Australian Journal of Basic and Applied Sciences

2021 August; 15(8): pages 1-9
https://doi.org/10.22587/ajbas.2021.15.8.1

CASE STUDY AENSI PUBLICATIONS

Studies On The Fungal Isolates Of The Soil Spots Of Sweet Potato (*Ipomoae batatas* (L.) Lam) Root Tubers In The Field

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Received date: 15 May 2020, Accepted date: 22 July 2021

Cite as: M. D. Sila., C.I.C. Ogbonna., D. D. Nyam., P. A. Wuyep., V.M. Shutt., 2021. Studies On The Fungal Isolates Of The Soil Spots Of Sweet Potato (*Ipomoae batatas* (L.) LAM) Root Tubers In The Field. Australian Journal of Basic and Applied Sciences, 15(8): 1-9. DOI: 10.22587/ajbas.2021.15.8.1.

ABSTRACT

Sweet potato *(Ipomoea batatas* (L) Lam) deterioration commences from the farm by fungal biodeteriogens and might continue unabatedly in storage to reduce the marketability of the commodity. It becomes necessary to isolate and identify these biodeteriogens to develop strategies of handling the organisms either in the farm or in the store. The soil spots of sweet potato cultivars: CIP 4400648, Ex-Igbariam, Tanzania, TIS 8461 and TIS 87/0087) were investigated in Rayfield on the Jos Plateau to isolate and identify the mycoflora associated with the cultivars. A fifty gram weight (50.00g) of soil each was collected and was also assessed for ecological parameters. Mycorrhizal region of the root tubers was also examined. Amylolytic activity in the experimental soil and some of the isolates were determined. The experimental soil had MC of 25%, 2.8% organic matter, some non-metallic elements and pH range of 6.2 – 6.4. The fungal isolates from the farm that were observed were Ascomycetes (2), Phycomycetes (9) and Hyphomycetes (28). Two species of thermophiles (Mucor pusillus and Scytalidium thermophilum), four species of thermotolerants and thirty-three mesophiles were isolated. The genus Aspergillus had the highest number of species. Sixty nine percent (69%) of the fungal isolates was made up of Hyphomycetes, twenty three per cent (23%) Phycomycetes while the Ascomycetes were eight percent (8%). Five yeast species also constituted the isolates. Fungal species of mycorrhizal regions were similar with those of the soil spots. The soil suspension had amylolytic activity and some of the isolates. The study has clearly shown that field fungi are in close association with the root tubers in the farm where they could commence the deterioration process of the farm produce which could continue unabatedly during storage resulting in its poor shelf-life. Therefore, harvested root tubers should be processed immediately into secondary products after harvest to avoid the deteriorative effects of field fungi transferred into storage. Formulation of secondary products with extended shelf-life than the wholesome root tubers, using advanced technology, is the next phase of activity on this farm produce.

Keywords: Amylolytic activity, Cultivars, Mycorrhizal region, Mycoflora, Field and Storage fungi

INTRODUCTION

Fungi may infect sweet potato root tubers in the field during harvest and storage. The organisms establish the most severe cause of post-harvest loss in sweet potato root tubers, which could have originated from the field (Sila et al., 2017). These organisms are widely distributed in the air, soil and on dead and decaying plant material in the farm. Studies on harvested root tubers have shown that various factors are responsible for losses of the root tubers. Some of the sweet potatoes are infected by field fungi which are transferred into storage (Arora and Arora, 2007). A wide range of soils used for the cultivation of sweet potatoes have been examined for the presence of fungi. It was observed from these studies that farm soil is home to also all microbial forms, fungi and yeast inclusive (You et al., 2014).

Post-harvest pathogens can be divided into those that penetrate the produce in the farm, but develop in the root tissues after harvest during storage or retailing on the one hand, and those that initiate penetration and colonization after harvest during handling and

storage on the other (Arya, 2010). Some post-harvest losses have been attributed to fungal biodeteriogens from the field that persist in the root tubers during storage until environmental factors are not favourable for survival.

