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NATURAL PLANT EXTRACTS AND POST HARVEST MANAGEMENT OF YAMS IN STORAGE: A REVIEW

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ABSTRACT
Nigeria accounts for 70% of global yam supply and more than 25% of yams produced every year are lost to various kinds of diseases and pests. Controlling the diseases and pests and the pathogens inciting them is important for the mitigation of loss in storage yams. The indiscriminate use of synthetic chemicals led to the development of resistance in these organisms, pests and plants brought about the utilization of higher concentrations, with corresponding rise in toxicity to humans and food products. A new approach to the control of pathogens which hampers quality food production and human safety has been implemented by the application of plant extracts. This approach has been considered to support the advantage of organic farming. These plant extracts (antimicrobial agents) when isolated are contained in the phyto-chemical constituents (Alkaloids, Saponins, Tannins etc.) of the plants. The antimicrobial activities of such plant extracts have been linked to the presence of bioactive compounds which sometimes serve to protect the plants themselves against bacteria, fungi and viral infections and exhibiting their antimicrobial properties on these organisms. However, this review is randomly dispersed in literature, and thus, summarizes the research results obtained on the different plant extracts as control measures for yams in storage and the efficacy of these plant extracts on rots.

Keywords: Plant extracts, fungal diseases, Post-harvest, and Yam

Introduction

Numerous losses of yam crops resulting from many causes (pathological and non-pathological) both before and during storage have been reported in Nigeria and elsewhere (Arinze, 2005 and Markson *et al.*, 2012). Of these two causes of yam loss, pathological losses (losses resulting from the activities of pathogens) is the most severe. In yams, more than 25% of yams produced every year are lost to various kinds of diseases and pests (Anukwuorji *et al.*, 2016), and this has become a major threat to food security. Although several methods have been developed for the storage of yams; the traditional yam barn, in spite of its inadequacies, remains the most popular among farmers (Ogba, 2013). This has precipitated a pronounced post-harvest storage loss, which remains an impediment in the production of this important crop. Yam tuber naturally has a periderm (outer cover) which microorganisms cannot easily penetrate and its losses are attributed by many studies due to rot, which is a pathological problem of yam tubers brought by the activities of bacteria, fungi, nematodes, rodents, and man during weeding, harvesting and postharvest handling. Wounds/injuries caused by these activities facilitate the penetration and development of rot microorganisms (Okigbo, 2004 and Shiriki, 2015). Amusa (2003), categorized storage rots of yams into three groups: dry rot (caused by several fungi including *Botryodiplodia theobromae, Aspergillus* spp and *Penicillium* spp), soft rot (usually involving *Rhizopus* spp, *Sclerotium rolfsii* and *Mucor circinelloides*) and wet rot (which results from secondary infection by *Erwinia carotovora*). Nahunnaro (2008), indicated that Rots are exacerbated by high ambient temperatures and relative humidity.

Postharvest deterioration and rot caused by various microorganisms is seen as the single most important factor militating against commercial yam production in Nigeria, besides dearth of research for development and capacity building in yam-based research (Enyiukwu *et al.*, 2014). The control of post harvest diseases has been mainly based on synthetic fungicide application such as, thiabendazole, imazalil and sodium ortho-phenyl phonate (Harbant, 2011). The use of synthetic chemical fungicides is an old age practice to control rots. However, the indiscriminate use of many synthetic fungicides is associated with many human, technical, environmental, non-target organisms and even pest, cause management problems such as, resistance of micro-organisms, food and food product contamination with toxic residues, increased cost of application, handling hazards, and environmental contamination. Environmentally friendly plant extracts are considered as great potentials as alternatives to synthetic fungicides (Harbant, *ibid*), but the actual use of these products for the control of post-harvest pathogens of tubers generally, and in particular for yam pathogens is however, still limited. Harvested tubers are stored in different storage facilities pending sale, consumption or used for planting.

