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Effects of Moisture Content Directional Loss / Dry Matter Content in the Fungal Deterioration of Sweet Potato (*Ipomoea batatas* (L) Lam) Root Tubers during Storage

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ABSTRACT

Moisture content (MC) loss is a key factor in the deterioration of harvested sweet potato root tubers. Five improved cultivars: CIP4400168, Ex-Igbariam, Tanzania, TIS 8164 and TIS 87/0087 were collected from sweet potato farmers in Jos, propagated; harvested after 4 months; stored for 8 weeks in a barn and were analyzed fortnightly for moisture content (MC) directional loss and dry matter (DM) content from the surface (peel) and different depths (slices) of the circumferences. Fungal biodeteriogens penetration of the samples was also analyzed to determine MC and DM effects on their colonization. The peels before storage highest mean percentage MC ranged between 44 and 54% in-depth (5th layer) with DM of 56% and 46% respectively. The root tuber CIP 4400168 had the highest peel MC of 43 and 53% in-depth (5th layer) with DM of 57 and 47% respectively. The MC was low at the peels with less water saturated DM and high within the in-depth layers with more water saturated DM an indication that MC directional loss was towards it. This was the trend in the other cultivars resulting in their significant differences ($P \leq 0.05$) in the parameters. A total of 30 biodeteriogens were isolated, *Aspergillus niger*, *A. oryzae*, *A. terreus*, *Candida albicans*, *Rhodotorula* sp had 100% occurrence. *Mucor pusillus* and *A. oryzae*, were isolated from the peels and all the depths (1-7 layers) with pH range of 3.87 - 6.67. The harvested produce should be processed into secondary products to avoid the effects of MC directional loss which was evident after fortnight storage in the barn.

Key Words: Biodeteriogens, slices (in-depths), moisture content directional loss, dry matter content, shelf life.

Introduction

he sweet potato root tuber used for food is a complex organ of the plant possessing a variety of chemical compounds (Ellong *et al.*, 2014 Ganiyat *et al*., 2016; Sila *et al*., 2018; Sila *et al*., 2020). One of these is its high moisture content (MC) which is extremely variable among cultivars. Decay which manifests in different types of root tuber rots as a result of microbial deterioration; hardening of the commodity due to prolong storage or extensive exposure to scourging sunlight and excessive weight loss during retailing in the market are all attributed to the effects of the MC of the harvested root tubers (Olaitan, 2010; Sila *et al.*, 2017). The MC of stored sweet potato also plays a key role in their sprouting (sprouted root tubers) which in some cases commences in the farm.

Oyeyipo (2012) stated that the high moisture content and other nutrients of the fresh root tubers and handling faults make them highly susceptible to microbial colonization and deterioration. The average percentage moisture content of the fresh sweet potato root tuber after harvest ranges from 62.58 – 65 (Liu *et al.*, 2009). As a result the average dry matter content is low and ranges between 25 - 30% (Amoah *et al.*, 2011). The dry matter is composed of carbohydrate which consists of starch and sugars with lesser amounts of pectin, hemicellulose and cellulose (Rose and Hilda, 2011). The relative composition varies with the root tuber maturity and storage period. On the average, starch constitutes 60 – 70% of dry matter, depending on the soil type and the fertilizer used in its production but the proportion of starch to other carbohydrates varies greatly (Adda, 2019).

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The starch of sweet potato granules is made up of amylopectin and amylose molecules (Meludu, 2010). The carbohydrate in sweet potato undergoes ready enzyme transformation into sugars: glucose, fructose, maltose and sucrose constituting 10% of it. The dry matter of harvested sweet potato root tubers with the more appropriate moisture content predisposes them to fungal deterioration during storage.

Therefore it becomes necessary to determine the moisture content and its directional loss in the stored root tubers either towards the outer or inner parts of its circumference. In this research the directional moisture content (MC) loss in the stored root tubers at a specified storage time and its dry matter content were investigated with the view to determine if there is any relationship in terms of the number and species of fungi that colonized the produce resulting in its deterioration (Clark *et al*., 2013; Oduola *et al*., 2018). Colonization of the storage root tuber by fungal biodeteriogens is highly influenced by the more appropriate moisture content of the dry matter and it is the motive for this research.