Food security and sustainability are one of the ways of addressing the problem of food scarcity and shortage due to the activities of fungi in the field. Thus food security will reduce the deterioration and scarcity of the root tubers (Oduola et al., 2018). On the Jos Plateau sweet potato is basically produced for its storage roots which are eaten fresh, steamed, fried or boiled. The root tubers are also processed into powder and sweeteners that require refining while the vines and the leaves are dried and fed to livestock as hay. Thus the root tuber has enormous potentials to be an effective and economical source of energy, antioxidants and anthocyanins, root protein and vitamin A (Oladoye et al., 2013). It can be incorporated into other products to prepare local indigenous foods. However, the shelf-life of this product is seriously hampered by the activities of fungal species in the farm and could continue unabatedly during storage.

These biodeteriogens constitute major impediments to the drives for food security on the Jos Plateau. Therefore the objective of this study was to identify the experimental plot of sweet potato farm soil fungal species (field fungi) which could be transferred with the harvested root tubers into the store and might persist in the stored root tubers to constitute part of the decaying fungi (storage fungi).

MATERIALS AND METHODS

Fungal Isolations from the Soil Samples of the Farm.

A fifty gram weight (50g) of soil crumb was collected from each spot where the experimental sweet potato cultivars were CIP 4400648, Ex-Igbariam, Tanzania, TIS8461 and TIS 87/0087 were grown in Rayfield. Each sample was put in a sterile polythene bag, labeled, and transported to the Microbiology laboratory at the National Veterinary Research Institute (NVRI) Vom for detailed studies of the myco-flora contents. This experiment was done to find out whether there is any relationship between the field fungi where the experimental root tubers were grown and the Storage fungi.

Each soil crumb was put into a clean crucible, stirred to obtain a homogenous mixture, sifted with a 2.00mm mesh sieve then a weight of 0.03g was dispensed in thirty sterile culture plates employing the soil plate method. A volume of 15ml of Malt Extract Agar (MEA) was then run into each plate. The culture plates were then swirled to obtain a proper mixing of the soil and the culture medium and then set.

The resultant culture plates were divided into 3 batches of 10 plates each. The first batch was incubated at 25^0C, the second at 37^0C and the third at 45^0C for the isolation of mesophilic, thermotolerant and thermophilic fungi respectively. Control plates without soil crumbs were set up for each temperature; beakers containing water were inserted in the high-temperature incubators to minimize dehydration. The plates were examined after 24 and 48 hours for yeasts and 2 – 4 days for fungi and after 14 days for additional fungal colonies.

Purification of the fungal isolates

The fungal colonies that developed were subjected to series of sub-culturing using Sabouraud Glucose Agar (SGA) until pure cultures were obtained.

Sweet potato root tuber Mycorrhizal flora

In a separate experiment samples of soil were collected from the mycorrhizal region of the cultivated root tubers. The soil particles were scraped from the skin of the root tubers that were pulled out and not dugout. The mycorrhizal soil crumbs were then plated out on MEA. Visible hyphae were also scraped from the surface region of the pulled out root tubers and cultured accordingly.

Soil Ecological determinations

Soil samples were collected from the different spots of the experimental plot and tested for the pH range and percentage moisture content.

Determination of the percentage Moisture content

In this experiment, a weight of 50g of soil sample was collected from the experimental plot and dried to constant weight. The percentage moisture content was determined using the formula:

$$\frac{x-y}{x} \text{ x } \frac{100}{1}$$

Where x = initial weight of soil

y = weight of soil after drying to constant weight

Three determinations were made from the soil samples collected at guided random and the average result was then recorded.

pH determination.
This experiment collected 50g of soil from the experimental soil then stirred in 100ml of distilled water. The pH of the resultant soil suspension was then determined with the aid of the LABTECH DIGITAL pH meter, an average of three determinations was made.

Non-metallic Elements determination.
The presence of the non-metallic elements essential for microbial growth in the experimental plot of land was assessed by the use of 'Perkin – Elmer Element Analyzer following the method described by Natten and MacDonald (1970).

Organic or Carbon content determination
The percentage of the organic content of the experimental soil was determined by burning the soil sample used to determine its percentage moisture content. The 50g soil sample was put in the furnace and burnt. The weight difference between the dry soil and the burnt soil was regarded as the organic or carbon content of the soil. The percentage organic content was determined using the formula:

$$\frac{y - z}{y} \times 100$$

Where y = Weight of soil dried to constant weight

z = Weight of burnt soil

Subculturing of *Aspergillus* and *Penicillium* species
The Aspergilli and Penicilli isolates were further cultured on Czapek Dox Agar (CZA) to aid their identification since they grow rapidly and produce pigments in this medium.

