prevention of Storage Rot of Yam Tubers. Pesticide Science 11, 491 – 494.

Okoli, O. O. (1980). Dry Matter Accumulation and Tuber Sprouting in Yams *(Discorea* Spp.) Exper. Agric. 16, 161 – 167.

Okoli, O.O., Nwokoye, J. V. and Udugwu, C. C. (1984). Economic Indices for Clonal Selection and Breeding of Yams. In Tropical Root Crops: Production and Uses in Africa (E. R. Terry; E. V. Doku, O. B. Arene and N. M. Mahungu eds.) IDRC-221e, 125-128.

Okonkwo, S.N.C. (1985). The Botany of the Yam Plant and its Exploitation in Enhanced Productivity of the Crop. In Advances in Yam Research. The Biochemistry and Technology of the Yam Tuber. (Osuyi, G. ed.) Biochemical Society of Nigeria and Anambra State University of Technology. Pp 3 – 29.

Olayide, C and Adesuyi, S. A. (1979). Inherent Constraints to high Productivity and Low Production Cost in Yam *(Discorea* Spp) with Special Reference to *Discorea rotundata* poir. In "Yams, *Ignames"* (Miege J. and Lyonga S. N. eds.) Clarendon Press, Oxford, Pp 147 – 160.

Olorunda, A. O., Mckelvie, A. D., and Malklon, A. E. S. (1974). Effect of Temperature and Chlorpropham on the Storage of the Yam. J. Sci. Food Agric. 25, 1233 – 1238.

Onwueme, I. C. (1973). The Sprouting Process in Yam (Discorea Spp.) Tuber Pieces. J. Agric. Sci. Camb. 81, 375 – 389.

Onwueme, I. C. (1977). Effect of Varying the Time of the First Harvest, and of Late Planting, on Double – Harvest Yield of yam *(Discorea rotundata)* in Field Plots. J. Agric. Sci. Camb. 88, 737 -741.

Onwueme, I. C. (1978). The Tropical Tuber Crops: Yams, Cassava, Sweet Potato, Cocoyams. John Wiley and Sons; New York. Pp 234.

Orkwor, G. C., Asiedu, R. and Ekanayake, I. J, eds. (1998) Food yams. Advances in Research, IITA and NRCRI, Nigeria

Osagie, A. U and Opute, F. I (1981). Major lipid Constituents of *Dioscorea rotundata* Tuber during Growth and Maturation. J. Expt. Bot. 32, 737 – 740.

Osagie, A. U (1991). Sugar Composition of Yam *(Dioscorea)* Tubers during Post Harvest Storage. J. Food Composition.

Osagie, A. U. (1992) The Yam Tuber in Storage. Post harvest Research Unit, University of Benin, Nigeria Pp 107 – 173.

Osunde, Z.D. (2002). Prediction of Sprouting and Weight Loss of Yam in Local Storage Structures in Niger State of Nigeria. Pp 65 - 95

Osunde, Z.D., Yisa, M.G., and El-Okene, A.M. (2003). Proceedings of the 4th International Conference and 25th Annual General Meeting of the Nigerian Institution of Agricultural Engineers. Vol. 25.

Oyeniran, J. O and Adesuyi, S. A. (1983). A Preliminary Experiment on the Chemical Preservation of Yams. Ann. Rep. Nig. Stored Prod. Res. Institute (1979/80) Tech.. Rep. No 6. Pp 63 – 77.

Passam, H. C., Read, S. J. and Rickard, J. E. (1976). Wound Repair in Yam Tubers: the Nature of the Wound and its Repair. Trop. Sci. 18, 1- 11.

Passam, H. C. and Noon, R. A. (1977). Deterioration of Yams and Cassava during Storage. Proceedings of the Association of Applied Biologists 85, 436 – 439.

Passam, H. C., Read, S. J. and Rickard, J. E (1978). The Respiration of Yam Tubers and its Contribution to Storage Losses. *Trop. Agric* 55, 207 – 214.

Passam, H. C. (1977). Sprouting and Apical Dominance of Yam Tubers. Tropical Science 19, 29 -39.

Passam, H. C. (1982). Dormancy of Yams in Relation to Storage. In

Yams. *Ignames* (Eds J. Miege & S. N. Lyonga), Pp 285 – 293. Oxford: Clarendon Press.

