

Original Research Article

Pathogenicity of fungi isolated from spoiled sweet oranges (*Citrus sinensis*) and from the air in the environment of the orange section of the Gaboru market in Maiduguri, Nigeria.

ABSTRACT

Aim: Though Oranges are very important crops for man both economically and in terms of nutrition, they have a short life span due to poor handling during harvesting, transporting, and storage of the fruits. The ubiquitous nature of fungi makes them ready contaminants for these oranges especially when their skin is broken. The aim of this study is to isolate, identify and determine the pathogenicity of fungi responsible for spoilage in sweet oranges and investigate the presence of fungi in the air of the environment where these oranges are sold.

Place and duration of study: Department of Microbiology Faculty of Science University of Maiduguri between September and October 2020

Methodology: A total of 100 samples of ripe oranges with signs of spoilage (n=100) were collected from 10 selling points in the Gaboru fruit market in Maiduguri, Borno state of Nigeria, and analyzed for fungal isolates using morphometric techniques. Two mycological media (PDA and MEA) were used for isolation, by deploying direct plating method. Petri dishes containing prepared PDA were also exposed to the air in the shops for some minutes ranging from 5 minutes to 20 minutes. Morphometric analysis was carried out to identify the fungal isolates using macroscopic and microscopic observed features. Pathogenicity tests were carried out to ascertain the ability of these isolates to cause spoilage.

Results: The results of the morphometric characterization revealed the presence of seven (*Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, and *Penicillium oxalicum*, *Rhizopus oryzae*, *Cladosporium sphaerospermum* and *Scopulariopsis brevicaulis*) different fungi from the air and from the deteriorating oranges. Only 4 of the isolates which were also positive for pathogenicity were observed to be responsible for causing spoilage of the oranges while all 7 isolates were isolated from the air in the sales environment. *Penicillium oxalicum* was isolated from 80 out of the 100 oranges making it the most predominant organism causing spoilage in the oranges

Conclusion: The findings of this study showed that fungal contaminants were responsible for the spoilage of oranges in this market and many of them were present in the air in the shops where these oranges were sold and stored leading to serious economic losses for both farmers and consumers.

Keywords: Environment, spoilage, fruits, economic loss. nutritional value, fungi

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1. Introduction

According to [1] A fruit is the mature ovary of a plant or the succulent edible part of woody plants. It is the edible and fleshy seed-associated structures of certain plants, which could be sweet (such as apples, oranges, grapes, berries and bananas) or non-sweet (such as lemon and olives) when in their raw forms [2]. They are energy-dense foods that play an important role in human nutrition and health, particularly as sources of vitamin C, thiamine, niacin, pyridoxine, folic acid, minerals and dietary fiber and other bioactive compounds [3]. Fruits are an important component of a balanced daily diet in humans that can help to sustain a healthy life.

In the specific, fruits contain sufficient quantity of potassium, which is important for the reduction of bone loss and occurrence of kidney stones [4].

Fruits are important for proper functioning of the brain as it stimulates the memory recall [1] and supplies the human body with adequate fibre necessary for a healthy digestive system [4] They are also rich in antioxidants and folic acid; their regular consumption helps the body maintain optimum health [5].

Some of the benefits that can be obtained from consumption of fruits and vegetables are longer life span [6] improved mental health better cardiovascular health [7] reduced risks of some cancers and weight management [8]. The economic value of fruits is limited by the relatively short shelf-life which is attributed to decay by pathogens during post-harvest handling [9]

Sweet Orange belongs to the group of fruits call citruses and other members of the family include lemons, grapes and tangerines. They contain flavonoids, which are antioxidants that could neutralize free radicals, protect from heart diseases and improve blood flow through the coronary arteries [10]. Sweet Oranges contain a high quantity of vitamin C, folate and thiamin. Vitamin C protects the body from free radicals that could destroy the body and helps in wound healing and holding blood vessels, tendons, ligaments and bone together [7]

A large portion of the sweet oranges sold within Maiduguri metropolis are transported into the state from other parts of the country and the poor road network coupled with insecurity has extended the length of time the fruits spend in transit and the level of hazards they are exposed to [11]. Many economically important fruits are usually contaminated by fungi resulting in loss of nutritional and economic value [12].