Identification of the Fungal Isolates
The fungal isolates were examined microscopically to determine their identities. In addition, the cultural characteristics and morphological parameters of the isolates were considered. Fungal stock cultures aided the identification process. References were also made to Domsch and Gams, 1972; von Arx, 1974; Samson et al., 1984; Barnett and Hunter, 1998; Nyongesa et al., 2015).

Identification of the Yeast isolates
The yeast isolates were examined microscopically and various biochemical tests such as India ink (wet preparation) test, urease test, fermentation test, and sugar assimilation test were finally carried out to identify the organisms.

The Aerial mycoflora of the Sweet potato root tuber Storage environment
The aerial mycoflora of the sweet potato root tubers storage environment was carried out employing the Petri dish culturing exposure method. Freshly prepared culture plates of MEA were exposed at the root tuber storage barn. Fifteen of such plates were closed at one hour and incubated at the different temperatures of 250C, 370C and 450C to isolate mesophilic, thermotolerant and thermophilic fungi. 5 exposed plates were incubated at each temperature the resultant fungal colonies were purified and identified. Control plates that were not exposed were also incubated at different temperatures.

Amylolytic activity in the Experimental soil of the Plot
In separate experiments, soil samples were collected from each of the experimental soil at the mycorrhizal region of the root tubers and tested for the presence of extracellular amylase (Ogbonna and Ogbonna 2016). In this method, suspensions of 1g of the soil sample were obtained. This was used to flood the surface of starch agar for a period of 24 hours. After that, the excess soil suspension was drained out, and the surface of the starch agar plate was then flooded with Lugol iodine solution. The hydrolyzed region because of amylolytic activity was supposed to be colourless, while the non-hydrolyzed portion was supposed to remain blue-black in colour. The result obtained was duly recorded. A positive effect depicted amylolytic activity in the mycorrhizal zone of the root tuber and hence the abilities of the associated fungi to produce extracellular amylase.

Amylase production by some of the Fungal isolates
Some of the fungal isolates from the decaying sweet potato root tubers that exhibited high percentages of occurrence and those that had been conventionally employed for amylolytic studies were chosen for detailed investigation on their abilities to produce amylase. The enzymatic studies were centred on amylase production mainly because sweet potato has high starch content.

The species of the fungal isolates from the decaying root tubers included: *Emiricella nidulans, Aspergillus niger, A. oryzae, A.parasiticus and A.terreus* were cultured on starch agar for a period of 7 days. Their mycelia were subsequently scraped with the aid of a sterile blade and then the surfaces of the culture plates were flooded with Lugol iodine solution. The hydrolyzed part of the starch agar due to amylolytic activity was supposed to be colourless while the non-hydrolyzed portions were supposed to be blue-black, as Ogbonna (1980) reported. A positive result confirmed the ability of that particular test fungus (isolate) to produce amylase and, therefore, its ability to utilize the starch component of the sweet potato root tuber and its deterioration.

Fungal isolation Experiments from the Peels of the Harvested Root tubers

Fungal isolation experiments were carried out on the peels of the harvested root tubers. This was done in order to find out whether there was any relation between the fungal flora of the peels of the harvested root tubers and the fungal flora of the soil (field fungi) from where they were harvested.

Some of the harvested root tubers that showed signs of decay were picked out and were subjected to fungal isolation experiments. Portions of the decaying root tubers were cut into pieces aseptically with the aid of a sterile sharp knife. The resultant pieces of the root tubers were plated out on MEA. The pieces of the root tubers were distributed in sterile Petri dishes, a volume of 15ml of MEA was run into each petri dish, swirled to obtain a mixture of the pieces and the agar medium the plates were allowed solidify.

A total of 30 culture plates were prepared and were divided into 3 batches, each containing 10 plates. The first batch of plates was incubated at 25^0C, the second at 37^0C and the third at 45^0C for the isolation of mesophilic, thermotolerant and thermophilic fungi respectively. Control plates were also set up but without pieces of the root tubers. The culture plates were examined after 24 – 48 hours for the development of yeast colonies and after 2 – 4 days for those of fungal colonies. The culture plates were re-examined after 14 days for additional fungal colonies. The fungal isolation experiments were carried out on a fortnightly base and for a period of 8 weeks.