Materials and Methods

The study Area and Sweet Potato Cultivars

The study area is the sweet potato farm in Jos. The farm is composed of soil that is adequately drained, pH of 5, organic content of 4%, and moisture content of 50%, receives adequate rays of sunshine both in the wet and dry seasons of the year. Five improved cultivars: CIP4400168, Ex-Igbariam, Tanzania, TIS 8164 and TIS 87/0087 were collected from sweet potato farmers supplied with the cultivars from National Root Crops Research Institute, Umudike and were cultivated on the farm.

Storage Facility

The storage method of Okwuowulu and Osiegbu (2002) was modified to construct an In-door barn; measuring 4m x 1m within an empty room with 2 windows gauzed; floor was washed then filled with fine sand and ash to a height of 4.00cm; stones of equal dimensions were placed on the corners and middle of the area; wooden planks of equal length were laid on top of the stones to provide a flat surface area; ply-woods of 1.0m height were used to demarcate the area.

The cultivars (CIP 440164, Ex-Eghariam, Tanzania, TIS8164 and TIS 87/0087) were harvested 4 months after planting on the farm. Each weighing 100kg without blemish was put in a plastic basket with wide opening on top, ample openings on the sides to facilitate air circulation. Two baskets of each cultivar were placed on the flat surface of the barn to form two rows, the first was used to isolate and identify associated fungal species while the second was used to monitor directional moisture content loss and its dry matter.

The entire space between the rows of the baskets and the walls of the ply-wood was filled with *Digitaria* straw covering the root tubers sparsely to prevent rapid moisture content loss. The entire room provided the shade which kept the root tubers cool as well as serving as a wind break was adopted for an in-door barn which allow for air to circulate freely within the storage root tubers without interference of humans and rats.

Determination of Moisture Content (MC) on Wet Weight Basis

The percentage MC on wet weight basis of the Surfaces (Peels) and the different depths of cultivars were determined fort-nightly before and during the storage of the root tubers. Each tuber was picked from the barn and was washed with tap water. The surface (peel) was carefully removed with a pen knife. The underlining flesh was held in a longitudinal position on top of a clean chop board and was sectioned into five (5) depths, each 5cm thick towards the centre of its circumference. The peels and the 5 layers (depths) were chopped into chips which were analysed for moisture content as follows:

$$\%MC = \frac{\text{Wet Weight} - \text{Dry Weight}}{\text{Wet Weight}} \text{ x } 100$$

Each experiment was replicated; the average values were recorded and analyzed statistically.

Dry Matter Content Determination

The dry matter content of the peels and each of the 5 layers (depths) were obtained by the subtraction of the percentage moisture content from the fresh weight and the average values were also recorded and analyzed statistically.

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Statistical Analysis

The data obtained from the moisture content and dry matter analyses of the samples were statistically analyzed using Two-Way Analysis of Variance (ANOVA) and were computed with Statistical Package for Social Science (SPSS) version 8. Duncan's New Multiple Range Test (DMRT) was specifically preferred to check for significant difference ($p \leq 0.05$) between means.

Tests on the Depth of Biodeteriogens Penetration of the Stored Root Tubers

The stored root tubers were picked fortnightly from the barn and sliced into various layers from the surface. The peel constituted the first layer which was numbered (1). The layer from the surface was (2). The third layer was numbered 3, the fourth layer 4, 5^{th} layer 5, 6^{th} layer 6 and the final layer (to the centre) of the root tuber 7. Each layer was then cut into pieces of 1 × 1cm dimension aseptically and was plated out on Malt Extract Agar (MEA) and Sabouraud Glucose Agar (SGA). The culture plates of each layer were allowed to solidify and were divided into 5 batches of the root tubers, each batch containing 5 plates and incubated at 25^0C. The experiments were carried out in order to determine the depth of penetration of the fungal colonizers into the root tubers and the levels of the layering that had the highest fungal species vis a vis the depth that had the lowest and highest moisture content and dry matter most suitable for fungal colonization resulting in stored tuber deterioration.