There are about 250,000 to 500,000 species of plants on Earth and only a small percentage (1% to 10%) of these plants are used as food by both humans and other animal species (Shiriki, 2019). Therapeutic efficacy of many indigenous plants for several disorders has been described by practitioners of traditional medicine. Antimicrobial properties of medicinal plants are being increasingly reported from different parts of the world. The World Health Organization estimates that plant extracts or their active constituents are used as folk medicine in traditional therapies of 80% of the world's population (Shiriki, *ibid*). Recently, the antimicrobial activity of some higher plant products that are biodegradable, safe to human health, cheap and readily available has attracted the attention of researchers in the control of plant and post-harvest diseases (Shiriki, 2015). The aim of the study therefore, is to appraise the losses in yam storage and explore various natural plant extracts as a control method for post-harvest diseases of yam.

Efficacy of Plant Extracts on Pathogens

A huge number of plants extracts have being proven useful and successful as biological control agents against diseases in plants and tubers crops (Amadioha and Obi, 1999; Onifade, 2000; Okigbo and Emoghene, 2004; Okigbo and Nmeka, 2005, Okigbo and Ogbonnaya 2006 and Oyelana *et al.*, 2011), without side effects on humans and environment. These include: *Carica papaya*, *Cassia fistula*, *Zingiber officinale*, *Senna alata*, neem, lantana plants, wood ash, palm oil, *Terminalia catapa* (fruit plant-leaves), *Passiflora edulis* (passion fruit-fruit peels), *Daniella oliveri* (Chiha-Tiv-leaves), *Ceiba pentandra* (Vambe-Tiv-leaves) and *Jatropha tanjorensis* (Catholic plant-leaves), and a whole lot of others. Plants have the ability to synthesize aromatic secondary metabolites, like phenols, phenolic acids, quinones, flavones, flavonoids, flavonols, tannins and coumarins (Cowan, 1999). This group of compounds show antimicrobial effect and serves as plant defense mechanisms against pathogenic microorganisms (Das *et al*., 2010) via several ways including; inhibiting protein synthesis, interfering with nucleic acid synthesis, breaking the peptide bonds, acting as chelating agents, inhibiting metabolic pathways, interfering with cell wall synthesis, or by preventing utilization of available nutrients by the microorganisms (Alum *et al.*, 2014). The success registered from these studies manifested the high potential of botanicals as alternatives to the use of synthetic fungicides in curing and protection of yam tubers from rots. Hence, they have practical and cost-effective implications, especially to small scale farmers with limited access to commercial synthetic fungicides, but with ease of access to such botanicals. Additionally, use of botanical extracts will complement other rot control measures such as host plant resistance. It also provides an opportunity for further exploration and validation of indigenous technical knowledge which ought to enrich the knowledge base.

Plant Extracts as a Post-Harvest Pathogen/Rot Control Agent

Several researchers have investigated effects of extracts of some Nigerian indigenous plants on pathogens and rot of yam tuber crops. Amusa *et al*., (2003) reported the use of Tecto (Thiabendazole), locally made dry gins or wood ash before storage (Ogali *et al.,* 1991), has been found to protect yam tubers against fungal infection in storage. . Okigbo *et al.,* (2005), evaluated control of yam tuber rot with hot water leaf extracts of *Xylopia aethiopica* and *Zingiber officinale*. The potency of *Xylopia aethiopica* and *Zingiber officinale* were used to control yam tuber rot caused by *Fusarium oxysporum*, *Aspergillus niger*, *Aspergillus flavus*. *Xylopia aethiopica* and Ginger (*Zinigiber officinale*), were found to be fungitoxic against the test fungi. The extracts suppressed the growth of these fungi in culture and reduced rot development in yam tubers.

