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Assessment of Fungal Responsible for the Deterioration of Sweet Potatoes in the Tudun Wada Market, Gusau, Zamfara State, Nigeria

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Abstract This research identifies the fungi that contribute to the degradation of sweet potatoes at Tudun Wada Market in Gusau, Zamfara State. Thirty-six sweet potato samples, along with six additional tubers for pathogenicity testing, were collected from various market points. Standard microbiological techniques were applied to isolate, screen, and identify fungi linked to spoilage. Percentage occurrence and pathogenicity tests were conducted to ascertain the prevalence and assess the impact on tuber weight loss. Physiological changes during storage, such as softening, drying, discoloration, and an offensive odor, were recorded. Fungal counts ranged from 2.5±1.0 cfu/ml to 4.±1.5 cfu/ml, with Yan Dankali exhibiting the lowest count and Yan Kayan Koli the highest. Identified fungal genera included *Aspergillus niger*, *Aspergillus flavus*, *Botryodiplodia theobromoae*, *Fusarium oxysporium*, *Rhizopus stolonifer*, and *Penicillium species*. *Aspergillus niger* occurred higher, while *Botryodiplodia theobromoae* had the least occurrence. Pathogenicity tests aid in determining the fungi's role in sweet potato spoilage, penetrating tubers through injuries, and thriving in storage conditions. Starch breakdown by these microorganisms precipitated sweet potato deterioration. Although specific management practices for potato diseases are underdeveloped, adopting healthy planting materials and sanitation measures could mitigate fungal diseases in sweet potatoes propagated through vine cuttings.

Keywords Sweet Potatoes, Fungal, Tudun Wada

1. Introduction

Sweet potato (Ipomoea batatas Lam) is a member of the Convolvulaceae family and Ipomoea genus, widely cultivated globally. Recognized as the fourth most crucial food crop after rice, yam, and wheat, sweet potatoes offer significant nutritional value, serving as a vital source of essential vitamins, minerals, and carbohydrates for both human and animal consumption, as well as industrial applications [1,2]. In Nigeria, sweet potatoes hold a staple food status, frequently available at local markets such as Tudun Wada Market in Gusau, Zamfara State. However, post-harvest storage and transportation challenges make sweet potatoes susceptible to spoilage, leading to substantial economic losses for farmers and vendors [3].

Fungal infestation stands out as a major contributor to sweet potato spoilage, rendering the tubers unfit for consumption [4]. The storage of sweet potato tubers post-harvest is crucial to regulating market supply and extending the availability of fresh tubers, particularly during off-seasons or under specific economic and climatic conditions [5]. The high moisture content and low mechanical strength of fresh roots, coupled with their

elevated respiratory rate, create conditions conducive to microbial decay, predominantly caused by fungi and bacteria [6].

Various fungi, including *Botryodiplodia theobromae*, *Cerato cystis*, *Rhizopus oryzae*, *Aspergillus flavus*, *Fusarium solani*, and *Sclerotium rolfsii*, contribute to soft rot disease in sweet potato tubers [6,3]. This not only poses a challenge to food security but also results in significant post-harvest losses, a critical issue in developing nations grappling with food scarcity [7,8].

Efforts to preserve sweet potatoes post-harvest involve methods such as controlled temperature and humidity curing, disinfectant use, and cold storage. However, the effectiveness of these methods remains limited, and an estimated 25% to 40% of stored agricultural products are lost annually in the tropics due to inadequate storage facilities [9]. While traditional storage methods, including open floor exposure and burial, contribute to heavy losses through sprouting, rodent damage, and microbial infestation, controlled environmental conditions can extend the shelf-life of sweet potatoes for several months [10].

This research addresses the critical issue of fungal-induced spoilage in sweet potatoes, specifically those available at Tudun Wada Market. The cultivation and distribution of sweet potatoes are vital for local economies and food security in regions like Zamfara State, making it imperative to understand and mitigate the factors contributing to post-harvest losses. Fungi, ubiquitous microorganisms, play a significant role in post-harvest deterioration, emphasizing the need for a comprehensive evaluation and characterization of the fungal strains responsible for sweet potato spoilage. This study aims to determine the quantity and characterize the specific fungal strains responsible for the deterioration of sweet potatoes in Tudun Wada Market.