Ramanujam, T. and Nair, S.G (1982). Control of Sprouting in Edible Yams. Journal of Root crops, 8/1 & 2 pp 49-54

Ricci, P., Coleno, A. and Fevre, F. (1978). Storage Problems in the Cush – Cush Yam. 2 – Control of *Penicillium Oxalicum* Rots. *Annales Dephyto Pathologie* 10, 433 – 440.

Rivera, J. R, Gonzalez, M. A, and Collazo, R. and Cuevas, R. (1974). An Improved Method for Storing Yam (*Discorea alata*). *J Agric. Univ. PR 58, 456 – 465.*

Sauphanor, B. and Ratnadass, A. (1985). Insect Problems Encountered in Yam Storage in the Ivory Coast. L' Agronomie Tropicale 40, 262 – 270.

Schmutterer, H., Ascher, K.R.S., and Rembold, H. (1980). Natural Pesticides from the Neem Tree. Proceedings of the First Neem Conference. Rottach Egern, Published by the German Agency for Technical Cooperation (G T Z) Eadhborn F R G .

Thompson, A. K., Been, B. O. and Perkins, C. (1977). Reduction of Wastage in Stored Yams. in: Proc. 3rd Symp. Int. Soc. Trop. Root Crops; Ibadan, Nigeria, IITA, Ibadan, 443 – 449.

Warthen, J. D. (1979). *Azadirachta indica:* a Source of Insect Feeding Inhibitors and Growth Regulators. Science and Education Administration, Agricultural Review and Manuals, Northeastern series No. 4, April 1979 USDA, Beltsville, U.S.A.

Wickham, L.D (1981). The Extension of Dormancy in Tropical Yams (*Dioscorea* spp.) Ph.D. Thesis. University of the West Indies, Trinidad, 168 Pp.

Wickam, L. D; Wilson, L.A; and Passam, H. C. (1981). Tuber Germination and Early Growth in Four Edible *Dioscorea* Species. Ann. Bot. 47, 87 – 95.

Wickham, L. D, Passam, H. C, and Wilson, L. A. (1984). Dormancy Responses to Post – Harvest Application of Growth Regulators in *Dioscorea* Species. 2. Dormancy Responses in Ware Tubers of *d. Alata and d. Esculenta.* Journal of Agricultural Science, Cambridge 102, 433 – 436.

APPENDIX A

TABLE A_1 Monthly Average Temperature in the Two Barns

Months	BWF 8am (^oC)	BWOF 8am (^oC)	BWF 12noon (^oC)	BWOF 12noon (^oC)	BWF 4pm (^oC)	BWOF 4pm (^oC)	BWF 8pm (^oC)	BWOF 8pm (^oC)
Jan	20.5	23	27	30	29.5	32	26	28
Feb	26.5	29.5	31	34	34.5	36.5	30	32
Mar	28	31	32	35.5	36	38	32	33.5
April	28.5	32	32.5	36	35.5	37	31	33
May	30	32.5	31.5	33.5	33.5	35.5	29	31
June	29	31.5	31	32.5	32	34	30.5	31.5

TABLE A_2 Monthly Average Humidity in the Two Barns

Months	BWF 8am (%)	BWOF 8am (%)	BWF 12noon (%)	BWOF 12noon (%)	BWF 4pm (%)	BWOF 4pm (%)	BWF 8pm (%)	BWOF 8pm (%)
Jan	31.2	29.5	32.4	30.5	32.4	28	30.7	26.5
Feb	32	30	30.5	26.5	28	25	29.8	25.5
Mar	51.5	49	35.5	32	32.4	26	32.4	29
April	57	55	40.7	36.5	35	32	39.8	36
May	57	55	50.5	47	45.8	42.5	51.5	49.5
June	60.4	55	55.9	51.5	53.4	48.5	56.5	55

APPENDIX B

TABLE B_1 Monthly Average Sprout Weights of Yam Tubers in the Two Barns

Months	Barn with Fan (g)	Barn without Fan (g)
Jan	7.4	13.5
Feb	24.1	27.4
Mar	18.3	27
April	20	28.6
May	29	44.7
June	0	0

TABLE B_2 Monthly Average Percentage Weight Loss of Yam Tubers in the Two Barns

Months	Barn with Fan (%)	Barn without Fan (%)
Jan	2.5	4.6
Feb	5.8	8.3
Mar	23	27.7
April	15.1	17.7
May	20.6	22.9
June	25.1	28.8