The high level of sugars and nutrients present in fruits in addition to their low pH value makes them very susceptible to fungal spoilage especially during storage [13].

The spoilage of fruits by fungal contaminants is a source of serious potential health hazard to man due to the mycotoxins they produce which can result in mycotoxicoses in man when ingested. Severe economic loss to farmers, traders and the society in general also occurs as a result of fungal spoilage of sweet oranges.

This present study was carried out to isolate, identify and determine the pathogenicity of fungi responsible for spoilage in sweet oranges and investigate the presence of these fungal isolates in the air of the environment where these oranges are sold.

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According to [1]

2. MATERIALS AND METHODS

2.1 Sample collection

One hundred oranges with visible signs of spoilage were collected from 10 different shops in Gamboru fruit market in Maiduguri, Borno state. They were stored in sterile polythene bags separately, and they were transported to the Microbiology laboratory, for fungal isolation. All the glass wares used were properly washed, dried, and sterilized. The workbench was also disinfected with 95% ethanol to curtail contamination. Petri dishes containing prepared PDA were also taken to the orange shops and exposed to the air for 5 minutes, 10 minutes, 15 minutes, and 20 minutes respectively.

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2.2 Isolation of fungi from Orange

The fungal isolation technique was carried out using the method of [14] modified. Potato Dextrose Agar (PDA) and Malt Extract Agar were prepared following the manufacturer's instruction and 1mg/ml of chloramphenicol was added to prevent bacterial growth. Both media were aseptically poured into separate Petri-dishes and allowed to solidify. samples were first surface sterilized by washing under running tap water in order to remove dirt and sand. The infected portions of the various samples were excised and cut into 2 mm pieces with a flamed surgical blade, surface sterilized with 1% NaOCl and rinsed in 4 successive distilled water. The excised infected portions were then plated onto the prepared Petri-dishes by placing them on three extreme ends of the Petri- dish. These plates and those that were exposed to the air in the Orange sales environment were incubated at 28°C for five days. The colonies that developed were subcultured repeatedly on PDA to obtain pure cultures.

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2.3 Macroscopic and microscopic identification

Seven days old pure cultures of the fungal isolates were identified on the basis of macromorphological characteristics such as colony colour, shape, size, and colour of the reverse side of the culture. micromorphological observations were made by mounting small portions of the fungal growth on a glass slide, teasing it out, and staining it with a drop of lactophenol in cotton blue solution which was then observed under X10 and x40 objective lens of a light microscope. The presence of septa, the shape of spores, and other microscopic features were observed [15].

2.4 Pathogenicity of Isolated Fungi

Eight healthy oranges were surface sterilized with 90% ethanol, and incisions were made on them using a sterile 4mm cork borer; a similar sterile cork-borer was used to cut pellets of agar containing the cultures of fungal mycelia of each of the four isolates. These fungi were then inoculated into the hole created on the healthy fruits in a laminar flow chamber. The inoculated wound was sealed with petroleum jelly. Two controls with incision but no inoculation were established. The inoculated fruits and the controls were placed in clean zip lock polythene bags (one fruit per bag) each moistened with-wet balls of absorbent cotton wool to create a humid environment and incubated at 28° c for 5 days. After 72 hours, the inoculated fruits were observed for symptom development. The fungal agents were re-isolated from the infected fruits and compared with the original isolates.

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3. RESULTS

A total of 7 fungal isolates were recorded in this study 4 from the spoilt sweet oranges, which include *Aspergillus fumigatus* infecting 10% of the oranges, *Aspergillus flavus*, infecting 23% while *Aspergillus niger*, and *Penicillium oxalicum* were the two prominent ones occurring in 26% and 41% of the oranges respectively. All the fungi isolated from the spoilt fruits were also isolated from the air in the shops while three fungal species were isolated from the air in the sales environment was not isolated from the spoilt oranges. These fungal species that are peculiar to the air in the shops include *Aspergillus terreus*, *Cladosporium sphaerospermum* and *Scopulariopsis brevicaulis* the pathogenicity test showed that *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger* and *Penicillium oxalicum* were all responsible for spoilage in the oranges. The healthy oranges developed the observed symptoms and these organisms were re-isolated from the newly infected oranges.

