International Journal of Innovations in Biological and Chemical Sciences, Volume 12, 2019, 11-17

The Methods of Controlling Yam Tuber Rot in Storage: A review

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ABSTRACT
Postharvest rot pathogens constitute a major threat to the enormous potential of yam tuber (*Dioscorea* species) in enhancing food security and safety. The control of yam rot in storage has been an object of research for decades especially in Africa, Asia and certain parts of Europe where yam is produced in large quantities. Various control methods ranging from the use of synthetic chemical, bio-control agents, curing, nanobiotechnology and the use of plant extracts; have been explored to tackle the menace of post-harvest rot of yam tubers. It was discovered that even though most researchers are discouraging the use of synthetic chemicals because of the associated environmental hazards and the inducement of resistance in targeted pathogens, it is still the most effective method in controlling the rot of yam tuber in storage due to its immediate action especially when compared to the use of biological control agents which often require some days before its effect is noticed. It is necessary that curing precedes any of the control method adopted coupled with an appropriate storage structure. There is an urgent need to understand the mode of action of all the plant extracts proven by research to possess anti-rot properties so as to enhance its applicability. Standardization of plant extracts will also go a long way in enhancing their efficacy, especially at various concentrations; as it has been reported in the use of synthetic chemicals. Nanobiotechnology should be explored for possible solutions in addressing the strain of rot pathogens that have become resistant to synthetic chemicals. This review provides a critical analysis of all the control methods listed above, their strengths and weaknesses, the effect of storage techniques and structures on the microbial deterioration of yam while giving insight into ways of maximizing and improving them.
Key words: Yam, rot, control, storage, microbial deterioration and postharvest

INTRODUCTION

Yam rot is the microbial or biological degradation of yam tubers in yam barn or storage facilities [1]. Rot of yam tuber is a major factor militating against their postharvest life [2] making the tubers unappealing and unmarketable to consumers [3]. These rot pathogens usually produce metabolites and extracellular enzymes that degrade cell wall polymers leading to the maceration of the parenchymatous tissues [1].This is a major challenge in a bid to maximize yam tuber as a tool of food security in a world where several countries are plague with food scarcity and hunger [4].

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Receiving Date: October 22, 2019;
Acceptance Date: November 02, 2019;
Publication Date: November 07, 2019

ISSN 2047-9093

Postharvest losses caused by pathogens are between 25%-50% [4]. Bacteria, fungi, nematodes and virus are chief of the phyto-pathogenic organisms that cause rot of yam tubers at all stages in storage [3]. The important genus associated with yam tuber rot in storage as reviewed empirically by Enyiukwu et al., [4] are *Colletotrichum, Fusarium, Aspergillus, Macrophomina, Rhizopus* and *Penicillum*. Ramesh, [5] also implicated *Sclerotium rolfsii* that causes *Sclerotium* rot, *Botrydiplodia theobromae* that causes Black rot or *Botryodiplodia, Rhizopu* spp.*(Rhizopus* rot), (*Fusarium* spp.*) Fusarium* rot and *Erwinia carotovora (Erwinia* rot) *Botryodiplodia theobromae, Fusarium oxysporum, Fusarium solani, Aspergillus flavus, Aspergillus niger, Penicillium chrysogenum, Penicillium oxalicum*, *Trichoderma viride, Rhizoctonia* spp., and *Rhizopus nodosus* are other pathogenic fungi that have isolated and identify to be responsible for rot of yam tuber in storage [2]. The greatest losses of agricultural produce have been attributed to post harvest deterioration especially when left unchecked. Some of the efforts made towards the control of postharvest pathogens of agricultural produce includes: the use of chemicals, curing, and plant extracts application and the use of plant extracts [4]. Rot inciting organisms can be soft, wet or dry [4]. Severity of post harvest rot differs with the host species and varieties [9] and the virulence of pathogens causing the rot also play a vital role in severity [6]. In Nigeria, the life span of white yam varieties in storage is usually 6 months; because of this poor storability; they are usually sold immediately after harvest to prevent post harvest losses [3]. Apart from poor storage facilities which can expose tubers to microbial attack, lack of expertise in terms of post harvest handling contribute to the losses recorded by most farmers [3]. Post harvest rot of yam tubers are usually preceded by mechanical injuries on the tubers which can occur during harvest, transportation or even during storage, these wounds serves as opening for pathogenic infestations [5]. This review critically analyzed and summarized the various methods used in the control of yam tuber rot in storage, their characteristic strength and weaknesses while highlighting the possible research gaps for urgent consideration.