Purification of the Microbial Isolates

The fungal and yeast colonies that developed on the media employed were subjected to series of sub culturing until pure cultures were obtained. The *Aspergillus* and *Penicillium* isolates were further cultured on Czapek Dox Agar (CZA) to aid their identifications since they produce pigments in this medium.

Identification of the Fungal Isolates

The fungal biodeteriogens were identified first microscopically then cultural characteristics and morphological parameters were considered, stock cultures also aided the process. References were made to different compendiums and Laboratory manuals of various authors such as Domsch and Gams (1972), von-Arx (1974), Ellis (1971a, 1976), Barron (1977), Raper and Fennel (1977), Pitt (1979), Barnett and Hunter (1998), and Nyongesa *et al*. (2015).

Identification of the Yeast Isolates

The unicellular yeasts were examined microscopically and various biochemical tests: India ink (wet preparation) test, Urease test, Fermentation test and Sugar assimilation test were carried out to finally identify the yeast isolates.

The Effects of both Moisture Content and Dry Matter Concentrations at Different Depths of the Stored Cultivars

The moisture content directional loss of the root tubers was analyzed fortnightly to determine its effects on their colonization by decay fungal biodeteriogens. Each root tuber was picked from the barn and was analyzed for percentage moisture content and dry matter to determine whether the directional moisture content loss had effect on the fungal distribution towards the outer or inner part of the circumference of the stored root tuber.

Determination of the stored root tuber pH

The peels and decay portions of the stored root tubers pH were also determined by carefully removing them with a pen knife, chopped into smaller chips then put into a mortar and crushed with a pestle into paste. Five grams of each paste was dispensed into 50ml of distilled water the solutions were stirred and sieved into supernatants and used to determine the pH with LABTECH DIGITAL pH meter. The pH meter was first standardized with a buffer pH 7 the electrode was then employed to determine the pH of supernatants.

Result

Tables 1a shows that the highest mean % moisture content (MC) of the stored root tuber peels before storage ranged between 44 and 54% in-depth (5^{th} layer) with dry matter (DM) of 56 and46% in Table 1b. After 8 weeks, peels had mean % MC of 31.6 and 39.9% in-depth (5^{th} layer) with DM of 68.4 and 60.1%. Generally, the mean % MC values were low towards the peels and high away from it in all the root tubers.

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Table 1a: Mean Percentage Moisture Content (MC) of the Root Tubers Peels and Depths Before and during 2, 4, 6 and 8 Weeks of Storage

Storage time	Depth (cm)					
	Peels	1st	2nd	3rd	4th	5th
Before storage	44.00±3.14[b]	47.60±1.68[ab]	48.50±2.52[ab]	49.80±2.96[ab]	51.00±3.51[ab]	54.20±3.07[a]
2 weeks	43.00±3.09[b]	48.20±2.42[ab]	48.90±3.16[ab]	48.00±3.05[ab]	48.50±3.68[ab]	52.40±1.41[a]
4 weeks	36.30±3.05[b]	38.70±2.26[ab]	36.90±2.24[ab]	37.70±2.88[ab]	39.80±2.87[ab]	42.10±3.42[a]
6 weeks	34.50±1.99[b]	36.60±1.78[ab]	37.00±2.07[ab]	38.80±2.13[ab]	41.00±2.60[ab]	42.80±2.82[a]
8 weeks	31.60±2.02[b]	34.30±2.05[ab]	37.40±3.04[ab]	36.40±2.81[ab]	37.80±2.71[ab]	39.90±3.15[a]
L.S.D	7.70					
P-value	<0.0001					

At P≤0.05 there was a significant difference in the mean percentage moisture content of the root tubers before and during storage. Values are presented as mean± standard error of means. Ranking was done across the peels and different depths and values with the same super script are not significant.