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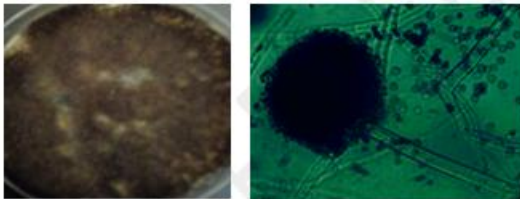
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Table 1: Macroscopic and Microscopic description of fungal isolates

S/N	Macroscopic Observations	Microscopic Observations	Name of Isolate
1.	Colonies on Potato dextrose agar attained a diameter of 4-5 cm within 7 days. It consists of a compact white or yellow basal felt with a dense layer of dark brown to black conidiophores.	Conidiophore stipes are smooth-walled, hyaline, and brown in colour. Phialides are borne on metulae. Conidia globose and rough-walled.	<i>Aspergillus niger</i>
2.	Colonies on Potato dextrose agar attained a diameter of 4 cm within 7 days. It appears blueish green in colour with white edges becoming powdery with age. The reverse is uncoloured.	Conidiophore stipes are smooth-walled, hyaline, and tetraverticillate. Metulae is smooth-walled and cylindrical bearing 2-4 phialides each. Phialides and conidia are cylindrical	<i>Penicillium oxalicum</i>
3.	Colonies on Potato dextrose agar attained a diameter of 3-5 cm within 7 days consisting of a felt of dark green conidiophores mixed with aerial hyphae.	Conidiophores are short, smooth-walled, and green. Vesicles are clavate. Phialides are directly borne on the vesicle. Conidia are globose.	<i>Aspergillus fumigatus</i>
4.	Colonies on Potato dextrose agar attained a diameter of 3-5 cm within 7 days. It consists of a dense felt of yellow-green conidiophores.	Conidiophores are hyaline and coarse, vesicles are globose. Phialides are borne directly on the vesicle. Conidia are globose to sub globose pale green and echinulate.	<i>Aspergillus flavus</i>

Table: 1 continued: Macroscopic and Microscopic description of fungal isolates

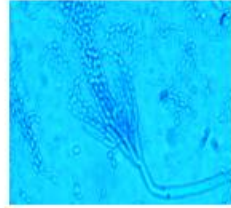
S/N	Macroscopic Observations	Microscopic Observations	Name of Isolate
5.	Colonies on potato Dextrose Agar attained a diameter of 3.5-5.0cm at 7 days consisting of a dense felt of yellow-brown conidiophore,	Conidiophores are hyaline and smooth-walled. Vesicles are subglobose and phialides are borne on metulae. Conidia are globose, hyaline and smooth.	<i>Aspergillus terreus</i>
6.	Colony on PDA attains a diameter of 2cm in 10 days, velvety and olivaceous brown. The reverse is greenish-black.	Conidiophores arise laterally and terminally from the hyphae bearing several branched conidial chains. Dark olivaceous- brown and smooth-walled.	<i>Cladosporium sphaerospermum</i>
7.	Colonies on potato Dextrose Agar attained a diameter of 3cm in 7days light rose brown at first becoming dark brown,	Conidiogenous cells are borne singly on arial hyphae or in groups of 2-10 on short conidiophores. Conidiospores are globose with a truncate smooth-walled, olive to brown in colour	<i>Scopulariopsis brevicaulis</i>



Obverse view

Micrograph (X40)

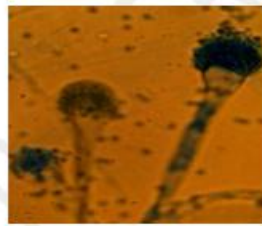
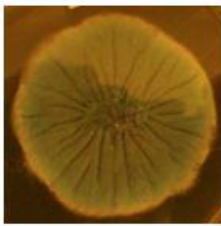
Plate i: *Aspergillus niger* isolated from oranges and the air in the orange sales environment