APPENDIX C

TABLE C_1 **Monthly Average Sprout Weights of Yam Tubers Treated With Neem Tree Extracts and Control (Barn with Fan)**

Months	Neem Bark Extract (g)	Neem Leaf Slurry (g)	Control (g)
Jan	5.2	11.0	0
Feb	17.3	19.0	23.5
March	13.8	12.6	14.0
April	10.1	13.5	32.0
May	8.5	20.0	48.9
June	0	0	0

TABLE C_2 **Monthly Average Sprout Weights of Yam Tubers Treated With Neem Tree Extracts and Control (Barn without Fan)**

Months	Neem Bark Extract	Neem Leaf Slurry	Control
Jan	24.0	9.3	14.1
Feb	22.9	24.5	26.5
March	11.6	22.6	34.5
April	19.7	14.0	39
May	36.6	28.3	49.0
June	0	0	0

TABLE C_3 Monthly Average Percentage Weight Loss of Yam Tubers Treated with Neem Tree Extract and Control (Barn with Fan)

Months	Neem bark extract	Neem leaf slurry	Control
Jan	3.9	1.6	2.1
Feb	6.5	5.2	6
March	27.6	18.2	22.9
April	19.9	11.4	14.1
May	22.4	18.3	21
June	28.4	22	25.2

TABLE C_4 Monthly Average Percentage Weight Loss of Yam Tubers Treated with Neem Tree Extract and Control (Barn without Fan)

Months	Neem bark extract	Neem leaf slurry	Control
Jan	9.7	1.7	2.3
Feb	12.8	6.2	6.6
March	32.5	2.4	26.
April	21.9	13.1	15.8
May	28.1	18.7	21.7
June	33.1	23.9	26.2

APPENDIX D

TABLE D_1 **Monthly Average Sprout Weights of Yam Tubers Treated with CIPC Solution (In three levels) and Control (Barn with Fan)**

Months	CIPC solution Level 1	CIPC solution Level 2	CIPC solution Level3	Control
Jan	5.38	4.28	5.57	0
Feb	18.42	25.26	29.02	23.5
March	20.62	13.10	16.74	14.0
April	1.47	23.29	15.74	32.0
May	0	32.99	14.61	48.9
June	0	0	0	0

TABLE D_2 **Monthly Average Sprout Weights of Yam Tubers Treated with CIPC Solution (In three levels) and Control (Barn without Fan)**

Months	CIPC Solution Level 1	CIPC Solution Level 2	CIPC Solution Level 3	Control
Jan	1.05	2.34	18.14	14.1
Feb	22.61	34.85	20.19	26.5
March	20.32	11.56	38.52	34.5
April	31.68	31.35	58.34	39.0
May	32.46	46.64	45.12	49
June	0	0	0	0

TABLE D_3 **Monthly Average Sprout Weights of Yam Tubers Treated with CIPC Powder (In three levels) and Control (Barn with Fan)**

Months	CIPC Solution Level 1	CIPC Solution Level 2	CIPC Solution Level 3	Control
Jan	11.87	2.62	4.11	0
Feb	14.87	25.67	21.25	23.5
March	18.15	20.81	46.44	14.0
April	28.2	21.16	26.86	32.0
May	0	23.01	23.3	48.9
June	0	0	0	0

TABLE D_4 **Monthly Average Sprout Weights of Yam Tubers Treated with CIPC powder (In three levels) and Control (Barn without Fan)**

Months	CIPC Powder Level 1	CIPC Powder Level 2	CIPC Powder Level 3	Control
Jan	6.12	4.29	2.61	14.0
Feb	9.77	27.95	19.11	26.5
March	28.85	32.56	27.97	34.5
April	16.28	39.2	17.64	39
May	29.94	62.87	36.12	49
June	0	0	0	0

APPENDIX E

TABLE E_1 Sprout Weights (g) (Barn with Fan)

