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Mycological Indoor Air Quality Assessment of Ultra-Modern Market Grains' Grinding Mills in Dutse, Northwest Nigeria

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ABSTRACT

This research aimed to assess the mycological indoor air quality of the grains' grinding mills situated in the Dutse ultra-modern market. A simple random sampling method was employed to select nine (9) shops where grains are milled. Settle plate method through the use of fifty-four (54) sterile sabouraud dextrose agar (SDA) plates was adopted for fungal isolation in the morning, afternoon and evening. Fungal isolates were subsequently identified using standardized methods. Results obtained indicate that depending on the sampling period and operation status of the grinding mills, all the sampling points examined were heavily contaminated with total mean fungal load in the morning (4084 CFU/m^3), evening (3867 CFU/m^3), and afternoon (3818 CFU/m^3). However, the mean fungal load obtained in the morning from shop C (6426 CFU/m^3) was significantly different from other shops ($p< 0.05$) while the mean fungal loads obtained across all the shops in the afternoon and evening were not significantly different from each other ($p> 0.005$). Mucor plambeaus (22.22%), Aspergillus flavus (16.67%), Aspergillus niger (20.37%), Fusarium spp. (22.22%) and Penicillium spp. (18.52%) were isolated across the grinding mills. Results obtained indicate that depending on the time of the day and operation status of the grinding mills, the studied indoor environment allowed fungal aerosols to build up which could serve as a potential reservoir of fungal infections. It is therefore recommended that safety measures should be adopted with a view to reducing fungal pollution at the grains' grinding mills.

INTRODUCTION

Indoor air quality (IAQ) signifies the parameters of air present in an enclosed building. Pollutants that are found in a typical indoor environment can vary based on the prevailing anthropogenic interference, biological and chemical resources available at any point in time. Air is composed of gas that contains a mixture of mostly Nitrogen and Oxygen. The need for air in terms of the survival of humans, animals, and plants cannot be substituted. The quality of the air needed for breathing plays a huge role in defining the health status of humans and animals (Adeleye *et al.*, 2018). According to Nejadkoorki (2015), microbial toxins, bacteria, fungi, yeasts, volatile organic compounds, viruses, protozoa, insect allergens, pet and insect allergens are some of the elements that are found in the air. Depending on the microorganisms involved, exposure to bio-aerosols can lead to the development of asthma, contact dermatitis, chronic bronchitis, rhinitis, sinusitis, hypersensitive pneumonitis, organic dust toxic syndrome, and aspergillosis in immunosuppressed individuals (Bünger *et al.*, 2000; Douwes *et al.*, 2003; Viegas *et al.*, 2015). Evidence that people working in grains' grinding mills developing respiratory ailments have been reported by Dacarro *et al*. (2005).

Fungi and bacteria play a huge role in inducing the quality of the indoor air environment (Abed, 2014). This author submitted further that dankness and insufficient ventilation aid the presence of several biological agents in an indoor environment. According to World Health Organization (WHO), people that reside in moldy buildings are at great risk of developing respiratory ailments and aggravation of asthma (McMahon *et al.,* 2012). Walking, talking, sneezing, and coughing are some of the human activities that can freely breed airborne biological particulate matter in an indoor environment (Adeleye *et al*., 2018). Consequently, the need to conduct air quality monitoring to extricate between the causative agents that produce unfriendly health effects is inevitable (Madukasi *et al.,* 2010).

Environmental factors like temperature and relative humidity play a significant role in determining the growth of bio-aerosols in an indoor environment (Onmek *et al.,* 2020). These authors reported further that poor ventilation, crowded conditions, and an increase in the number of air conditions inside building nowadays can facilitate the spreading and the survival rates of airborne particles and also can increase the chance of people at risk of airborne infections. Amongst dust particles that are available in a typical indoor environment, fungi that reproduce through the formation of spores, some gram-positive bacteria, and some viruses have got the capability of surviving for a lengthy time in the air (Hassan *et al.*, 2017). According to McCormick *et al.* (2010), although *Aspergillus fumigatus* does not have virulence traits and can resist environmental stresses, it is a key airborne fungus that can cause mass infection. These authors reported further that the fungus has the capability of triggering numerous human diseases if its conidia are huffed into the lungs.