Okigbo (2006) also reported the antifungal effects of two tropical plant leaf extracts (*Ocimum gratissimum* and *Aframomum melegueta*) on postharvest yam (*Dioscorea* spp.) rot. Effects of leaf extracts of *Ocimum gratissimum* and *Aframomum melegueta* on spore germination and mycelial reduction of *Aspergillus niger*, *A. flavus*, *Fusarium oxsporium Rhizopus stolonifer*, *Botryodiplodia theobromae* and *Penicillium chrysogenum* were studied. The leaf extracts with ethanol extraction were most effective, followed by cold-water and hot water extraction. The fungicidal activity with *Ocimum gratissimum* leaf extracts was more effective. *In vitro* inoculation of fresh yam with *A. niger*, *A. flavus* and *F. oxsporum* at room temperature for 3 months showed typical rot symptoms characteristic of the disease.

The effect of different plant extracts in the control of yam rot induced by *Rhizopus stolonifer* on stored yam (*Dioscorea* sp.) was carried out by Nahunnaro (2008) in Yola, Adamawa State, Nigeria. The treatments were plantain ash, neem seed oil, bitter leave extract, palm oil and a control. The result showed that the most prevalent fungus associated with yam rots in the study area was *Rizopus stolonifer.* The result further indicated that plantain ash gave the best control with regards to the number of spotted growth at 16days after inoculation (DAI). Similarly, plantain ash recorded the least growth diameter of 5.5cm at 16 DAI, followed by palm oil (5.73cm) and bitter leave extract (5.75cm). It was further observed that palm oil recorded the lowest weight loss of 9%, followed by plantain ash and neem seed oil at 16 DAI. This study revealed that the application of plantain ash and palm oil particularly on bruised yam tubers could assist in prolonging the shelf life and reduce rots due to *Rhizopus stolonifer* and other related rot agents.

Osunde (2008), reported the effect of 3 treatments: neem bark water extract, neem bark slurry and neem leaf slurry on the quality of stored yam. Ibrahim *et al.*, (1987), observed that sprouting was delayed by one month in all neem-treated tubers. Rotting was also delayed by three months in tubers treated with neem bark extract; a similar result was observed when using neem bark extract and neem leaf slurry for sprouting (Orhevba, 2006). However, the neem treatments in this case did not have any effect in reducing or delaying rotting. The effect of lime and neem wood ash treatment in three different cultivars of bruised *D. rotundata* tubers showed that lime was more effective in controlling rot in stored yam tubers than neem wood ash (Cornelius and Aduro, 1999). He stated another means of controlling rot and inhibiting sprouting in yam tubers is the use of palm wine; farmer's claim that tubers treated with palm wine show less rot but this claim is yet to be investigated.

Taiga (2009), reported the efficacy of three plants extracts (*Azadirachta indica*, *Nicotiana tabacum* and *Aloe barbadensis*) in prevention of rot-depth caused by four isolated pathogens (*F. oxysporium, R. stolonifer,P. oxalicum* and *A. niger*) in the yam tubers. The study indicated that 30 and 40% concentrations of cold and hot extracts of *N. tabacum*, completely prevented rot-depth caused by the four isolated pathogens in the yam tubers tested. Only the hot extract of *A. barbadensis* at 20, 30 and 40% concentrations completely prevented rot caused by *F. oxysporium, R. stolonifer and P. oxalicum,* while only the 40% concentration of its cold extract had similar effect on only the three pathogens like the hot extract. Also, only 30 and 40% concentrations of hot extract of *A. indica* prevented rot lesions caused by three pathogens (*F. oxysporium, R. stolonifer and P. oxalicum),* The hot extract of *N. tabacum* was most fungitoxic, followed by hot extracts of *A. barbadensis and A. indica* respectively.