Treatment/Period		Jan	Feb	March	April	May	June
Neem Bark Extract							
	R_1	5.22	31.9	13.92	9.02	8.49	-
	R_2	-	23.92	21.4	16.81	10.82	-
	R_3	-	47.9	6.03	4.32	6.32	-
Neem Leaf Slurry							
	R_1	11.04	26.88	38.99	-	14.4	-
	R_2	-	15.07	24.8	19.79	31.39	-
	R_3	-	28.48	3.87	9.18	14.45	-
CIPC Solution							
L_1	R_1	16.14	4.54	-	43.07	-	-
	R_2	-	4.89	-	3.22	4.41	-
	R_3	-	45.84	61.86	13.75	-	-
L_2	R_1	-	25.29	-	44.31	32.99	-
	R_2	2.83	39.32	34.66	11.62	51.95	-
	R_3	-	11.16	4.65	13.95	14.04	-
L_3	R_1	-	25.73	4.76	16.72	31.73	-
	R_2	-	41.87	1.76	14.82	-	-
	R_3	6.72	19.47	43.7	15.67	12.09	-
CIPC Powder							
L_1	R_1	26.7	23.28	19.67	20.07	-	-
	R_2	8.91	12.14	22.45	44.79	-	-
	R_3	-	9.29	12.33	19.74	-	-
L_2	R_1	-	45.79	-	38.21	42.12	-
	R_2	7.86	-	56.23	2.87	-	-
	R_3	-	31.22	6.2	22.41	26.91	-
L_3	R_1	-	37.97	33.5	30.65	27.48	-
	R_2	-	11.14	39.66	11.05	24.26	-
	R_3	12.32	14.81	66.17	38.83	18.16	-
Control							
	R1	-	18.09	6.35	43.21	40.91	-
	R2	-	14.65	-	7.13	-	-
	R3	-	24.4	21.64	45.44	56.97	-

TABLE E_2 Sprout Weights (g) (Barn without Fan)

Treatment/Period		Jan	Feb	March	April	May	June
Neem Bark Extract							
	R_1	29.08	41.17	14.21	8.7	29.74	-
	R_2	18.96	6.28	72.99	35.27	44.08	-
	R_3	-	21.13	14.1	15.13	35.98	-
Neem Leaf Slurry							
	R_1	10.2	12.18	-	6.35	15.55	-
	R_2	-	11.16	-	25.99	20.97	-
	R_3	8.39	20.3	-	9.43	48.45	-
CIPC Solution							
L_1	R_1	3.16	24.89	22.15	44.1	24.19	-
	R_2	-	18.86	14.96	28.1	39.87	-
	R3	-	24.07	23.84	22.84	33.33	-
L2	R1	7.02	16.91	23.95	46.65	76.22	-
	R2	-	65.36	6.25	22.24	9.18	-
	R3	-	22.29	4.48	30.16	25.43	-
L3	R1	-	6.36	29.18	30.16	25.43	-
	R2	29.9	49.87	39.38	48.8	13.99	-
	R3	24.52	4.33	47.01	96.06	95.95	-
CIPC Powder							
L1	R1	13.44	-	38.29	26.65	46.54	-
	R2	-	12.14	25.45	22.2	19.29	-
	R3	4.91	17.18	22.81	-	24	-
L2	R1	12.88	29.26	19.22	37.45	54.2	-
	R2	-	29.49	31.17	16.45	55.29	-
	R3	-	25.1	47.3	63.71	79.1	-
L3	R1	-	31.72	24.42	33.9	39.24	-
	R2	7.83	13.25	33.35	14.99	28.27	-
	R3	-	12.37	26.14	4.03	40.85	-
Control							
	R1	-	-	12.15	31.97	20.74	-
	R2	14.13	25.75	47.33	25.67	77.97	-
	R3	-	27.28	44.14	29.28	48.48	-

APPENDIX F

TABLE F_1 Monthly Weights (g) of Yam Tubers (Barn with Fan)