Obverse view

Micrograph (X40)

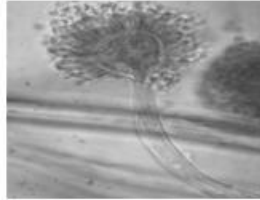
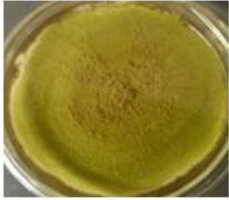
Plate ii: *Penicillium oxalicum* isolated from Oranges and the air in the orange sales environment.



Obverse view

Micrograph (X40)

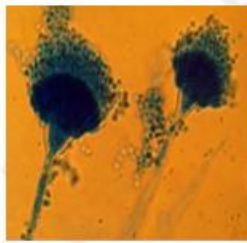
Plate iii: *Aspergillus fumigatus* isolated from oranges and the air in the orange shops



Obverse view

Micrograph (X40)

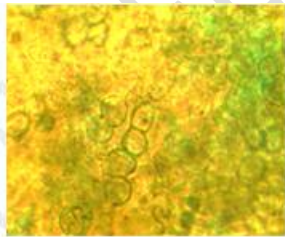
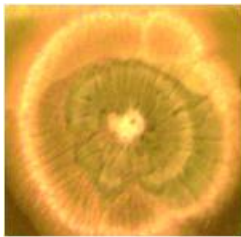
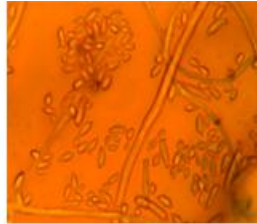
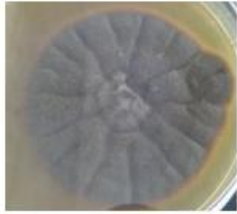
Plate iv: *Aspergillus flavus* isolated from Oranges and the air in the orange sales environment



Obverse view

Micrograph (X40)

Plate v: *Aspergillus terreus* isolated from the air in the orange shops



Obverse view

Micrograph (X40)

Plate vii: *Scopulariopsis brevicaulis* isolated from the air in orange shops

Table:2 Rate of fungal occurrence in orange samples

S/N	Fungi	Total number of samples	Number of samples it occurred in
1.	<i>Penicillium oxalicum</i>	100	82
2.	<i>Aspergillus niger</i>	100	53
3.	<i>Aspergillus flavus</i>	100	47
4.	<i>Aspergillus fumigatus</i>	100	20

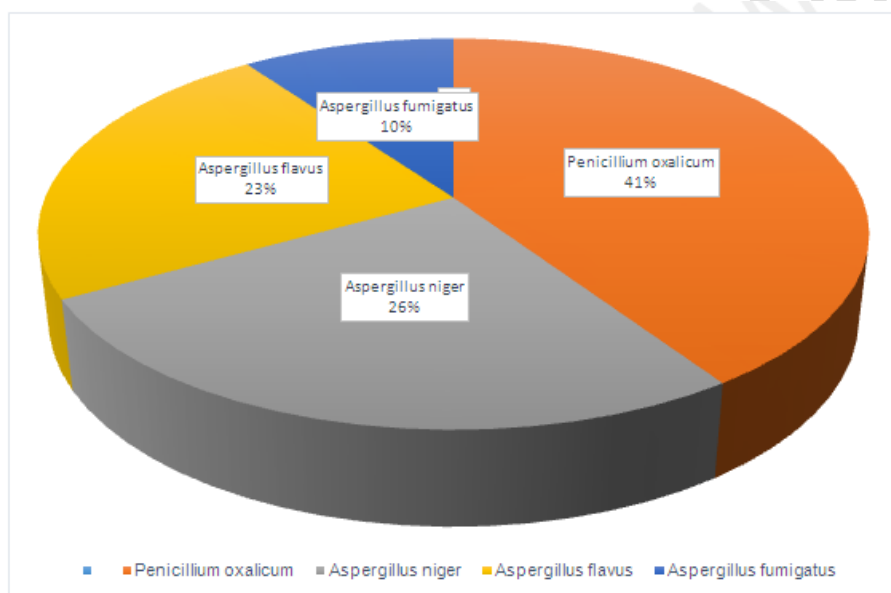


Figure 1: Percentage occurrence of each fungal species in one hundred samples (%)