Serna-Saldivar (2012) did define grain as a small, dry seed, hard that is or not attached to hull or fruit layer, garnered for the consumption of humans and animals. This author reported further that a grain crop is a grain-producing plant that has two key types being commercial grain crops which are cereals and legumes. The availability of a low water activity has practically made microbial contamination of grains flour an issue that is not noticeable as such (Dacarro *et al*., 2005). These authors further reiterated that flours generated from grains generally have a water activity (0.87) level or lower depending on their moisture and temperature. Inhalation of bio-aerosols by workers in agricultural fields and those working with grains had led to many diseases like toxic syndrome, allergic alveolitis, and asthma (Dutkiewicz *et al.,* 2000). Generation of dusty particles in grains' grinding mills is inevitable. These dusty particles encourage the unhindered growth of airborne microorganisms provided that there are favorable environmental conditions (Dacarro *et al*., 2005). It has been established by Weidenborner *et al.* (2000) that molds start growing in flours when the water content goes above a range of 13–15%.

In a typical indoor environment, air that is breathed in by people is profusely inhabited with microorganisms known as bioaerosols ranging from bacteria, fungi, and molds Yassin and Almiuqatea (2010). Bioaerosols are constantly extant in our environment and the majority of the time, it may not be worrisome most especially if its quantity at source poses no problems and air quantities are kept within judicious bounds. Nevertheless, when some bioaerosols are inhaled into the lungs, it can lead to the development of airborne diseases like respiratory infections, pneumonia, asthma, and rhinitis (U.S National Institution of Health, 2014). Prevention and reduction of microbial contaminants in flours are viable alternatives adopted to enhance the acceptance of the final products coupled with aiding significant production costs in the milling process (Dacarro *et al*., 2005). According to Yassin and Almiuqatea (2010), a typical indoor environment enhances more favorable and optimum conditions for the existence of fungal aerosols. It is against this background that this study was conducted to assess the mycological indoor air quality of the grains' grinding mills in the Dutse ultra-modern market. The study was staged based on the null hypothesis that stated that there is no variation between the indoor fungal loads obtainable in the shops housing the grains' grinding mills.

METHODS

Description of Study Area

This study was conducted in the ultra-modern market situated in Dutse Urban. According to Peel *et al.* (2007), Dutse is the capital of Jigawa State,

Nigeria. The authors reported further that geographically, it lies on latitude of 11°42'8.46" N and longitude of 9°20'2.46" E. It is home to Federal University Dutse which was established in November 2011. Dutse ultra-modern market grains' grinding mills are located on the latitude of 11°41'31.7" N and longitude of 9°20'47.3" E.

Sampling Technique

Out of the thirty (30) shops present in the grains' grinding mills, nine (9) shops were selected randomly for air sampling. Six (6) samples were collected from each selected shop in the morning, afternoon, and evening thereby leading to the collection of fifty-four (54) indoor air samples.

Preparation of Culture Plates and Collection of Air Samples

A sensitive weighing balance was used to measure sixty-five grams (65g) of sabouraud dextrose agar (SDA) and 0.05g chloramphenicol into a conical flask. It was subsequently dissolved with100mL of distilled water following the instructions of the manufacturer. Chloramphenicol was added to inhibit the growth of broad-spectrum bacteria on the agar plates during incubation (Sa'id and Salihu, 2018). The culture media was autoclaved and aseptically poured into fifty-four (54) sterilized petri dishes. The plates were labeled with sample number, time of collection, and operation status of the grinding mills.

The petri dishes were transported to the grains' grinding mills in sealed bags as done by Adeleye *et al*. (2018). Indoor air sampling was done using the settle plate method (Fekadu & Getachewu, 2015). This was done by placing the prepared agar plates at a point that was very close to where each operator of the milling machines was standing in each shop, specifically at about one (1) meter above the ground representing human breathing zone (Adeleye *et al*., 2018). All the plates were exposed for twenty (20) minutes as prescribed by Sa'id and Salihu (2018). After this exposure, the agar plates were covered and immediately taken to the laboratory in sealed plastic bags. The agar plates were subsequently incubated for 5 days at 25 °C (Sa'id and Salihu, 2018).

Enumeration and Identification of Fungal Isolates

The enumeration of the fungal colonies was done with an electric colony counter leading to the generation of fungal Colony Forming Units (CFU). Afterwards, the Colony Forming Units per cubic meter (CFU/m^3) of the fungal isolates in the plates were determined using the equation outlined by Gutarowska (2010); Borrego *et al*. (2010); Enitan *et al.* (2017);

$$N = 5a \times 10^4 (bt)^{-1}$$

Where:

N= microbial CFU/m^3 of indoor air

a= number of colonies per petri dish

b= dish surface area (cm^2)

t= exposure time of the petri dish (in minutes).