Purification of the Fungal isolates

The yeast and fungal colonies that developed were subjected to series of sub-culturing until pure cultures were obtained.

Identification of the Isolates

The yeast isolates were subjected to Gram – staining experiments and to the relevant biochemical experiments for identification as stated above. The fungal isolates were subjected to microscopic examinations in order to get them identified. The morphological details were thoroughly studied as stated above. References were also made to stock cultures.

pH Determination of the Harvested Root tubers

The peels and decay portions of the harvested root tubers pH were also determined by carefully removing them with a penknife, chopped into smaller chips, then put into a mortar and crushed with a pestle into a paste. Five grams of each paste was dispensed into 50.00ml of distilled water to produce the solution. Finally, the solution was stirred and sieved into supernatant to determine the pH with the LABTECH DIGITAL pH meter.

RESULTS

Fungal isolates from the Experimental soil

The fungal isolates from the experimental plot of land included 2 Ascomycetes, 9 Phycomycetes and 28 Hyphomycetes. The isolates also included 2 species of thermophiles (*Mucor pusillus* lindt and *Scytalidium thermophilum* Austwick), 4 species of thermotolerants and 33 mesophiles. The genus *Aspergillus* had the highest number of species (13). It was followed by the genus, *Fusarium* which had 7 species and *Mortierella* which had five species.

The rest of the genera isolated had at least one species. Fugal species were isolated from soil samples collected from the spot where Ex-Igbarium and Tanzania were cultivated than where CIP 440168, TIS 8164 and TIS 87/0087 were cultivated. Twenty nine (29) fungal species were isolated from soil spot where Ex–Igbariam was grown while 26 fungal isolates were isolated from the spot where Tanzania was grown. The least number of 21 fungal species was isolated from the soil spot where CIP 4400168 was cultivated. The fungal species that occurred on all the five soil cultivation spots included: *Aspergillus candidus, A. clavatus, A. flavus, A. fumigatus, A. terreus, Mucor pucillus and Rhizopus stolonifer*.

The fungal species which had 100% frequency of occurrence were *A. flavus, A. fumigatus, Mucor pucillus and Rhizopus stolonifer*. Sixty nine percent (69%) of the fungal isolates was made up of Hyphomycetes, twenty three percent (23%) Phycomycetes while the Ascomycetes were found to have eight percent (8%) of the fungal isolates. The details of the fungal isolations are presented in Table 1.

Table 1: Occurrence of the Isolates in the Soil Samples from the farm at Rayfield

Fungal isolates	Occurrence in zones of Sweet potato cultivation					
	CIP	EX	TAN	TIS 81	TIS 87	TOTAL
Ascomycetes						
Emericella nidulans (Eldam) Vuill	+	+	+	-	-	3
Eurotium amstelodami Mangi	+	+	-	-	+	3
Hyphomycetes						
Aspergillus candidus link.	+	+	+	+	+	5
A. clavatus Desm.	+	+	+	+	+	5
A. carneus Blochwite	-	+	+	+	+	4
A. flavus link ex.Gray.	+	+	+	+	+	5
A. fumigatus Fres	+	+	+	+	+	5
A. niger van Tieghem	+	-	-	+	+	3
A. oryzae (Ahlburg) Cohn	+	-	+	-	+	3
A. sydowii Thom and Church	+	-	-	+	+	3
A. tamarii kita	-	+	+	-	-	2
A. terreus Ihom	+	+	+	-	+	4
A. versicola (Vuill) Tiraboschi	-	+	+	+	-	3
A. wentii Wehmer	-	+	+	-	+	3
Botrytis cinerea Pers	+	-	-	+	+	3
Cylindrocarpon olidum Wollenw	-	-	+	+	-	2
Fusarium culmorum (W.G. Smith) Saac	+	+	-	-	-	2
F. oxysporum Schlecht	-	+	+	+	+	4
F. poae (Peck) Wollenw	-	+	+	+	+	4
F. redolens Wollenw	+	-	-	-	-	1
F. semitectum Berk and Rav.	-	+	+	-	-	2
F. sporotrichoides Sherb.	-	-	+	+	+	3
F. tricinctum (Corda) Saac.	+	+	-	-	-	2
Helminthosporium velutinum link	-	+	+	-	-	2
Helminthosporium sp.	+	+	-	-	-	2
Penicillium paraherquei Abe ex.G. Smith	+	-	-	-	-	1
Phialophora americana (Nannf) Hughes.	-	+	-	+	+	3
Phymatotrichopsis omnivore (Dugger) Henneb	-	-	-	+	-	1
Scytalidium lignicola Pesante	+	-	-	+	+	3
S. thermophilum Austwick	-	-	+	+	-	2
Phycomycetes						
Mortierella isabellina Oudem	-	+	+	-	-	2
M. humilis linnem	+	+	+	-	-	3
M. nana linnem	-	+	-	-	+	2
M. ramanniana (Moller) Linnem	-	-	-	+	-	1
M. Vinacea Dixor Stewart	-	+	+	+	+	4
Mucor pusillus lindt	+	+	+	+	+	5
Rhizopus stolonifer (Ehrenb) Link	+	+	+	+	+	5
Syncephalastrum racemosum Cohn	-	+	-	-	+	2
S. verruculosum Misra	-	-	+	-	+	2
Yeasts						
Candida albicans (Berkhout)	-	+	+	+	+	4
Debaryomyces hanseni (Zopf)	-	+	-	+	-	2
Rhodotorula glutinis(Fres) Harrison	-	-	-	-	+	1
Rhodotorula sp	-	+	+	-	-	2
Saccharomyces cerevisiae (Hansen).	+	-	-	-		1
Total	21	29	26	23	25	124