Ezeibekwe (2009) investigated the potency of Aloe-vera gel extract on fungal organisms associated with yam rot. Fungi isolated were *Fusarium oxysporium* Schlech ex Fr., *Rhizopus oryzae* Went., Botryodiplodia *theobromae* Pat, and *Fusarium solani* Mart sacc. Pathogenicity test was carried out to confirm these organisms as the pathological agents of the yam rot. The Aloe-vera gel at the different concentrations of 25, 50 and 100% did not inhibit the growth of these fungi when tested for its antifungal potency ($p= 0.05$). The result of his study showed that Aloe-vera gel did not actually inhibit fungal growth as there was progression in the growth and development of the fungi. Okigbo *et al.*, (2010), investigated the potency of some leave extracts of *Chromolaena odorata* and *Azadirachta indica* with ethanol and water as the extracting solvent against some fungi pathogen causing rot (*Fusarium oxysporum, Aspergillus niger and Botryodiplodia theobromae*). The extracts were found to be fungitoxic against all the tested fungi. *Azadirachta indica* was found to inhibit organisms more than *Chromoleana odorata*.

In another study (Ijato, 2011), cold water and ethanol extracts of two fungicidal plants (*Zingiber officinale* and *Ocimum gratissimum*) were screened for their *in vitro* effects on rot fungi of yam using 60 and 80% aqueous extract and 20 and 30% ethanol extract of each concentration. The two concentrations of aqueous and ethanol extracts were found to have inhibitory effects on all the rot fungi isolated from yam, 80% aqueous extract of *Zingiber officinale* inhibited *Fusarium oxysporum* to 66.70%, 80% aqueous extract of *Ocimum. gratissimum* inhibited *Botrydioploidia theobromae* to 60.00%, 73.33% inhibition of *Aspergillus flavus* was also recorded using 30% ethanol extract of *Zingiber officinale,* the same concentration of *Ocimum gratissimum* inhibited *Aspergillus niger* to 70.00%. Both aqueous and ethanol extract of *Zingiber officinale* and *Ocimum gratissimum* had potential inhibitory effect on all the rot fungi.

Oyelana *et al.,* (2011), evaluated the antimicrobial activity of leaf extracts of *Ficus thonningii*, *F. saussureana*, *F. exasperate* and *F. sur* against eight (8) fungal species which include: *Aspergillus flavus, A. niger, Botryodiplodia theobromae, Fausarium oxysporum, F. solani, P. chrysogenum, P. oxalicum* and *Rhizopus stolonifer* and two (2) bacteria species of *Pseudomonas* and *Klebsiella* isolated from *Dioscorea rotundata* from South-West Nigeria. The extracts from the *Ficus* species had low antimicrobial effect at 25 and 50 $mgmL^{-1}$ concentrations, while a significant reduction of mycelia growth was observed at 75 and 100 $mg\ mL^{-1}$ concentrations. The presence of alkaloids, flavonoids and cardiac glycosides in the leaves of these species may have conferred the antimicrobial properties on these species. Application of the fungal pathogens isolated on healthy tubers and the subsequent development of rots confirmed these organisms as the natural pathogens of this crop. The extracts from all the four *Ficus* species exerted significant antimicrobial effect on all the test organisms at 75 and 100 mg ml^{-1}concentrations.

Shiriki *et al.*, (2015), evaluated the antimicrobial activity of five plant aqueous extracts: *Terminalia catapa* (common name fruit), *Passiflora edulis* (passion fruit), *Daniella oliveri (*Chiha-Tiv*)*, *Ceiba pentandr*a (Vambe-Tiv*)*, *Jatropha tanjorensis* (Catholic plant) against Five fungi species (*Aspergillus niger*, *Rhizopus stolonifera*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Penicillium marnessei*) and four bacteria species (*Serratia marcescens*, *Erwinia carotovora*, *Klebsiella oxytoca* and *Pseudomonas aeruginosa*). He reported varying degrees of inhibition; the aqueous extract from *Passiflora edulis*, *Ceiba pentandra* and *Jatropha tanjorensis* were able to inhibit all the fungi completely.