DISCUSSION

When fruits are transported or stored at suboptimal conditions, fungi grow, cause spoilage and a number of them produce mycotoxins which are responsible for mycotoxicoses in man.

In this study, most of the spoilage was caused by *Penicillium oxalicum* as it was the most prevalent of the four isolates on the sweet oranges, it was isolated from eighty of the orange samples. This organism was also isolated from the air in the shops where these oranges are sold.

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This is in line with the study of [16] who identified *Penicillium* species as one of the fungi responsible for post-harvest rot in sweet oranges in Yemen. They also reported the isolation of *Aspergillus niger*, *Aspergillus flavus*, and *Aspergillus fumigatus*.

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This result also agrees with the findings of [15] also reported the isolation of *A. niger*, *A. flavus* and *A. fumigatus* as being responsible for the spoilage of sweet oranges (*Citrus sinensis* L) in Sokoto state. In their study, they isolated *Rhizopus stolonifer* which was not isolated in this study. *Penicillium oxalicum* is a widespread species associated with oil seeds, cereals, fruit, and vegetables. It has been identified as a known producer of mycotoxins such as Oxaline, Secalonic acid D, and roquefortine C [17]. *Aspergillus niger* which was isolated in this study is a common contaminant occurring on a wide range of substances such as plants, fruits, vegetables, and nuts, some strains of this species have been implicated in the production of ochratoxins. *A. flavus* is the principal producer of aflatoxins, it is widely distributed in nature; it grows on several agricultural crops before harvest or during storage and its growth is affected by temperature and relative humidity of the environment [18]. *Aspergillus fumigatus* which is also widely distributed in nature produces versicolorins, sterigmatocystin, and tremorgenic mycotoxins among others [19]. Also the results obtained from the air sampling carried out in the shops where the oranges are sold, revealed the presence of all the fungal isolates reported in this study. A study by [20] also reported *Aspergillus*, *Penicillium*, and *Cladosporium* as some of the major fungal isolates found to be present in the air in some fruit markets in India which is also in agreement with the results obtained from this study. According to a study carried out in China by [21]. *Cladosporium* was one of the fungi frequently isolated in the air which agrees with the findings of this study.

4.CONCLUSION: This study has shown that the spoilage of oranges resulting in economic loss to both farmers and consumers is majorly caused by fungi species present in the air around the facilities where the oranges are sold and stored, and these fungi have been found to be pathogenic, thereby predisposing the oranges to fungal spoilage. This calls for further research to investigate the possibility of fumigating the fruit markets using fungicides periodically so as to minimize the loss occurring from these fungal contaminants.

References

1. Mintah, B.K, Eliason, A.E, Nsiah, M, Baah, E.M, Hagan, E, Oforu, D.B. Consumption of fruits among students: A case of Public University in Ghana (2012). *African Journal of Food, Agriculture, Nutrition and Development*. 12(2):5979-5993.
2. Mauseth, J. D. Botany: An Introduction to Plant Biology (2003). Massachusetts: Jones and Bartlett; pp. 271-272.
3. Wargovich, M. J. Anticancer properties of fruits and vegetables (2000). *Hort Sc* 35: 573-575.
4. USDA. Why is it important to eat fruit? Available from http://www.mypyramid.gov/pyramid/fruits_why.html. [Accessed: 2019-10-10]