2. Materials and Methods

2.1. Sample Collection

The samples were systematically collected from various designated points within Tudun Wada Market in Gusau metropolis on two different market days. The collection comprised a total of thirty-six (36) sweet potato tubers, with six (6) tubers procured from each of the following locations: Yan Kaji, Yan Markade, Kasuwar Kanawa, Yan Dakali, Yan Tumatur, and Yan Kayan Koli. Each designated point contributed a combination of four (4) slightly unhealthy sweet potatoes, resulting in a collective total of twenty-four (24) tubers, and two (2) healthy sweet potatoes, contributing to a total of twelve (12) tubers. From the healthy potatoes, six (6) tubers were dedicated to the pathogenicity test, while the remaining six (6) served as control samples. The samples were collected with a sterile polyethylene bag and transported to the Federal University Gusau, Microbiology laboratory for further analysis.

2.2. Sample Preparation

The purchased slightly unhealthy potatoes were kept for 14 days to enable complete spoilage. They were stored in perforated plastic bags to mimic the ventilation and storage practices commonly observed in informal market environments. Throughout the storage period, care was taken to avoid exposure to direct sunlight and extreme temperature fluctuations, which could potentially alter the spoilage process. Physiological changes were observed within these days. Afterward, cotton wool moistened with 70% ethanol was used to sterilize the knife. The sterile knife was then used to cut the unhealthy sample open and the decaying inner part was cut into pieces. A sterile mortar and pestle were used for homogenization. One gram of each of the homogenized sample was weighed and used for serial dilution.

2.3. Isolation of Fungal

The spread plate method was utilized in this procedure. One-milliliter aliquots of the serially diluted sample (10^{-4}) were evenly spread across the surface of potato dextrose agar (PDA) and placed in a sterile petri dish. Chloramphenicol was added to prevent bacterial proliferation. The plates were incubated in an inverted position at 28℃ for five days. Subsequently, the fungal colonies that developed were counted using a colony counter and the result was recorded. Each colony was subcultured on sterile PDA plates and stored on PDA slants, for further characterization and identification

2.4. Characterization and Identification of the Fungal Isolate

The characterization and identification of the molds were determined using the lactophenol cotton blue test and microscopic examination. Each fungus's identity was verified by referencing a mycological atlas.

2.4.1. Slide culture test

The potato dextrose agar was placed on the surface of the slide. A sterile straight wire loop was used to transfer a small portion of the mold isolate onto the agar surface. The isolate was spread evenly over the agar to facilitate growth. The inoculated slide was incubated at room temperature for 24 hours. After this, the slide was viewed under the microscope to observe the growth and characteristics of the mold colonies.

2.4.2. Microscopic Examination

Lactophenol cotton blue solution was used for the microscopic examination. A sterile straight wire loop was used to pick a small portion of the fungal colony from the subculture PDA plates. The fungal sample was carefully

placed on the slide containing lactophenol cotton blue solution. The sample was aseptically emulsified on the slide. A cover slip was placed over the emulsified sample after which it was viewed under the microscope using 10× and 40× objective lenses to examine the detailed morphological features of the fungal sample.

2.5. Pathogenicity test of the fungal isolates

The pathogenicity test of the isolates was carried out as described by Onuorah and Obika [11]. Six (6) healthy sweet potato tubers were thoroughly washed with tap water, followed by rinsing with distilled water, marked and surface-disinfected using 70% ethanol solution. Carefully, with the aid of a flamed cock borer of 5mm diameter, holes were bored on the healthy sweet potato tubers, and the cylindrical flesh was removed. Solid medium containing the pure culture of each isolate was inoculated into the bored hole of the sweet potato tuber and the holes were covered with petroleum jelly (Vaseline). Care was taken to ensure that the activity was completed in the shortest possible time ≤1 minute to avoid contamination. A control experiment was set up in which the bored hole was left without inoculation. The potato samples were labeled and incubated at room temperature for 14 days. Their initial and final (rotting) weight were measured and the percentage of weight loss was calculated. The fungi were later re-isolated from the inoculated potato and compared with the initial isolates.

Percentage (%) of weight loss = individual weight of sweet potatoes/total weight of sweet potatoes x 100

3. Results

The physiological deterioration rate of sweet potato tubers from the Tudun Wada market is presented in Table 1. The changes that the tubers undergo from days 1-14 are as follows: from days 1-5, no softening is observed; from days 6-8, slight changes are noted; days 9-11 sees complete softening, and drying occurs from days 12-14. Additionally, color changes are observed from milky to darkish black, and a slight odor is perceived from days 9-14.

The total fungal count of the sweet potatoes tuber in Tudun wada Market is presented in Table 2. The count ranged from $2.5 \pm 1.0 \times 10^{-4}$ cfu/ml to $4 \pm 1.2 \times 10^{-4}$ cfu/ml. Yan kayan koli had the highest count while Yankaji had the least count.

