A REVIEW OF BIOLOGICAL CONTROL METHODS FOR POST HARVEST YAMS (*Dioscorea* spp.) IN STORAGE IN SOUTH EASTERN NIGERIA

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ABSTRACT

Yams (*Dioscorea* spp.) are an important food in West Africa and Nigeria alone produces 21, 814 million tons of yams per year, making it the worlds largest yam producer. It is estimated that after six months in storage up to 56% of the crop is lost due to rot. The losses due to bacteria and fungi were determined in this study, and use of biological control agent for reduction of pathogens of yams in storage was compared with the popularly used chemical fungicides. Limited work has been done on the use of plant leaves extract or antagonistic microorganisms for the control of yam tuber rot in storage. This study demonstrated that surface of harvested yam can be manipulated to get antagonist that can control yam pathogens. Biological control, where effective, is cheap, usually persistent and not toxic to workers using the method. The excellent tuber surface competence of some biological control agents such as *Trichoderma viride* Pers. ex S.F Gray is clearly shown by its lasting residual effect on tuber surface of yams in storage barns and this renders unnecessary the costly repeated respraying used in chemical pesticides. The simplified method of application of the bioagent and the outstanding control of the storage disease attained, recommends biocontrol approach to low resources yam farmers in Tropical Africa and elsewhere.

Keywords: Biocontrol, Chemical, curing, low temperature, plant extracts, Nigeria, yams.

1. INTRODUCTION

Edible varieties of yam (*Dioscorea* spp.) are important food crops in West Africa, the Caribbean's, the Northern and Central parts of South-East Asia including parts of China, Japan, Malaysia and Oceania [1]. Yam is one of the comparatively few words of West African origin to have entered European language. The word was derived from Mande 'niam' or the Temme 'en yame'. This was adapted into Portuguese as 'ynhame' and hence into Spanish as 'name', French 'igname' and English 'yam [2].

The Food and Agricultural Organization [3] of the United Nations estimated that the world production is around 30.2 million tons per year. Over 90% of world yam production is derived from West Africa, especially from five countries in the yam zone, namely: Nigeria, Benin, Togo, Ghana and Ivory Coast [4]. Nigeria alone produces three quarters of the world total output of yams. For instance, in 1998, Nigeria produced about 70% of all yam tubers. There are only six species in Nigeria consumed as food out of all the species of yams. These are *Dioscorea rotundata* Poir, *D. alata* L., D. *dementorum* (Knuth) Pax, *D. cayenensis* Lam, *D. esculenta* (Lour) Burk and *D. bulbifera* L. [5, 6]. Of these species of yams, the last two are not commonly found in the markets hence only a low percentage of the population uses them for food [7].

Losses in yams in storage mostly to rot are considered to be heavy in Nigeria. These losses are attributed by many workers due to rot, which is a pathological problem of yam tubers brought about by bacteria, fungi and nematodes [4, 8]. The losses were estimated by to be 10-15% in the first three months [9] while Coursey [9] and Adesuyi [10] estimated the loss to be 50% and 56%, respectively, after 6 months in the yam barn.

A great many chemicals have been used in reducing post harvest spoilage of yams. Pesticides are not the most desirable means of disease control [11]. They are expensive, cause environmental pollution and may induce pathogen resistance [12, 13]. Biological control is generally favored as a method of plant disease management because it does not have any of those disadvantages of chemicals and tends to be more durable in its effect. Being inexpensive in comparison to chemicals, it is considered to be readily suitable for developing countries.

The aim of the present study is to appraise the losses in white yam in storage and explore various control methods for post harvest diseases of yam in Nigeria.

LOSSES IN STORAGE

Post-harvest handling and storage of yams is an essential aspect of economic development in Nigeria. Accurate figures on yam production in Nigeria are hard to come by, but it was estimated at two hundred million Naira (N200 m) or two million dollars ($2m) [8] with estimated losses in storage of over twenty million Naira (N20m), or two hundred thousand dollars ($200,000). These losses are attributed by many workers mostly to rot caused by bacteria, fungi and nematodes [8, 14]. Most of the pathogens of yam tuber are soil-born, but manifestations of the tuber diseases are observed mostly during storage (**Table 1**).