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5. Tribble, D.L. Antioxidant consumption and risk of coronary heart disease, emphasis on vitamin C, vitamin E and beta-carotene; a statement for health care professionals from the American Heart Association (1999). *Circulation*.;99:591-595
6. Bellavia A, Larsson SC, Bottai M, Wolk A, Orsini N. Fruit and vegetable consumption and all-cause mortality: A dose-response analysis (2013). *The American Journal of Clinical Nutrition*.1;98(2):454-459
7. Oyebode, O. Gordon-Dseagu, V. Walker, A. Mindell, J.S. Fruit and vegetable consumption and all-cause, cancer and CVD mortality: Analysis of Health Survey for England data (2014). *Journal of Epidemiology and Community Health*. 31:
8. Boffetta P, Couto E, Wichmann J, Ferrari P, Trichopoulos D, Bueno-de-Mesquita HB. Fruit and vegetable intake and overall cancer risk in the European Prospective Investigation into Cancer and Nutrition (EPIC) (2010). *Journal of the National Cancer Institute*. 1: 20-24
9. Zhu S.J. Non-chemical approaches to decay control in postharvest fruit (2006). In: Nouredine, B., Norio, S. (Eds.), *Advances in Postharvest Technologies for Horticultural Crops*. Research Signpost, Trivandrum, India, pp. 297–313.
10. Conner, T.S, Brookie, K.L, Carr, A.C, Mainvil, L.A, Vissers, M.C.M. Let them eat fruit! The effect of fruit and vegetable consumption on psychological well-being in young adults: A randomized controlled trial (2017). *PLoS One*. 12(2).
11. Olife, I.C, Ibeagha, O.A, Onwualu, A.P. Citrus Fruit Value Chain Development In Nigeria(2015). *Journal of Biology, Agriculture and Health care*. vol 5, no.4; 2224-3208pp
12. Onuorah, S., Obika, I. Okafor, U. Filamentous fungi associated with the spoilage of post-harvest sweet orange fruits (*Citrus sinensis*) sold in Awka Major Markets, Nigeria. *Bioengineering and Bioscience*, Vol. 3, No.3, 44-49, (2015). DOI:10.13189/bb.2015.030303.
13. Singh D, Sharma, R.R. Postharvest diseases of fruit and vegetables and their management. In: Prasad, D. (Ed.), *Sustainable Pest Management* (2007). Daya Publishing House, New Delhi, India.
14. Thiyam B. and Sharma, G.D. Isolation and identification of fungi associated with local fruits of Barak Valley, Assam (2013). *Curr. World Env*. 8,2
15. Tafinta, I., Shehu, K. Abdulganiyyu, H., Rabe, A.M and Usman, A. Isolation and Identification of Fungi Associated with the Spoilage of Sweet Orange (*Citrus Sinensis*) Fruits In Sokoto State (2014). *Nigerian Journal of Basic and Applied Sciences*. 21. 193. 10.4314/njb. v21i3.4.
16. Abdullah, Q., Mahmoud, A., Al-harethi, A. Isolation and Identification of Fungal Post-Harvest Rot of Some Fruits in Yemen (2016). *PSM Microbiol.*, 01(1): 36-44.
17. Samson, R.A., Frisvad, J.C. and Hoekstra, E.S., *Introduction to Food and Airborne Fungi*, (2004). 7th Edn. Pp 101-108. Central bureau Voor Schimmelcultures, Utrecht, the Netherlands.
18. Giorni, P. Leggrieri, M.C., Magan, N. and Battilani, P. Comparison of temperature and moisture requirements for sporulation of *Aspergillus flavus* sclerotia on natural and artificial substrates(2012). *Fungal Biology*. 116(6):637-642.
19. Mwanza, M. A comparative study of fungi and mycotoxin contamination in animal products from selected rural and urban areas of South Africa with particular reference to the impact of this on the health of rural black people (2011). PhD Thesis. University of Johannesburg, South Africa.
20. Maansi Vermani and Namita Bedi. Prevalence of Culturable Airborne Fungi in Fruit Markets of Delhi and Noida, India (2014). In *Proceedings (Vermani Prevalence OC*
21. Nageen, Y., Asemoloye, M.D., Pölme, S. Analysis of culturable airborne fungi in outdoor environments in Tianjin, China (2021). *BMC Microbiol* **21**, 134