Yeasts isolates from the Experimental soil

The average colony diameter of the yeasts isolated ranged between 10 to 30mm. Cream, white and occasionally pink and red colours were observed in the plates. The creamy colonies grew faster and best at 37^0C, often submerging the other yeasts. The colonies of the yeasts became much larger after 48 hours of incubation. Colour change from white in some species to cream, yellow and tan while others remained mucoid and fluidy were all observed. The yeast-like organisms grew on the sabouraud glucose agar plates within 48 hours of incubation at 25^0C and 37^0C, but few small, creamy colonies were observed in the plates incubated at 45^0C. Fast-growing fungi such as *Mucor, Rhizopus, and Aspergillus* species contaminated the yeasts making it difficult to isolate them in pure culture but series of subculturing the organisms on fresh plates of sabouraud glucose agar (SGA) eliminated such

contaminants. Some of the colonies became dry and matted with crenated edges. Of the eight yeasts isolates, none showed presence of capsules and none exhibited urease activity. *Candida albicans* was the only yeasts that produced germ tube within 3 hours of incubation.

The biochemical reactions of the yeast isolates revealed a mixed carbohydrate fermentation and assimilation pattern (Table 2). The yeasts assimilated more sugars rather than fermented them. *Rhodotorula* species did not ferment any of the sugars but assimilated only glucose, while other yeasts were weak and varied in their reactions to all the tests carried out. The experimental soil spots from the farm at Rayfield had 5 yeast isolates (Table 2). However, yeast species with greater affinity for sugars of the root tubers were more in number in the soil spots sampled.

Table 2: The Biochemical Features of the Yeast Isolates

Gram staining	Germ Tube Test	India Ink Test	Fermentation Test					Sugar Assimilation Test					Ureae Test	Growth at 25^0C	Growth at 37^0C	Growth at 45^0C	Yeast
			Gal	Glu	Lac	Matt	Suc	Gal	Glu	Lac	Matt	Suc					
+	+	-	+	+	-	+	+	+	+	-	+	+	-	+	+	-	***Candida aIbicans* (Berkhout)**
+	-		-	+	-	-	+w	+	+	-v	+	+	-	+	+	-	***Debaryomyces hansenii* (Zopt)**
+	-	-	-	+v	-	-	+	-v	+	-	+	+	-	+	+	-	***Hansenula* sp**
+	-	-	-	-	-	-	-	+w	+	-	+w	-	-	+	+	-	***Rhodotorula glutinis* (Fres) Harrison**
+	-	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	***Rhodotorula* sp.**
+	-	-	+v	+	-	+v	+v	-v	+	-	+v	+v	-	+	+	-	***Saccharomyces cerevisiae* (Hansen)**
+	-	-	-	+w	-	+w	+w	-	+	-	+	+	-	+	+	-	***Saccharomycopsis fibuligera* Lindner**
+	-	-	-	+	-	+	+	-	+	-	+	+	-	+	+	-	***Schizosaccharomyces pombe* Lindner**