It is frequently believed that yams store well, but the little documentary evidence that is available on the magnitude of storage losses suggests that contrary to this popularly held opinion, substantial losses occur. In a review of yam storage losses, Coursey illustrated how these losses vary considerably in magnitude and nature from country to country, region to region, species to species and even variety to variety, concluding that in general, the losses that occur during storage, even under the best conditions are much more serious than is generally realized [9]. Although, there is a great variation among varieties, losses in weight of 10-20% after only three months' storage and 30-60% after six months are not unusual even for sound tubers, and even greater losses occur if infection by rotting organisms takes place.

The importance of microbial rotting in causing storage losses has been emphasized by several workers [6, 15, 16, 17, 18, 19, 20]. These workers concluded that the entry of pathogens occurs through wounds or cuts and natural openings on the surface of the tubers.

Table 1. List of Microorganisms isolated from yam tuber rots (5,14,15,21)

Microorganisms isolated from yam tuber rots
Aspergillus flavus Lark ex Fr.,
Aspergillus niger Van Tiegh
Aspergillus tamari Kita
Botryodiplodia theoromeae Pat
Cladosporium herbarium Link
Cladosporium sphaerospermum [15]
Collectortrichum sp.
Cylindrocarpon radiciola Wollenw
Erwinia spp.
Fusarium moniliforme var subglutinans Wollenw & Reinke
Fusarium oxysporum Schlecht ex Fr.
Fusarium poa (Peck) Woron
*Fusarium solani (*Mart.) Sacc.
Geotrichum candidum Link.
Hendersonula toruloidea Natrass
*Macrophomina phaseoli (*Maubi*)* Ashby.
Penicillium spp.
Penicillium chrysogenum Thom.
Penicillium expansum (Link) Thom.
Penicillium italicum Wehmer
Penicillium oxalicum Currie and Thom.
Penicillium sclerotigenum Yamamato
Rhizoctonia sp.
Rhizopus sp.
Rhizopus stolonifer (Enrenb. ex Fr.) Lind.
Serratia sp.
Trichoderma sp.
Trichoderma viride Pers. ex S.F. Gray.

LOSSES DUE TO ROT

Losses in yams in storage due to rot are considered heavy in Nigeria. The evaluation of rot in different parts of Nigeria showed that extent of rotting ranged from 0.5 to 18% at harvesting while storage rot ranged from 3 to 25% [16]. Microbial rotting of yam tubers accounts for a substantial proportion of the annual losses in yam production in Nigeria. Preharvest rots is due to infection by microorganisms in the soil [17]. Okigbo and Ikediugwu associated the different forms of tuber rotting they observed in the storage barn to microbial attacks that probably took place in the field and increased in storage [21]. Stored yams may suffer from fungal diseases, causing rot which quickly spreads. Fungi which are associated with storage losses are *Botryodiploidia theobromae* Pat, *Fusarium moniliforme* var *subgluctinans* Wollen and Reink, *Penicilium sclerotigenum* Yamamoto, *Rosellina bundodes* (Berk and Br.) Sacc, *Aspergillus niger* Van Tiegh, *Hendersonula toruloidea, Macrophomina phaseoli, Rhizopus nodosus* N' Amyslowski and the bacteria, *Serratia* spp. [4]

Other fungi which have been reported as secondary invaders are *Fusarium oxsyporium* Schlecht, *Cladosporium sphearospermum, Fusarium solani, Geotrichum candidum* [4,14,15,21].

It is significant to note that rotting in storage probably started in the soil and progressed in storage. This may happen when infected tubers do not show perceptible external symptoms [5,16,21]. Each type of rot is characteristic of its causal organism. The incidence of rotting varies with the species and with varieties within each species of yam [17]. They also noted that it would probably vary with the site of planting since the distribution of the causal organism may vary from place to place. It has been observed that in the case of white yams, rotting appeared first at the tail ends of yams and then proceeds towards the head regions [21]. Rot vary due to variations in the distribution of the microorganism. It does not relate to the soil mineral status because the differences in the mineral status are not known to be correlated with type of organism isolated nor total percentage of rot [6].