Ethanol, gentamicin and methanol extracts of water yam peel at different concentration on *Fusarium oxysporum, Rhizopus stolonifer, Botryodiplodia theobromae and Trichoderma viride* isolated from white yam was investigated for its antimycotic effect by Okigbo et al., (2015). Gentamicin, ethanol and methanol extracts were effective in controlling the establishment of the test pathogens in vitro and in vivo. Ethanol extract exhibited the highest potency in inhibition with increase in concentration. This was attributed to the inherent biochemical constituents of water yam peel extracts that was found to contain alkaloids, tannins, flavanoids, saponins and sterols. Gentamicin, though a known strong antibiotic had the minimum total inhibition.

Onuh *et al.*, (2015), reported that *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus stolonifera*, *Penicillium marneffei*, *Erwinia carotovora* and *Pseudomonas aeruginosa* were completely inhibited with aqueous extracts of *Terminalia catapa*, *Passiflora edulis*, *Daniella oliveri*, *Ceiba pentandra*, *Jatropha tanjorensis*, *Azadirachta indica*, *Carica papaya*, *Moringa oleifera*, and *Mangifera indica* . The result they obtained showed that *Passiflora edulis* had the best antimicrobial activity for both fungi and bacteria; indeed it inhibited completely *Rhizopus stolonifera*, which was stubborn with most of the other plants. *Azadirachta indica*, *Carica papaya*, *Moringa oleifera*, and *Mangifera indica* were also able to inhibit most of the fungi but not completely. *Terminalia catapa* and *Jatropha tanjorensis* were most effective against the bacteria. *Erwinia carotovora* was completely inhibited by *Terminalia catapa* and *Pseudomonas aeruginosa* was completely inhibited by *Jatropha tanjorensis*. *Daniella oliveri* and *Ceiba pentandra* had the least inhibition against the isolates. Generally, the fresh plant extract shows more activity compared to the dry plant extract.

Nweke (2015) studied the in vitro activity of mycelia growth and spore germination of *Botryodiplodia theobromae* Pat, causal organism of yam tuber rot using water and ethanol extracts of leaves of *Cassia alata* L., *Azadirachta indica* A. Juss., and *Citrus aurantifolia.* The water and ethanol extracts showed varying degrees of fungitoxicity with the ethanol extracts being more effective. Mycelial growth of *B. theobromae* was significantly ($P < 0.05$) reduced by ethanol extracts of *C. aurantifolia* (60.37 – 73.83%), A. *indica* (51.44 – 60.46%) and *C. alata* (50 – 58.51%) during the period of incubation. Spore germination was also significantly ($P < 0.05$) reduced by ethanol extract of *C. aurantifolia* (59.68%), *A. indica* (48.69%) and *C. alata* (47.19%). The phytochemical screening of the extracts of the plant species revealed the presence of alkaloids, flavonoids, glycosides, saponins, tannins, phytobatannins and terpenes.

Anukwuorji (2016), investigated the effects of four plant extracts (*Moringa oleifera*, *Azadirachta indica*, *Gongronema latifolium* and *Xylopia aethiopicum*) on *Fusarium solani*, *Aspergillus niger*, *Botryodiplodia theobromae* and *Rhizopus stolonifer* that had the highest prevalence among the eight fungal pathogens responsible for yam rot in storage. The Phytochemical test of these plant materials showed the presence of alkaloid, flavonoid, glycosides, saponin and tannins at different quantities. The study reported that all the plant extracts inhibited the growth of the test organisms at varying degrees. The degrees of inhibition were dependent on concentration of extract, extraction medium and the test organism. The highest inhibitory values were obtained from ethanol extracts of *Moringa oleifera* and *Azadirachta indica* at 7.5% and 10.0% concentration each, while *Gongronema latifolium* and *Xylopia aethiopicum* gave lower inhibitory values. This suggests that *Moringa oleifera* and *Azadirachta indica* are good bio-killers and their biological active ingredients can be exploited for the control of yam rot.