Storage Structure and Method

The storage methods that have been adopted by yam farmers in Ghana, Nigeria and other parts of the world includes: trench silos, leaving yam tubers on the ridges after maturity, storage of fresh yam tubers in the yam barn, platform storage, storage under conical protective roof, storage of yam tubers in heaps on the ground [2,7]. An improved yam storage method require the use of healthy and sound tubers; adequate curing, fungicide treatment, protection from rain and direct sunlight, ventilation to expel heat generated by respiration of the tubers, regular inspection, removal of rotting tubers and sprouts [7]. Modern and traditional yam barns have been proven to lead to storage losses both qualitatively and quantitatively [8]. Proper selection of yam tubers, storage structures and storage methods are vital in winning the war against rot inciting organism. Nwaigwe et al., [7] emphasized the fact that the quality and type of storage facilities affect the shell life of yam tubers and their subsequent susceptibility to rot. The efficiency of storage structures are determined by climate, purpose for storage, type of building material, resources, availability of labour and socio-cultural beliefs that surrounds the storage [7].

Despite the inadequacies of the traditional yam barn, it is still popularly used by farmers in developing countries [9]. Maalekuu et al., [10] revealed that 60% of farmers in Ghana uses yam barn while 30% make use of open sided and the remaining 10% stores them as heaps on the floor. They established that the open sided storage method is the best in terms of protection from decay and pest damage.

The genotypic composition of yam tubers affect their performance in storage structure, there was significant differences in the durability of yam tubers stored in either pit, barn, platform or heap [11]. Harvested yam tubers stored in dugs pits are more prone to rot through soil borne pathogens [2].

According to Akpenpunn et al., [12] there was no significant difference between the yam tubers stored in wooden box and those arranged on a platform. They stressed that the choice of storage structures are dependent on the volumes of yam tubers to be stored and the cost of storage structures.

ISSN 2047-9093

The efficacy of curing before storage has been demonstrated by Eze el al., [13]. Storage temperature is also very vital in reducing post harvest losses of yam tubers [12]. Lee and Park [14] was able to prolong the storage potential of Chinese yam tuber (*Dioscorea polystachya* Turcz) for more than seven months through curing with heated air and storing at a temperature of 3^0-4^0C. Whatever reduces the physiological activities of yam tubers also protect them from post harvest deterioration. Storage of yam tubers should be accompanied by techniques such as gamma radiation, plant extracts application, chemical treatments for optimal protection from rot [12]. As reviewed by Nwaigwe el at., [7] advance storage methods have been more efficient especially in the area of refrigerated storage in combination with fungicides and gamma radiation to prevent sprouting and rot. This method is relatively expensive especially in developing countries where there is no stable power supply. There is need to improve the local storage methods or storage innovations that will accommodate the variation that exist in the susceptibility of various *Dioscorea* species to rot causing pathogens [9, 6].