2. METHODS OF CONTROL OF LOSSES DUE TO POST HARVEST DISEASES

A. Chemical control

Losses may be reduced by direct application of yam tubers. Various chemicals have been used in reducing postharvest spoilage (Table 2). Those reported to reduce storage losses of yams include sodium orthophenylphenate, borax, captan, thiobendazole and benomyl [18,24,25]. Captan could completely inhibited germination of spores of *Botryodiplodia theobromae*, *Fusarium moniliforme*, and *Penicillium sclerotigenum* while benlate and thiobendazole were able to arrest the germination of the spores as well as the growth of the organisms [31]. Losses due to rot were significantly reduces for storage periods of up to 10 weeks by lime-washing the tubers [9]. Other researchers have used other chemicals: *Campbell et al.* [22] used naphthalene acetic acid; Adesuyi [10] benlate and captan; Satoh and Tenabe [23] maleic hydrazide; Nnodu and Nwankiti, [24] wood ash, bleach (Sodium Hypochlorite) and Ogali *et al.*, [25] lime and local gin (**Table 2**).

Table 2. Some Chemical Pesticides Used for Control Post Harvest Yam Rots.

CHEMICALS	SOURCE
Sodium orthophenylphenate,	Booth, [18]
Borax	Coursey, [4]
Captan	Ogundana, [3]
Thiobendazole	Coursey, [4]
Benomyl	Coursey, [4]
Naphalene acetic acid	Campbell *et al.*, [22]
Benlate and captan	Adesuyi, [10]
Maleic hydrazidine	Satoh and Tenabe, [23]
Sodium Hypochlorite	Nnodu and Nwankiti, [24]
Lime and local gin	Ogali *et al*, [25]

Fungicides are not the most desirable means of disease control for several important reasons. Fungicides are heavily regulated and vary from country to country in their use and registration [26]. Additionally, they are expensive, can cause environmental pollution and may induce pathogen resistance. Furthermore, fungicides can cause stunting and chlorosis of young seedlings [26]. Unfortunately, there are reports on the emergence of fungal strains resistant to a number of fungicides [11,27]. This development therefore calls for other alternative approaches to the control of storage decay of yams.

B. Low Temperature Control

Low temperature storage also slows down the metabolism of pathogen and so frequently arrests rotting. However, the pathogens are rarely killed, so that when the produce is returned to ambient temperatures rotting may recommence rapidly. Some pathogens are low temperature tolerant thus the temperature required to kill the pathogen also caused chilling damage to yam [18,28]. With the use of sprout suppressants holding little promise at present as an economic means of prolonging the dormant period of yams [29,30], attention is beginning to be directed to temperature control as a practical alternative. By lowering the rate of a myriad of biochemical and physiological processes/reactions that ultimately lead to sprouting, low temperatures are able to prolong the storage life of yams by simply delaying sprouting. Various investigators have now shown that the storage life of sound mature tubers can be extended by as much as four months by temperatures of 16-17°C [28,29]. Three major obstacles to the widespread adoption of low temperature storage for yams by the average Nigerian farmer have been reported [30]. Firstly, low temperature storage calls for a technically sophisticated facility that requires some education and skill to operate. Secondly, given the inefficiencies of the National Electric Power Authority, it may not be a cost effective operation. Finally, and perhaps most importantly, storage of yams at the more effective lower temperature (about 10°C and below) subjects the tubers to the so-called low temperature injury or chilling damage [4]. Low temperature injury is regarded as the single most important factor holding back the adoption of low temperature storage for yams on a commercial scale.

C. Curing

One of the most effective and simple means of reducing post harvest water and pathological losses of several root crops is by curing. The term curing as applied to root and tuber crops is used to indicate their controlled exposure to relatively high temperatures and humidity for short periods (about 24 hours) after harvest with the intention of improving their subsequent storage life. Curing which was originally developed for potatoes, has been successfully applied to yams [10, 28, 30]. In general, the curing process involved exposure of the freshly harvested tubers to temperatures of 29-40°C and relative humidity of 90-95% for 5-7 days. Adesuyi [10] has however found that temperature of 25°C and 30°C and relative humidity of 55-62% for 5 days were also suitable for curing yams. Basically, subjecting the tubers to a short period of high temperature and humidity encourages natural thickening of the tuber skin tissue and the healing of any surface wounds, thereby reducing the rate of water loss and preventing wound infection. Wound healing or wound repair as it is called, involves the formation of suberin at wound sites followed by development of a periderm or cork layer. This protective layer of dead cells is known to inhibit excessive water loss, infection by wound pathogens and subsequent rot during storage [30]. The aim of curing is to promote the process of wound healing at those sites on the tuber where mechanical cuts and bruises have been inflicted during harvesting and subsequent transportation and handling.