Table 1a: Mean Percentage Dry Matter (DM) of the Root Tubers Peels and Depths Before and during 2, 4, 6 and 8 Weeks of Storage

Storage time	Depths (cm)					
	Peels	1 st	2 nd	3 rd	4 th	5 th
Before storage	56.00±3.14[a]	52.40±1.68[ab]	51.50±2.56[ab]	50.20±2.97[ab]	49.00±3.51[ab]	45.80±3.07b
2 weeks	57.00±3.09[a]	51.80±2.42[ab]	51.10±3.16[ab]	51.80±3.07[ab]	51.51±3.68[ab]	47.50±1.43b
4 weeks	62.74±2.81[a]	61.30±2.56[ab]	63.10±2.24[ab]	62.30±2.89[ab]	'60.20±2.87[ab]	57.90±3.42[b]
6 weeks	65.50±1.99[a]	63.40±1.78[ab]	63.00±2.07[ab]	61.20±2.13[ab]	59.00±2.60[ab]	57.30±2.82[b]
8 weeks	68.40± 2.02[a]	65.70±2.05[ab]	62.60±3.04[ab]	63.60±2.81[ab]	62.21±2.71[ab]	60.10±3.15[b]
L.S.D	0.20					
P-value	<0.0001					

At P≤0.05 there was no significant difference in the mean percentage dry matter content of the root tubers before and during storage. Values are presented as mean standard error of means. Ranking was done across the peels and different depth values with the same super script are not significant.

There were high significant differences (P ≤ 0.05) in the mean percentage MC and DM of the peels and the in-depth 5th layers of the cultivars as can be observed in Tables 1a and 1b. However the 2nd, 3rd and 4th layers of the stored cultivars differed in values in their mean percentage MC but the difference was not significant at (P ≤ 0.05). The analyses of the mean percentage MC and the DM of each root tuber peel and Depths (1st – 5th layers) during the 8 weeks of storage showed that CIP 4400168 had the highest surface (peel) mean moisture content (MC) of 43%, DM of 57% and in-depth (5th layer) MC of 53% and DM 47%.

However, Ex-Igbariam with the least peel mean percentage of 30.7% and DM of 49.3% had in-depth (5th layer) MC of 45.2% and DM of 54.8% (Figure 1).

The result of the species of fungi isolated from the stored root tubers of the different cultivars is as presented in Table 2. A total of 30 species of fungal biodeteriogens were isolated from the stored sweet potato tubers.

Aspergillus species were more in the constitution of the isolates and were followed by the Phycomycetes. *Aspergillus niger, A. oryzae* and *A. terries* had 100% occurrence and were followed by *Emericella nidulans, A. clavatus, A. fumigatus, A. parasiticus* and *Mucor pusillus* which had 80% of occurrence. Three yeast species: *Candida albicans*, *Rhodoturula* sp both had 100% occurrence and *Saccharomyces cerevisiae* were also isolated from the stored root tubers.

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Table 2: Species of Fungi Isolated from the Stored Root Tubers of the Different Cultivars