W=WeakReaction V=Variable

Mycorrhizal Fungi of the Experimental Soil

The mycorrhizal fungal isolates of the soil spot where the cultivar were grown included: two unidentified Ascomycetes and two unidentified Basidiomycetes; two species of *Aspergillus*, one species of *Endogone*, one species of *Emericella*, one species of *Mortierella*, one *Phanerochete* species, one species of *Pythium*, one species of *Rhizoctonia*, one species of *Rhizopus*, one species of *Zygorhychus*. More fungal species were isolated from soil samples collected from the mycorrhizal regions of Tanzania and TIS 8164 than from the mycorrhizal regions of CIP 4400168, Ex-Igbariam and TIS 87/0087. The species of fungi in the mycorrhizal regions of the root tubers were similar to those isolated from the experimental soil spots where the root tubers were grown. *Endogone* species, *Pythium* species *Rhizoctonia repens* and *Zygorhynchus heterogamous* were not isolated from the experimental soil spots where the root tubers were grown. The details are given in Table 3.

Table 3: The Mycorrhizal Fungal Isolates

	Sweet Potato Cultivars					
Fungal isolates	CIP	EX	TAN	TIS81	TIS86	TOTAL
Ascomycete 1	+	-	-	+	+	3
Ascomycete 2	+	+	+	+	+	5
Basidiomycete species 1	-	-	+	+	+	3
Basidiomycete species 2	-	-	-	+	+	2
Aspergillus clavatus Desm	-	+	+	+	-	3
Aspergillus terreus Ihom	+	+	+	+	+	5
Emericella nidulans (Eldem) Vuill	+	+	+	+	+	5
Endogone species	-	+	+	-	-	2
Mortierrella wolfii Mehrotra & Baijal	+	+	+	+	+	5
Phanerochete species	+	+	+	+	+	5
Pythium species	+	-	+	+	-	3
Rhizoctonia repens Kuhn	-	-	+	+	-	2
Rhizopus stolonifer (Elrenb) Lind	+	+	+	+	+	5
Zygorhynchus heterogamous Vuill	+	+	+	-	-	3
Total	9	9	12	12	9	51

CIP = CIP 4400168, EX = Ex-Igbariam, TAN =Tanzania, TIS81= TIS 8164, TIS 87 = TIS 87/0087.

Evidence of Amylase Presence in the Experimental soil Suspension

It was observed that the soil suspension hydrolyzed the starch of the starch Agar when it was used to flood the agar. The hydrolyzed area of the agar appeared colourless when it was flooded with Lugol iodine solution.

Physico-chemical Features of the Experimental soil

The experimental soil was found to have average moisture containing 25%, 2.8% organic matter, a pH range of 6.2 – 6.4. It was also found to contain the following non-metallic elements: Carbon, Chlorine, Nitrogen, Phosphorus and Sulphur. Thus, the moisture content and pH range level were within the values that would support fungal growth in pure culture. The details are given in Table 4.

Table 4: Physico – Chemical Features of the Experimental Soil

	Replicates			
Composition (%)	1	2	3	Mean
Moisture content	24	26	25	25
Organic matter	2.7	2.9	2.8	2.8
pH	6.2	6.3	6.4	6.3
Non metallic elements				
Carbon	+	+	+	
Chlorine	+	+	+	
Nitrogen	+	+	+	
Phosphorus	+	+	+	
Sulphur	+	+	+	

+ = Present

Species of Fungi isolated from the Peels of the Harvested Root tubers

The harvested sweet potato root tubers had thirteen species of fungi and four species of yeast. A total number of 17 species of fungi was isolated from the harvested sweet potato root tubers. Fifty-two per cent (52%) of the fungal isolates belonged to the Hyphomycetes, while 12% was found to belong to both Ascomycetes and Phycomycetes. The percentage of occurrences (24%) was found to belong to the Yeast. The peels mycoflora contained more Aspergilli than any of the species of fungi.

Amylase Production by Some of the Fungal isolates

The experiment on amylase production by some of the fungal isolates from the experimental soil revealed that *A. niger, A. oryzae, A. parasiticus, A. terreus and E. nidulans* were amylolytic and therefore could hydrolyze the starch component of the sweet potato tubers to glucose for sugar fungi to utilize.