The Antifungal effects of ginger rhizome extracts on Mycelial growth of some fungal pathogens of *Dioscorea rotundata* in Taraba state, Nigeria was investigated by Aji *and* Tunwari, (2018). The most commonly isolated fungi were *Aspergillus niger* and others are; *Aspergillus flavus* and *Rhizopus stolonifer*. All concentrations (0%, 20%, 40%, and 60) of extract used, suppressed the mycelia growth of the tested pathogens except the control treatment. The effect was proportional to concentrations, and inhibition value was highest at 60% concentration, for aqueous extraction. *Zingiber officinale* was more effective on *Aspergillus flavus and Rhizopus stolonifer*, for both aqueous and ethanol extractions. Phytochemical analysis showed that the extracts contain tannins, saponins, terpenoids, alkaloids, steroids. The presence of these compounds supports the use of the extracts as antimicrobial agents which can prolong the shelf–life of yam under storage.

Shiriki (2019), also reported nine (9) microorganisms, comprising of four bacteria (*Erwinia carotovora, Pseudomonas aeruginosa, Serratia marcescens, Klebsiella oxytoca*), and five fungi (*Rhizopus stolonifera, Aspergillus niger, Aspergillus flavus, and Penicillium marneffei*), isolated from rotten yam tubers, were treated with ten plants extracts (*Passiflora edulis, Daniella oliveri, Ceiba pentandra, Jatropha tanjorensis, Azadrichta indica, Carica papaya, Moringa oleifera, Mangifera indica, Terminalia catapa* and *Senna alata*), singly and synergistically by incorporation of extract in media for inhibition test. Two plant extracts singly and completely inhibited the growth of three organisms: *Terminalia catapa* at 100% and at 10^{-1} showed complete inhibition of *Erwinia carotovora*. *Passiflora edulis* at undiluted (100%) concentration, completely inhibited *Rhizopus stolonifer* and *Penicillium marneffei*. Synergistic plant extract recorded complete inhibition of all the four bacteria isolates at 2ml extract incorporation; ten (10ml) ml extract incorporation in media recorded complete inhibition of three out of the five fungi isolates: *Rhizopus stolonifer, Fusarium oxysporum* and *Penicillium marneffei* each;. The other two fungi recorded high inhibition of *Aspergillus niger* and *Aspergillus flavus* each. Hot aqueous synergistic plants extract recorded poor inhibition of the isolates as compared to the cold. Soxhlet solvent extracted synergistic plants extract, however, recorded lower inhibition as compared to hot aqueous synergistic plants extract and cold aqueous synergistic plants extracts. Room temperature solvent extracted synergistic plants extracts recorded inhibition that was same as that obtained with cold aqueous synergistic plants extract. This indicates that heat employed extractions recorded less inhibition activity.

Conclusion

Postharvest losses of yam crops in storage can only be reduced if they are protected with synthetic chemicals, but the perceived harmful effects of these chemicals currently in use on human and the environment no longer make them attractive to use. Based on the findings of this study, there are great potentials in the control of post-harvest pathogens/diseases of yams using natural plants available in Nigeria in their extracted form that are both human and environment friendly and at the same time cost effective, especially for resource poor farmers compared to procurement and use of chemically formulated fungicides. Extracts of plant origin are biodegradable and hence are efficient tools in reducing or eliminating pesticides persistence problems in the environment, because they offer wide ranging modes of action against pathogens. Plant extracts aids in delaying resistance to pests and diseases in agriculture and can be used in both conventional and organic farming systems. Pre-storage treatment of yam tuber crops with the proper plant extract can mitigate and inhibit the growth of pathogens and protect crops (especially yam) against storage rot, thus diminishing crop losses in storage. Furthermore, the extracts of these botanicals can be easily formulated and applied with ease with respect to farmers with little or no education.

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