Fungal isolates	Sweet potato root tubers					Total (%)
	CIP	EX	TAN	TIS 81	TIS 87	
Ascomycetes						
Emericella nidulans (Eldam) Vuill	+	+	+	-	+	4
Eurotium amstelodami Mangi	-		+	+	-	2
E. harbarioram (Wiggers) Link	+	-	-	+	-	2
Hyphomycetes						
Aspergillus candidus Link	+	+	+	-	-	3
A. clavatus Desm	+	+	+	-	+	4
A carneus Blochwitz	-	-		+	+	2
A. flavus link ex. Gray	+	+	+	+	+	5
A. fumigatus Fres	+	+	_	+	+	4
A. niger van Tieghem	+	+	+	+	+	5
A. oryzae (Ahlbarg) Cohn	+	+	+	+	+	5
A. parasiticus Speare	+	+	-	+	+	4
A. terreus Thom	+	+	+	+	+	5
A. Versiculor (Vuill) Tiraboschi	+	-	+	+	-	3
Botryodiplodia theobromae Sacc	-	+	+	+	-	3
Botrytis cinerea Pers	+	-	+	-	+	3
Fusarium culmorum (W.G.) Saac	+	-	-	+	+	3
F. oxysporum Schlecht	-	+	+	-	+	3
F. poae (Peck) Wollenw	+	-	-	+	-	2
F. sporotrichoides Sherb	+	-	+	+	-	3
Helminthosporium velutinum link	-	+	+	-	+	3
Penicillium paraherquei Abe ex.G.Smith	-	-	-	+	+	2
Scytalidium lignicola Pesante	+	-	-	+	-	2
Mortierella isabellina Dudem	+	+	-	+	-	3
M. nana Linnem	-	+	+	-	-	2
Torula herbaram (Pers) Link	-	+	+	-	+	3
Phycomycetes						
Mucor Pusillus Lindt	+	+	+	+	-	4
Rhizopus oligosporus Ehrenb ex. Corda	-	-	+	-	+	2
Yeasts						
Candida albicans Berkhout	+	+	+	-	+	4
Rhodotorula sp.	+	+	+	+	+	5
Saccharomyces cerevisiae Hansen	+	+	+	+	+	5
Total	21	19	21	20	19	100

Key: + Present – Absent; CIP = 4400168, EX = Ex-Igbariam, TAN = Tanzania, TIS 81 = TIS 8164, TIS87 = TIS 87/0087

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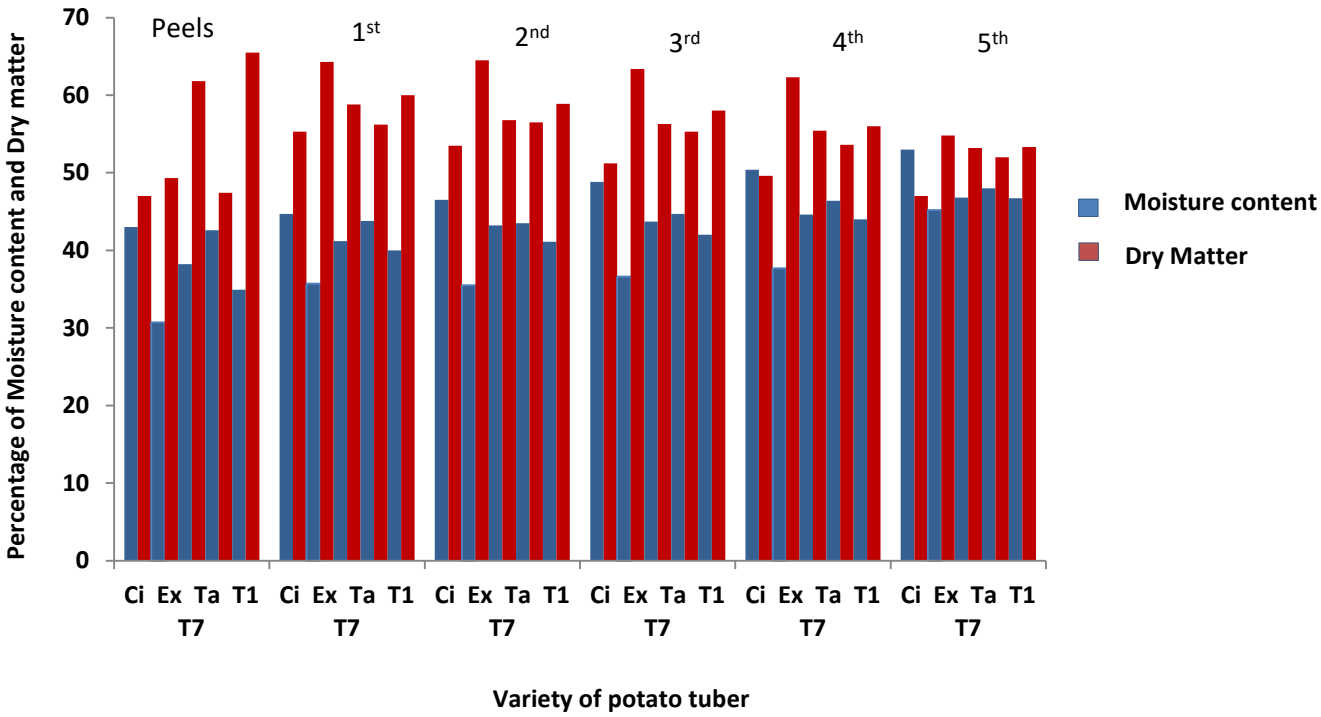