Yeast isolates from the Decaying Root tubers

The decayed tubers were found to be associated with some yeast species like *C. albicans, D. hansenii, Hanselula, sp, S. cerevisiae, S. fibuligera* and *S. pombe* reinforces the presence of sugar in the decaying or decayed sweet potato root tubers. These yeast isolates contain species that have fermentative abilities that could ferment the sugar component of the sweet potato tubers under favourable conditions. The yeast isolates were also found to assimilate carbon (Table 2).

Table 5: Fungal Isolates from the Peels of the Harvested Root Tubers.

	Sweet Potato Cultivars					
Fungal Isolates	CIP	EX	TAN	TIS 81	TIS 87	TOTAL
Ascomycetes						
Emericella nidulans (Eidam) Vuill.	-	-	-	+	-	1
Eurotium herbariorum (Wiggers) Link	-	+	-	-	-	1
Hyphomycetes.						
Aspergillus candidus Link	-	+	-	-	-	1
A. clavatus Desm	+	-	-	-	+	2
A. flavus Link ev. Gray	-	+	+	-	-	2
A. fumigatus fres	-	+	+	-	+	3
A. niger van Tieghem	+	-	-	-	+	2
A. oryzae (Ahlburg) cohn.	-	+	-	+	-	2
A. terreus Ihom	-	+	+	-	-	2
Fusarium oxysporum Schlecht	-	-	+	-	-	1
Penicillum paraherquei Abe ex.G.Smith	+	-	+	-	-	2
Phycomycetes						
Mucor pusillus Lindt	-	+	+	+	+	4
Rhizopus stolonifer (Ehrenh) Link	+	+	+	+	-	4
Yeasts						
*Saccharomyces cerevisiae (*Hansen)	+	+	+	+	-	4
Rhodotoru sp.	-	+	-	+	-	2
*Debaryomyces hansenii (*Zopf)	-	-	-	-	+	1
Rhodoturula glutinis (Fres) Harrison	-	-	+	+	-	2
Total	5	10	9	7	5	36

+Present, - Absent CIP = CIP 4400168, EX = Ex-Igbariam, TAN =Tanzania TIS81 = TIS 8164, TIS87 = TIS 87/0087.

pH of the Stored Root tubers

The mean pH values recorded in the stored sweet potato tubers 3.87 – 3.93 were within the ranges that will support the growth of fungi in pure culture. The details of the pH determinations are given in Table 6.

Table 6: The pH of the Root Tubers Surfaces (peels) and Decay Portions after Harvest

Root tuber	Peels	Decay portions
CIP 4400168	6.53	3.87
Ex-Igbariam	6.57	3.92
Tanzania	6.46	3.91
TIS 8164	6.54	3.93
TIS 87/0087	6.55	3.89

DISCUSSION

Thirty nine (39) species of fungi were isolated from the experimental soil where the sweet potato cultivars were grown. The Genus *Aspergillus* had the highest number of species. It was followed by the Genus *Fusarium* and then by *Mortierella*. A substantial number of the fungal isolates are potential biodeteriogens and could pose a great danger if they accompany the sweet potato root tubers to the storage house where their decay could lead to a major post-harvest or economic losses (Agu et al., 2015; Oduola et al.,2018).

In a similar study, Ogbonna and Pugh (1982) carried out a survey of fungi in soils collected at Jos, Nigeria. In their report, *Aspergillus*, represented by 25 species, with a total of 408 isolations, was the most frequently isolated genus. *Fusarium* (14 spp., 227 isolations), *Chaetomium* (8 spp., 185 isolations), *Trichoderma* (7 spp., 162 isolations) and *Penicillium* (10 spp., 98 isolations) were the other abundant genera. Total isolations of mesophilic fungi were most frequent in the rainy season but dematiaceous species were isolated more often in the dry season. The same authors isolated a total of 25 thermophilic and 15 thermotolerant fungal species during their survey of potentially biodeteriogenic from soils and compost samples.

Of the 39 species of fungi isolated from the experimental soil, 29 were isolated from the soil spot where the Ex – Igbariam cultivar was grown. It was followed by the soil spot (26) where Tanzania cultivar was grown, then by the soil spot (25) where TIS81/0087 was cultivated and then by the soil spot (23) where TIS87/8164 was grown. The least fungal isolated (21) was recorded from the soil spot where CIP cultivar was grown. The farm soil environment is unique in several ways; it contains a vast a ray of fungi and it is one of the most dynamic sites of biological interaction in nature. It is for this motive that the soil composition of the fungal species varied as observe by Ogbonna et al. (2015) Fungi in soil are presented as mycelial bits, rhizomorphs or as various types of spores; it is also for this motive that different fungal species were isolated from different experimental soil spots which is in agreement with the report of Rupsa et al. (2017).