Table 1. Physiological deterioration rate of sweet potatoes tuber from Tudun Wada Market

Storage days	Softening	Drying	Discoloration	Odour
Day one	-	-	Milky	-
Day two	-	-	Milky	-
Day three	-	-	Milky	-
Day four	-	-	Milky	-
Day five	-	-	Whitish	-
Day six	+	-	Whitish	-
Day seven	+	-	Reddish	-
Day eight	+	-	Reddish	-
Day nine	++	-	Reddish	+
Day ten	++	-	Black	+
Day eleven	++	-	Black	+
Day twelve	-	+	Dark	+
Day thirteen	-	+	Darker	+
Day fourteen	-	+	Darkish black	+

Table 2. Total fungal counts of sweet potato tubers in Tudu Wada Market

Designated point	Average fungal count (cfu/ml $\times 10^{-4}$)
Yan kaji	3 ±1.5
Yan markade	3.5+1.1
Kasuwar kanawa	3.3 ±0.9
Yan dankali	3.2 ±1.1
Yan tumatur	2.5 ±1.0
Yan kayan koli	4 ±1.2

The colonial and microscopic characteristics of the moulds isolated from sweet potatoes are shown in Table 3. The moulds identified were *Aspergillus niger, Aspergillus flavus, Fusarium* oxysporium, *Penicillium spp, Rhizopus stolonifer, Botryodiplodia theobromo.*

Table 3. Colonial and microscopic characteristics of the moulds, isolated from sweet potatoes tubers

Colonial characteristics	Microscopic characteristics	Organisms
Loose white mycelium turning dark brown to black during conidia development.	Large conidiospores with septate hyphae.	*Aspergillus niger*
Yellow fluffy mycelia, some black sporangiospores.	Septate hyphae with filamentous structure.	*Aspergillus flavus*
Fast-growing pink, cottony colony	Large sickle-shaped spores, may contain several cells.	*Fusarium* oxysporium
White fluffy luxuriant growth	Ellipsoidal cylindrical conidia, septate hyphae with simple conidiosphores.	*Penicillium spp*
Light grey colonies, rapidly filling petri dish, dense cottony mycelium, mass of sporangia.	Large sporangiospores, no septate hyphae. Dark ovoid to elongate conidia found in pycnidium. Presence of branched mycelia of various lengths and sizes.	*Rhizopus stolonifer*
Compact colonies with a dense layer of black conidia heads.	Large sporangiospores with no septate hyphae. Dark ovoid to elongate conidia found in pycnidium. Presence of branched mycelia of various lengths and sizes.	*Botryodiplodia theobromoe*

The percentage occurrence of fungal isolated from each designated point is presented in Table 4. The percentages are *Aspergillus niger* (16%), *Aspergillus flavus* (14%), *Botryodiplodia theobromoae* (10%), *Fusarium oxysporium* (11%), Rhizospus *stolonifer* (15%), *penicillum species* (13%).

Table 4. Percentage occurrence of fungal isolated from each designated point

Designated point	*Aspergillus niger* (%)	*Aspergillus flavus* (%)	*Fusarium oxysporium* (%)	*Penicillium spp* (%)	*Rhizopus stolonifer* (%)	*Botryodiplodia theobromoae* (%)
Yan kaji	7(43.8)	6(42.9)	-	6(46.2)	8(53)	-
Yan markade	3(18.8)	4(28.6)	5(46.5)	-	3(20)	-
Kasuwar kanawa	4(25)	-	3(27.3)	4(30.8)	-	-
Yan dankali	2(12.5)	-	-	-	-	4(40)
Yan tumatur	-	4(28.6	2(18.2)	-	-	-
Yan kayan koli	-	-	1(9.1)	3(23.1)	4(26.7)	6(60)
Total	16	14	11	13	15	10

The pathogenicity of the sweet potatoes isolated from Tudun wada Market is presented in Table 5. The initial weight and final weight were measured and also the percentages of weight loss were calculated using the formula Number individual weight of the sweet potatoes/total number of the overall weight the potatoes x 100.