Figure 1: Mean Percentage Moisture Content (MC) and Dry Matter (DM) of Each Root Tuber at Different Depths from the Peels during 8 weeks of Storage in the Barn

Key : Ci= CIP 4400168, Ex= Ex-Igbariam, Ta= Tanzania, T1 = TIS8164 and T2 = TIS87/0087

The result obtained from the depth of penetration of the stored sweet potato root tubers by the fungal colonisers revealed that the number of the species decreased from the surface of the tubers to their central portions (Table 3). The highest number of fungal isolates (33) was made from the peel close to the first layer (1) both containing low MC concentration within the less water saturated dry matter. The second highest number of isolates (21) was made from the second layer (2) while the third highest number of isolates (17) was made from the third layer (3) from the surface. The least number of isolates (2) was made from the central layer (7).

The Phycomycetes had a deeper penetration of the stored root tubers than any other class of fungi and were isolated from the first four layers of the root tubers. The isolate *M. pusillus* was isolated from all the layers (1-7) while *Syncephalastrm racemosus* was isolated from the first six layers but not from the central layer. The genus, *Aspergillus* had the highest number of isolates in the first layer.

However, the number declined with the exception of *A. oryzae* which occurred in all the layers too, a good amylase producer used in fermentation processes had 100% in terms of the stored root tubers penetration. *Fusarium* species were also isolated from the first three layers but their number declined from the first to the third layer.

All the fungal species that were isolated beyond the first layers may have been involved in the decay of the sweet potato tubers or were beneficiary from the products of sweet potato root tuber hydrolytic activities. Colonization by the biodeteriogens brought about more hydrolysis of their starchy component and the eventual deterioration of the circumference by the different penetrating fungal species.

The range of the mean pH values recorded in the stored root tubers 6.0 – 6.67 for some of them and 3.87 – 3.93 for their decay portions would support the growth of fungi. (Table 4) Fungi differ in their pH requirements in stored produces, most will grow well over pH range of 3-7 others can grow below pH 2.

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Table 3: Occurrence of Fungal Biodeteriogens from the Peels and at Different Depths of the Stored Root Tubers