The farmland at Rayfield with a mean pH of 6.3 was most suitable for the colonization of fungal species dominant in acid soil. The constant deposition of organic wastes on the farm bears the number of fungi since most fungi are heterotrophs. The fertility of the farm soil supported the growth and development of the different fungal isolates identified in this study as reported by Okwuowulu and Osiegbu (2002) that the fertility of the soil alters the composition of the flora and the relative dominance of genera such as *Aspergillus, Fusarium, Mucor, Penicillium and Trichoderma* which were identified in this study.

Five (5) yeast species were isolated from the soil spots of the root tubers on the farm. The yeast isolates: *Candida albicans, Debaryomyces hanseni, Rhodotorula glutinis* and *Saccharomyces cerevisiae* affirms the availability of sugar in the soil cavities of the root tubers. Some of these yeasts were similar with certain yeast species included in Oladoye et al. (2014) report. *Candida albicans* that was isolated from the soil samples, a human pathogen was encountered in the farm soil probably due to human activities.

A total of 14 fungi were isolated from the rhizosphere of the test sweet potato cultivars (Table 3). Twelve (12) species of fungi were isolated from Tanzania mycorrhizal environment, while 11 species of fungi were isolated from TIS 8164 mycorrhizal environment. The least number of fungi 9 was isolated from CIP 4400168, Ex-Igbariam and TIS 87/0087 mycorrhizal environments. Aditya (2012) reported that fungal species in each mycorrhizal zone are numerically different.

Some of the surfaces of the root tubers of the cultivars were covered with marshes of mycelia. Most vascular plants form stable associations with fungi that form mycorrhizae (literally, "fungus roots"). These fungi colonize the roots and functionally increase the area of interface between the plant roots and soil which is in agreement with Miranda (2011) who has reported that fungal hyphae that grow on the surface of root hairs increase the surface area of the root hairs and therefore facilitate the efficient uptake of nutrient and water. The fungus in mycorrhiza benefits by receiving organic nutrients such as sugars and amino acids from the plant.

All the fungal isolates from the peels of the harvested root tubers were isolated from the experimental soil. This, therefore, showed that the fungal propagules on the surface of the peels of the sweet potato tubers before storage must have originated from the soil. Their presence on the root tubers meant that the said species of soil fungi could become post-harvest fungi of tubers of sweet potato

in storage. Harvesting faults like cracks or wounds could facilitate the entry of the fungal propagules into the root tubers, leading to their eventual decay. That was why healthy harvested root tubers were selected for the root tuber storage studies. A total of 10 species of fungi were isolated from the peels of Ex-Igbariam tubers prior to storage. This was followed by Tanzania, which had 9 species of fungi, then by TIS8164 which had 7 and then by CIP4400168 and TIS87/0087, which had 5 species of fungi each. This means that Ex-Igbariam has the potential of being decayed faster if there were to be mismanagement in terms of storage techniques and if such surface fungal propagules are equipped with the necessary enzymes needed for the hydrolysis of the carbohydrate and other nutritional components of the sweet potato root tubers.

The Penicillia have been referred to as the predominant green and blue stain fungi, while the *Aspergillus niger* group has been referred to as the black stain fungi (Nyongesa et al., 2015). A number of factors have been attributed to the cause of spoilage of sweet potato root tubers. These include a high level of fungal metabolic activity within or on the root tubers by one or more species of fungi or a combination of species. It also involves the fungus metabolites' action on the pigments within the product or by the pigments synthesized by the fungi themselves, resulting from the infusibility of these pigments into the root tubers.

CONCLUSION

The study has clearly shown that field fungi are in close association with the root tubers in the farm where they could commence the farm produce's deterioration process, which could continue unabatedly during storage, resulting in its poor shelf-life. Therefore, harvested root tubers should be processed immediately into secondary products after harvest to avoid the deteriorative effects of field fungi transferred into storage. Thus, the next phase of activity on this farm produce is to formulate secondary products with extended shelf-life using advanced technology.

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