Biological Methods

Allelopathy is a biochemical process by which secondary metabolites from microorganisms and plants affect the growth of biological systems. It also entitles the release of chemical substances (antibiotic) which serve as growth inhibitors in a medium or environment [15]. Strains of *Trichoderma* produce harizianic acid, tricholin, alamethacin, vindian and peptaibois which are volatile and non volatile toxic metabolites that can prevent the growth of pathogens [15]. Lactic acid bacteria also produce organic acids, bacteriocins and peroxides that are very toxic to pathogens [8]. It has been established by Dania et al., [15] that *Trichoderma asperellum, Trichoderma longibrachiatum, Bacillus substilis*, *Pseudomonas fluorescens*, and *Bacillus cereus* control yam rot in vivo and in vitro.[16] also used *Trichoderma* harzianum to control the growth of *Colletotrichum species* which is fungi pathogen causing yam dry rot in Nigeria. *Pseudomonas chlroloplus* and *Trichoderma harzianum* inhibit the growth of *B. theobroma and F. solani* which are responsible for post harvest rot of yam [17]. Similarly; Adebola, el al., [18] reported that saprophytic yeast (*Rhodoturulu rubra, Cryptococcus neoformans* and *Toruiopsis candida*) control the postharvest rot of yam (*Discorea rotundata*), according to them the field efficacies still require further investigation. One of the advantages of biocontrol agents over chemical pesticides is that it does not require repeated or periodic applications, making it suitable for developing countries [17]. Adebola el al., [18] reported that saprophytic yeast has no carcinoqenic effect; therefore it is a safe biocontol agent of yam rot. Biological control of yam tuber rot has been adjudged to be environmental friendly, less expensive and very effective, the search for useful biological agents is increasing [16]. Natural host plant resistance to rot pathogens makes yam tuber safe for consumer and protect the environment because both chemical and botanicals have negative effects on the environments possessing physiological and deleterious effects on plant tissues [11]. The efficacy of the genus *Trichoderma* as biocontrol agent have been proven by various researchers [15, 1] especially *Trichoderma harzianum* [17, 16, 19] as earlier discussed. There is need to examine other genus like Pseudomonas and Bacillus for possible antagonistic ability. There is also need to explore the biochemical process responsible for the antagonist ability of *Trichoderma* and other bio-control agents that have been scientifically established. The mode of action of the various allochemicals produced by them should also be investigated [15].

Curing Method

Curing enhances the thickening of the skin and healing of wounds created as a result of post harvest handling during harvest or transportation. This heals the opening created on tubers by either bruises or pest preventing subsequent invasion by rot causing pathogen [5]. Tubers usually left in the open at a ambient temperature (28±20C) for 7-15 days to dehydrate the wet soil that was attached to the yam tubers during harvest. The tubers are then separated according to their shape and sizes [5]. It is usually carried out immediately after harvest especially for those that will be stored; this is normally achieved

ISSN 2047-9093

by arranging the yam tubers on the ground and covering with a grass layer and a canvas tarpaulin or jute bags. Plastic bags can also be used, although the tubers are not exposed to direct sunlight but the coverings are usually removed after 4 days [7]. Pit curing involves the process of placing yam tubers in a pit whose bottom is lined with sawdust or grass. The tubers are usually removed for storage after two weeks. Curing is the easiest way of controlling yam rot in storage; it can be carried out at little or no cost. More emphasis is needed to educate farmers on the need for curing before storage.

Chemical Method

Synthetic chemicals have been very effective in the control of yam tuber rot in storage, example of some of these synthetic chemicals includes: thiobendazole, forcelet, sodiumothiophenylphenate, borax, captan, benomyl, nordox, bleach (sodium hypochlorite) and mancozeb [19]. The efficacies of chemical fungicides have been demonstrated by [20], he established that both Metalaxyl Mancozeb WP and Shavit F71.5 WP were effective in the control of fungi rots in storage, with Shavit F71.5 WP been more potent. Thiabendazole (TBZ) is also effective against yam dry rot [8].

A survey by Maalekuu et al., [10] in Ghana shows that only few farmers (28%) applied Agro chemicals to the yam tubers before storage; as against the recommendation of Aidoo, [2] that yams tubers should be spray with fungicides before storage. Synthetic chemicals are too expensive and often leads to environmental hazards effecting non-target organisms [1]. Frequent use of chemicals has led to the outbreak of resistant strains of pathogens [19]. Despite the effectives of synthetic chemicals, it is been discouraged because of the aforementioned reasons. The use of either plant extracts or bio-control agent is been advocated by most yam researchers. It is worthy of note that Mancozeb is very effective against the rot of yam tubers irrespective of the concentration applied and duration [21, 19], unlike the plant extracts that required specific concentration for effectiveness [22, 21, 19] or biocontrol agent that need to be introduced for at least 2 days before effectiveness [16, 21, 8].