Fungal isolates	Occurrence in different depths and number							
	1(33)	2 (21)	3(17)	4(9)	5(3)	6(3)	7(2)	Total (88)
Ascomycetes								
Emericella nidulans (Eidem) Vuill	+	+	-	-	-	-	-	2
Eurotium amstelodami Mangi	+	-	-	-	-	-	-	1
E. harbariorum (Wiggers) Link	+	-	-	-	-	-	-	1
Hyphomycetes								
Asperqillus candidus Desm	+	-	-	-	-	-	-	1
A. clavatus Desm	+	-	-	-	-	-	-	1
A. carneus Blochwitz	+	+	-	-	-	-	-	2
A. flavus Link ex. Gray	+	-	-	-	-	-	-	1
A. fumigatus Fres	+	+	+	-	-	-	-	3
A. niger van Tieghem	+	+	+	+	-	-	-	4
A. oryzae (Ahlburg) Cohn	+	+	+	+	+	+	+	7
A. parasiticus Speare	+	-	-	-	-	-	-	1
A. terreus Thom	+	+	+	-	-	-	-	3
A. versicolor (Vuill) Tiraboschi	+	-	-	-	-	-	-	1
Botryodiplodia theobromae Saac	+	-	-	-	-	-	-	1
Botrytis cinerea Pers	+	+	-	-	-	-	-	2
Fusarium calmorum (W.G.) Saac	+	+	-	-	-	-	-	2
F. oxysporum Schlecht	+	+	+		-	-	-	3
F. poae (Peck) Wollenw	+	-	-	-	-	-	-	1
F. sporotrichoides Sherb	+	+	+	-	-	-	-	3
Helminthosporium velutinum Link	+	+	+	-	-	-	-	3
Penicillium paraherquei Abe ex. G. Smith	+	-	-	-	-	-	-	1
Scytalidum lignicola Pesante	+	-	-	-	-	-	-	1
Torula herbarum (Pers) Lick	+	-	-	-	-	-	-	1
Phycomcetes								
Mortierella isabellina Oudem	+	+	+	+	-	-	-	4
M. nana Linnem	+	+	+	+	-	-	-	4
M. ramanniana (Moller) Linnem	+	+	+	+	-	-	-	4
M. vinacea Dixor Stewart	+	+	+	+	-	-	-	4
Mucor pusillus Lindt	+	+	+	+	+	+	+	7
Rhizopus oligosporus Ehrenb ex. Corda	+	+	+	+	-	-	-	4
Syncephalastrum racemosus Cohn	+	+	+	+	+	+	-	6
Yeasts								
Candida albicans Berkhout	+	+	+	-	-	-	-	3
Saccharomyces cerevisiae Hansen	+	+	+	-	-	-	-	3
Rhodotorula sp	+	+	+	-	-	-	-	3

Key: + Present – Absent; CIP = 4400168, EX = Ex-Igbariam, TAN = Tanzania, TIS 81 = TIS 8164, TIS87 = TIS 87/0087

Table 4: The pH of the Stored Root Tubers and Decay Portions

Root tuber	Storage period (Weeks)					Decay portions
	Before storage	2wk	4wk	6wk	8wk	
CIP 4400168	6.53	6.53	6.53	6.50	6.00	3.87
Ex-Igbariam	6.57	6.55	6.51	6.50	6.50	3.92
Tanzania	6.46	6.44	6.41	6.40	6.40	3.91
TIS 8164	6.54	6.52	6.52	6.51	6.51	3.93
TIS 87/0087	6.55	6.53	6.52	6.52	6.00	3.89

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Discussion

The research has shown that directional moisture content loss was towards the surfaces (peel) of the stored root tubers with low MC values in comparison with the in-depth (5^{th} layers) with high MC values. The MC values were low with less water saturated DM towards the peel and high with more water saturated DM within the in-depth layers an indication that MC directional loss was towards the peels. The gradual MC loss of the stored root tubers brought their dry matter water activity (a_w) to the range of 50 – 60% which was most appropriate for fungal utilization and proliferation resulting in root tuber deterioration (Sila and Gyar, 2005).

The ranges of percentage moisture content recorded were within the limits that would support growth and development of the biodeteriogens. When the root tubers MC values became low at the peels the DM values became concentrated with sugars mobilized from the in-depth layers due to directional MC loss. The MC values analyzed in the stored root tubers were similar with the range of 52 – 65% reported by Liu *et al.* (2009). The MC loss which became evident after 2 weeks of storage of the root tubers in the barn caused the dry matter to become concentrated with glucose especially at the surfaces (peels) than the in-depth layers of the root tubers, hence more fungal species were isolated at the peels.