Treatment/Period		Before Storage	Jan	Feb	March	April	May	June
Neem Bark Extract								
	R_1	1.29	1.23	1.2	0.86	1.03	1.01	1.0
	R_2	1.48	1.41	1.36	1.04	1.11	1.09	1.05
	R_3	1.41	1.38	1.35	1.13	1.12	1.14	1.1
Neem Leaf Slurry								
	R_1	1.58	1.54	1.51	1.25	1.19	1.15	1.14
	R_2	1.39	1.33	1.30	1.04	1.2	1.11	1.03
	R_3	1.31	1.28	1.25	1.2	1.09	1.13	1.07
CIPC Solution								
L_1	R_1	1.53	1.49	1.45	1.15	1.4	1.2	1.16
	R_2	1.26	1.23	1.2	0.96	1.12	1.05	0.99
	R_3	1.58	1.53	1.48	1.26	1.4	1.3	1.2
L_2	R_1	1.61	1.57	1.52	1.2	1.27	1.23	1.4
	R_2	1.46	1.42	1.36	1.05	1.18	1.16	1.08
	R_3	1.36	1.33	1.3	1.0	1.15	1.09	0.98
L_3	R_1	1.36	1.33	1.3	1.03	1.16	1.09	1.02
	R_2	1.46	1.41	1.38	1.08	1.20	1.16	1.05
	R_3	1.48	1.44	1.4	1.16	128	1.21	1.13
CIPC Powder								
L_1	R_1	1.82	1.76	1.7	1.36	1.48	1.25	1.3
	R_2	1.78	1.64	1.62	1.38	1.48	1.55	1.51
	R_3	1.55	1.51	1.47	1.7	1.3	1.32	1.26
L_2	R_1	1.35	1.31	1.25	1.35	1.25	1.18	1.13
	R_2	1.69	1.53	1.48	1.16	1.3	1.24	1.1
	R_3	1.44	1.41	1.35	1.05	1.2	1.14	1.09
L_3	R_1	1.63	1.51	1.51	1.17	1.3	1.25	1.15
	R_2	1.44	1.41	1.36	1.43	1.17	1.12	1.03
	R_3	1.7	1.64	1.56	1.28	1.36	1.26	1.13
Control								
	R_1	1.51	1.45	1.42	1.14	1.25	1.14	1.06
	R_2	1.38	1.33	1.28	0.98	1.1	1.02	1.11
	R_3	1.61	1.56	1.5	1.17	1.29	1.17	1.09

TABLE F_2 Monthly Weights (g) of Yam Tubers (Barn without Fan)

Treatment/Period		Before Storage	Jan	Feb	March	April	May	June
Neem Bark Extract								
	R_1	1.14	1.13	1.29	0.96	1.12	1.03	1.02
	R_2	1.4	1.35	1.29	0.86	1.01	0.91	0.83
	R_3	1.26	1.19	1.12	0.92	1.07	0.98	0.87
Neem Leaf Slurry								
	R_1	1.28	1.26	1.19	0.99	1.15	1.08	1.03
	R_2	1.32	1.28	1.25	0.96	1.14	1.08	1.01
	R_3	1.29	1.26	1.21	0.91	1.09	1.0	0.92
CIPC Solution								
L_1	R_1	1.46	1.39	1.33	1.01	1.17	1.09	0.98
	R_2	1.38	1.31	1.24	1.04	1.18	1.15	1.04
	R_3	1.42	1.38	1.31	0.97	1.12	1.05	0.95
L_2	R_1	1.4	1.37	1.27	1.07	1.26	1.17	1.07
	R_2	1.46	1.39	1.3	0.96	1.17	0.93	0.84
	R_3	1.33	1.17	1.09	0.88	1.07	1.03	0.94
L_3	R_1	1.45	1.39	1.34	1.11	1.27	1.21	1.04
	R_2	1.71	1.65	1.59	1.24	1.04	1.33	1.24
	R_3	1.7	1.66	1.6	1.25	1.39	1.31	1.19
CIPC Powder								
L_1	R_1	1.37	1.37	1.27	0.97	1.13	1.06	0.96
	R_2	1.68	1.49	1.47	1.4	1.53	1.43	1.25
	R_3	1.64	1.48	1.41	1.16	1.32	1.2	1.06
L_2	R_1	1.46	1.42	1.36	1.04	1.22	1.15	1.04
	R_2	1.49	1.42	1.36	1.06	1.24	1.14	1.0
	R_3	1.51	1.48	1.45	1.24	1.02	1.25	1.13
L_3	R_1	1.35	1.33	1.25	0.85	1.04	0.97	0.89
	R_2	1.38	1.33	1.27	1.0	1.18	1.12	1.02
	R_3	1.33	131	1.24	0.95	1.15	1.07	1.0
Control								
	R_1	1.78	1.74	1.62	1.35	1.5	1.4	1.24
	R_2	1.65	1.62	1.56	1.21	1.4	1.28	1.28
	R_3	1.69	1.67	1.6	1.33	1.41	1.33	125