D. Natural Plant Extracts.

There are several local plant species whose extracts or biocides have proved efficacious in protecting yam produce before and after harvest (**Table 3**). The most popular one among them is the neem (*Azadiracta indica* A. Juss). Formulations of extracts of *A. indica* include water dispersible powder (WDP), dust preparation (DP) emulsifiable concentrate (EC), neem seed water extract (NSWE) and neem cake water extract (NCWE). The advantages of these natural plant products include local availability, little or no toxicity to humans and simple preparation procedures.

Table 3. Some Local Plants With Pesticidal Value

PLANT	COMMON NAMES
Azadiracta indica	Neem
Zingiber officinale	Ginger
Ocimum gratissimum	Scent leave
Xylopic aethiopica	African pepper
Carica papaya	Pawpaw
Citrus spp. (Peels)	Orange
Nicotiana tabaccum	Tobacco
Dennettia tripetala	Mmimi
Ricinus communis	Castor Bean
Piper guineenais	Pepper

E. Biological Control

The use of microorganisms to control crop pests and diseases, is an exciting and rapidly advancing branch of applied biology. Biological control of a plant disease involves any condition under which, or practice whereby, survival or activity of a pathogen is reduced through the agency of any other living organism, with the result that there is reduction in the evidence of the disease caused by the pathogen [32]. Biological control can be brought about either by introduction or by augmentation in numbers of one or more species of controlling organisms or by a change in environmental conditions designed to favor the multiplication and activity of such organisms or by a combination of both procedures [32].

Bacillus subtilis isolated from soil controlled rot of yams in storage, [20, 33]. The effective and rapid colonization of sites by *B. subtilis* when inoculated onto tuber surfaces was the basis for extended protection over time. Also, *Trichoderma viride* controls postharvest rot of yams, presumably by direct parasitism and antibiotic production [6,19] (**Table 4**) It is striking that the pathogens (along) produced substantial increases in early appearance of rots, but only small increases in the level by April. This may support the idea that damage at harvest facilitates attack by pathogens and that by April all the vulnerable tuber have been attached. Postharvest rot diseases of fruits and vegetables have been effectively controlled by artificially applying the antagonists [34,35] and also for yams [6,19, 20, 33]. The microflora on the surface of harvested commodities can be manipulated to enhance their resistance. It has been observed that epiphytic microorganisms and ectomycorrhizae function as part of the plants' defense [36]. Epiphytic microorganisms on the surfaces of fruits and vegetables could be managed to enhance resistance to postharvast diseases [37]. The control rot of strawberries in storage was done by treatment with an antagonistic *Trichoderma* species [38]. Control was enhanced by the selection of an isolate of *Trichoderma* that was better adapted to cold temperatures.

The rot of yam tubers in storage barn has also been controlled by introduction of antagonistic microorganism on the surface [6,20,33]. The high frequency of occurrence on the tuber-surface of yams storage for months even in the ambient environmental conditions of a traditional yam barn, renders repeated respraying that is required for chemical pesticides unnecessary [6]. When yams in storage barn were sprayed with the biological control agent, *Trichoderma viride* either alone or in combination with other yam pathogens, the amount of rot was reduced or totally suppressed (Table 4). Biological control with antagonists in the postharvest environment has advantage over biological control in the field. Greater control of environment under postharvest conditions appears to be the major advantage [20, 33, 37]. Also, antagonists can be more easily targeted to where they are applied to harvested commodities, compared with field or soil application [36].

Table 4. Cumulative percentage of rot during storage of yam tubers that were inoculated with *Trichoderma viride* D. (Biological control agent) and the post harvest pathogens of yams in different combinations [6].

Treatment	**%rot**			
	January	**February**	**March**	**April**
Uninoculated (Control)	0	16	16	44
Botryodiplodia theobromae alone	12	24	24	48
Aspergillus niger alone	28	44	44	52
Penicillium oxalicum alone	16	24	24	40
Trichoderma viride alone	0	0	0	0
T. viride X *B. theobromae*	0	0	0	0
T. viride X *A. niger*	0	4	4	8
T. viride X *P. oxalicum*	0	12	12	16

Therefore, from the foregoing, the application of biological control method for yam is relatively a new area in Nigeria. Biological control where effective is cheap, usually persistent, does not add to or increase the problem of man's pollution of the environment, and is not associated with the serious toxic hazards to the workers using the methods, or to consumers of the products. Because of these factors and the expense involved in the use of other methods of plant protection (e.g. chemical) it is often a favoured method recommended for use in underdeveloped countries.

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