Table 5. Pathogenicity of sweet potato isolates from Tudu Wada Market

Organism	Initial weight (kg)	Final decay weight (kg)	Initial percentage (%)	Final percentage (%)
Aspergillus niger	60.91	56.66	14	13
Aspergillus flavus	89.90	86.11	20	19
Botryodiplodia theobromoae	101.24	91.34	23	21
Fusarium oxysporium	60.51	50.46	14	11
Rhizopus stolonifer	36.88	34.16	8	8
Penicillium spp	95.12	86.40	21	19
Total	444.56	405	100	91

4. Discussion

This study was conducted to assess and describe the fungal contributing to the deterioration of sweet potatoes in the Tudun Wada Market, Gusau, Zamfara State, Nigeria. The physiological deterioration of sweet potato tubers at Tudun Wada Market, Gusau, Zamfara State, was assessed to describe fungal responsible for the deterioration. As shown in Table 1, from days 1-5, minimal softening occurred due to the presence of Phytoalexins, which offers protection against biotic and abiotic factors [12]. Subsequently, in (days 6-8), changes occurred as microorganisms and environmental factors altered the tuber's chemical composition. Complete softening manifested from days 8-13, this was attributed to the proliferation of microorganisms, environmental conditions, and poor handling. Drying was observed from days 12-14, resulting from continuous moisture loss. Discoloration stages were noted, and offensive odors emerged from days 12-14, which indicated alterations in sweet potato composition, aligning with findings by Ray and Ravi [6] on post-harvest food handling.

The study showed the total fungi count in the sweet potatoes. The average fungal counts ranged from 2.5 ± 1.0^{-4} cfu/ml to 4.0 ± 1.2^{-4} cfu/ml. Yan kayan Koli had the highest count, while Yan tumatur had the least count. (Table 2). This present work disagrees with the finding of Chiejina and Ukeh [13], who recorded that total fungal count at Awolowo University lle-efe Nigeria ranged from 2.10 ± cfu/ml to 2.90 ± cfu/ml.

The molds obtained from the deteriorated sweet potato were identified as *Apergillus niger, Fusarium oxysporium, Penicillium species, Aspergillus flavus, Botryodiplidia theobromoae and Rhizopus stolonifer* (Table 3). These fungi genera are responsible for post-harvest decay rot of sweet potato tubers, they produce various types of mycotoxins and enzymes [14]. This work corresponds with the finding of Paul *et al*. [15], who carried out research on the occurrence of sweet potato wilt and surface rot disease in Korea, and reported that *Aspergillus flavus, Botryodiplodia theobromae, Fusarium oxysporium,* and *Aspergillus niger* cause black rot, wilt rots, and delayed in germination and other important humans' diseases such as pneumonia.

Percentage occurrence of the fungal isolated from each designated point indicated that *Aspergillus niger* had the highest percentage of 16% while *Botyodiplodla theobromae* had the least percentage of occurrence of 10%, indicating that *Aspergillus niger* is found to be responsible for most of the sweet potatoes spoilage in Tudun wada market (Table 4).

These agree with the findings of Abdulrahman, *et al*. [16], who studied macroscopic and microscopic examination of fungi associated with *Ipomoea batatas lam* and reported that *Aspergillus niger* has the highest percentage of occurrence (45%) and *Aspergillus flavus* (30%) respectively. All fungi proved to be infectious on the sweet potato tubers, hence causing spoilage and surface damage during handling and harvesting.

The pathogenicity test conducted on sweet potato isolates from Tudun Wada market revealed that the inoculated isolates in healthy potato tubers exhibited identical characteristics to the re-isolated ones. This suggests that the fungi isolated from the initial potato tuber were the causative agents of spoilage. Botryodiplodia theobromoae exhibited the highest decay weight in this study.

This current study aligns with the discovery of Ayisa *et al*. [17], wherein they observed that the outcome of the pathogenicity test indicated that the isolates inoculated into healthy tubers displayed identical features to the re-isolated organisms.

The effect of fungi spoilage on the potato tubers led to hydrolysis of starch in the tubers leading to the elaboration of a lot of simple sugars for carbon and energy sources and subsequent colonization by post-harvest rots of sweet potato tubers. This may be due to low pH, moisture content, and nutritional composition which make it susceptible to infection by fungi [1].

5. Conclusions

Sweet potatoes, a globally consumed crop, face challenges from post-harvest spoilage, resulting in softening, drying, and discoloration. Tudun Wada Market's isolated fungi, including *Aspergillus niger*, *Aspergillus flavus*, and *Botryodiplodia* theobromoae, contribute to economic losses for traders. Aspergillus niger's dominance highlights its pivotal role in deterioration. The pathogenicity test solidifies the isolates' responsibility for spoilage, emphasizing their impact on market sweet potatoes. To mitigate these losses, implementing improved storage practices, such as controlled humidity and temperature, and introducing post-harvest management strategies could enhance sweet potato quality, ensuring a more sustainable supply chain and economic resilience for traders in Tudun Wada Market.

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