Plant Derived Pesticides/Fungicides

Plants contain anti-pathogenic metabolites such as alkaloids, glycosides, flavonoids, sterols, phenols and saponins [3] prominent among them is the neem plant Azidiratata indica others are *Carica papaya,* chromolena odorata, *Piper guineense, Zingiber officinale, Nicotiana tabacum* etc [19, 23]. The peel of water yam also possesses fungitoxic properties against the growth of *Fusarium oxysporum, Rhizopus stolonifer, Botryodiplodia theobromae and Trichoderma viride* [24]. Eleazu el al., [22] also attest to the antifungal properties of *Dioscorea alata* and *Dioscorea bulbfera.* Wood ash also acts as a disinfectant and deterrent form pathogens and certain insects [5]. The mode of extraction ranges from the use of water, ethanol and methanol as extractant [24]. Although according to in vovo and in vitro studies carried out by [23] ethanol is the best extractant, although the use of water has been encouraged because of it cheap availability. Pesticides/fungicides of plant origin are biodegradable, cheap, specific, environmentally safe and readily available [25]. According to Adebowale el al., [26] the storage life of yam tubers can be influenced by extract of neem plant, its application delayed the dormancy and sprouting of yam tubers preventing them from storage rot. To the best of my knowledge, there are little or on research information on the mode of action of the several plant extract that have established to control storage rots of yam tubers [21, 24, 3, 25, 19, 23]. Nguyen *el at*., [27] revealed that the mode of action of plant extracts can either be through induced resistance or direct antimicrobial action. Understanding the specific of mode of action of the identified plant extract will help to select it usage based on the situation in question. The toxicological effect of some of the plant extracts already proven by research on stored yam tubers also need to be well elucidated. Appropriate legislation on plant-ecosystem equilibrium as regards the exploration of some of the aforementioned plants especially *Chromolena odorata* might be necessary [28].

ISSN 2047-9093

Nanobiotechnology

The combination of plant extracts and silver nitrate to produce nano particles is known as a nanobiotechology [13]. This technology combines botanical extracts, curing and metallic nano particles to control rot pathogens of stored yam tubers. Recent advances in science have shown that nano-science a field that combines physical, chemical and biological procedures to produce nano-sized particles with great potentials and certain functions in various contexts [13]. The future of solving food security problems might just be dependent on the nano revolution currently taking place in sphere of technology and medical realm. There is arguably very little research in this area; to the best of my knowledge only Eze el al., [29] has worked on the fungitoxic ability of silverneem in the control of storage rot of yam tubers. They claim that the silverneem has no toxic chemical and adverse effect on food, although this claim is not yet substantiated by research either by them or other researchers. This emerging field can compliment other control methods that have been discussed earlier especially in addressing strain of pathogens that have become resistant to synthetic chemicals, if given adequate attention.

CONCLUSION AND RECOMMENDATIONS

All the methods use in the control of yam tuber rot in storage has their strength and weaknesses, therefore; appropriate curing of yam tubers before storage is necessary in other to get optimal result. Based on this review, the following are suggested: More felid trails should be carried out to broaden the use and acceptability of biocontrol agent. Researchers should also elucidate the mode of action of aforementioned biocontrol agents while exploring new genus like bacillus and Pseudomonas for possible antagonistic properties. The formulation and standardization of plant extracts should be improved and recommended after investigating their mode of action. Plant species that are already proven to possess antimicrobial properties are to be protected by law and their domestication should be encouraged. The methods used to store yam tubers should be improve through innovations that can accommodate the different species of yam.The use of nanobiotechnology in the control of yam tuber rot in storage should be given more research attention, especially to ascertain the level of toxicity and palatability on the treated yam tubers. An emphasis is needed on the unified use of curing, treatment techniques and coordinated storage temperature for optimal result in the protection of tubers. Finally, this research is not only strengthening the methods used in the control of yam tuber rots in storage, it has also provided a guide for farmers, yam stakeholders and policy makers on deciding the method to either adopt or improve for proper yam tuber rot management.

CONFLICTS OF INTEREST

The author has no conflicts of interest and he is solely responsible for the content of this work.

ACKNOWLEDGMENTS

I want to appreciate the support of Mr. Ogala Daikwo and Mrs Ameh Abibat for their support towards the writing of this review.

FUNDING ACKNOWLEDGMENT

Funding was not received from anybody, institution or government agencies towards writing this review.

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