A total of 30 species of fungal biodeteriogens were isolated from the stored samples. The Genus *Aspergillus* was more in the constitution of the isolates and was followed by: *Botryodiplodia, Botrytis, Emericella, Fusarium, Helminthosporium, Mortierella, Mucor Penicillium, Rhizopus*. *Scytalidium and Torula.* Fungal deterioration of sweet potato root tubers under different storage methods and time have been studied and reported by various workers (Chales *et al*., 2010); Jonathan *et al*., 2012; Oyeyipo, 2012) Most of the stored root tubers had become discoloured after 8 weeks of storage in the barn. Discolouration of the stored root tubers is due to heat produced by the respiring stored root tubers and is caused by pigments imparted on them by mycelia and spores of the storage fungi. 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.(Onwuka, 2005). *Aspergillus* had more species isolated from the stored root tubers than all species of the other genera isolated in this research. The *Aspergillus* species are capable of utilizing an enormous variety of organic material for food because of their ability to produce a large number of enzymes which are used to reduce their value and imparting musty odour to them. Several species are frequently found on stored grains and other foodstuffs like stored root tubers where they cause decay and subsequent losses.

The stored tubers were found to be associated also with three yeast species: *C. albicans, Rhodotorula sp and S. cerevisiae* which reinforced the presence of sugar in the stored root tubers due to MC directional loss. These yeast isolates contain species which produce amylases that can hydrolyse the starch components of the root tubers to glucose which becomes additional amounts to glucose produced during sprouting. The yeasts were able to infect the root tubers by secreting vary amounts of enzymes such as cellulase and amylase. These enzymes had the capacity to degrade the root tuber cell wall and possibly enhanced the pathogenicity of the yeasts (Oladoye *et al.,* 2013). The yeasts also have fermentative abilities that could ferment the sugar components of the sweet potato tubers to increase their deterioration physiologically. The inherent amylases especially those produced during sprouting which was observed during the study might have also hydrolyzed the starch component to glucose (Rees *et al*., 2003; Amoah *et al*., 2011). As the moisture content loss is exteriorly, the internal sugars are carried a long side with it and deposited at the peel, accounting for a higher population of the fungal biodeteriogens at this layer and those close to it. These activities greatly aided the root tubers deterioration during the storage period.

The results obtained from the experiment on the occurrence of fungal colonizers in different layers of the decayed sweet potato root tubers revealed that some of the species of fungi were not mere surface contaminants but had an in-depth penetration of the root tubers. The deep penetrators were mainly the phycomycetes. *M. pusillus* was found in all the layers of the root tubers that were investigated.

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The phycomycetes are known as sugar fungi and could be found in carbohydrate substrates that have substantial sugar contents (Onifade *et al.*, 2004). Most of them have the ability to hydrolyze starch to sugar with the aid of amylases that they produce. As the water in the tuber evaporates, the sugar component is deposited towards the surface area of the tuber. This therefore aids the tubers colonization by sugar-loving microorganisms which eventually bring about more hydrolysis of the starchy component of the tubers and their eventual decay. It is small wonder then why species of yeasts were also isolated from the decaying tubers. The sugar constituent of the tubers may be what was responsible for the yeasts colonization of the root tubers in storage.

Fungi differ in their pH requirements in stored produces, most will grow well over pH range of 3-7 others such as *Aspergillus* and *Penicillium* species can grow at pH 2 and below (Dania and Thomas, 2019). The pH values of the decayed and non- decayed root tubers were within the ranges that would support the growth of fungi in pure cultures**.**

The MC directional loss which became evident after 2 weeks of storage of the root tubers in the barn caused the dry matter to become concentrated with glucose especially at the surfaces (peels) than the in-depth layers of the root tubers, hence more fungal species were isolated at the peels. The gradual MC loss also brought their dry matter water activity (a_w) to the range of 50 – 60% which was most appropriate for fungal utilization and proliferation. The result obtained from the depth of penetration of the stored root tubers by the fungal colonizers revealed that the number of the species decreased from the surface of the tubers to their central portions due to directional moisture content loss which was more at the peels.

From the findings of this study, it is recommended that sweet potato root tubers storage should not exceed 2 weeks due to the effects of moisture content (MC) directional loss.

Processing the harvested root tubers into industrial products with extended shelf life is necessary for its keeping quality. The in-door storage barn will be examined for its storage parameters which enhanced the keeping quality of some of the stored root tubers.

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