Fungal colonies that had similar colonial attributes were subsequently sub-cultured into sterile SDA plates and further incubated for 5 days at 25°C. Fungal isolates were identified on the basis of macroscopic and microscopic examinations as outlined by Hayleeyesus and Manaye (2014); Enitan *et al*. (2017). This was done by adding a drop of distilled water at the center of a clean grease-free glass slide labeled A and B. Loopful of a fungal colony was collected from the fungal growth observed on the culture plates, mixed and a thin smear was made into a separate slide. The smears were allowed to air dry and heat-fixed by passing it three (3) times over a spirit lamp. The smears were placed on a staining rack. The smears were covered with a Lacto-phenol cotton blue stain for sixty (60) seconds. The two smears were rinsed with running water. The smears were allowed to air dry, the back of the glass slide was wiped with a piece of cotton wool. The glass slide was mounted on the microscope stage and observed using x10 and x40 objective lens. The morphology and cell arrangement were observed, snapped with an android phone, and recorded accordingly. Fungal isolates were identified with the aid of an Atlas of Mycology as described by Enitan *et al*. (2017).

Data Analyses

Descriptive statistics in form of tables were used to summarize results generated from the fungal Colony Forming Unit, colonial attributes, microscopic characteristics, and fungi identified. Results obtained on the fungal loads across all the shops and varying sample collection periods were subjected to analysis by Proc. GLM of GenStat version 17 and the means were separated using Duncan Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Fungal Loads Obtained in the Indoor Air of the Sampled Grinding Mills

A total of fifty-four (54) samples were collected during this study. The shop, sample number, petri dish label, operation status, sample collection time, and fungal loads of the selected shops (shop A to shop I) in the grinding mills are presented in Tables 1 to 9.

Table 1. Fungal Load Obtained in Samples from Shop A

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{36}	Active	8am-9am	Morning	2544
2	SDA_{35}	Active	9am-10am	Morning	4035
3	SDA_{11}	Active	1pm-2pm	Afternoon	3860
4	SDA_{10}	Not Active	2pm-3pm	Afternoon	3596
5	SDA_{17}	Not Active	4pm-5pm	Evening	2018
6	SDA_{46}	Active	5pm-6pm	Evening	3421

Note: OS= Operation status; CFU= Colony Forming Unit

Specifically, in shop A, it can be observed that when the grinding mils were in operation, the obtained fungal loads ranged between 2544 and 4035 CFU/m^3 while it ranged from 2018 and 3596 CFU/m^3 when the grinding mills were not in operation (Table 1).

Table 2. Fungal Load Obtained in Samples from Shop B

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{6}	Active	8am-9am	Morning	4298
2	SDA_{45}	Not Active	9am-10am	Morning	3465
3	SDA_{31}	Active	1pm-2pm	Afternoon	5614
4	SDA_{41}	Not Active	2pm-3pm	Afternoon	3421
5	SDA_{18}	Active	4pm-5pm	Evening	4912
6	SDA_{47}	Not Active	5pm-6pm	Evening	4035

Note: OS= Operation status; CFU= Colony Forming Unit

In shop B, the fungal loads recorded when the grinding mills were in operation ranged between 4298 and 5614 CFU/m^3 while it ranged between 3421 and 4035 CFU/m^3 when the mills were not in operation (Table 2).

Table 3. Fungal Load Obtained in Samples from Shop C

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{27}	Active	8am-9am	Morning	6228
2	SDA_{30}	Active	9am-10am	Morning	6623
3	SDA_{32}	Not Active	1pm-2pm	Afternoon	4649
4	SDA_{09}	Not Active	2pm-3pm	Afternoon	3333
5	SDA_{08}	Not Active	4pm-5pm	Evening	2807
6	SDA_{48}	Active	5pm-6pm	Evening	4298

Note: OS= Operation status; CFU= Colony Forming Unit

In shop C, it can be observed that while the grinding mills were not milling grains, the fungal loads ranged between 2807 and 4649 CFU/m^3 while it ranged between 4298 and 6228 CFU/m^3 when it was in operation (Table 3).

Table 4. Fungal Load Obtained in Samples from Shop D

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{20}	Active	8am-9am	Morning	5746
2	SDA_{25}	Active	9am-10am	Morning	3246
3	SDA_{23}	Not Active	1pm-2pm	Afternoon	3728
4	SDA_{03}	Not Active	2pm-3pm	Afternoon	3553
5	SDA_{13}	Active	4pm-5pm	Evening	4693
6	SDA_{49}	Active	5pm-6pm	Evening	4912

Note: OS= Operation status; CFU= Colony Forming Unit

The highest fungal load (5746 CFU/m^3) recorded in shop D when the grinding mills were in operation was recorded in the morning between 8 and 9 am while the lowest fungal load (3553 CFU/m^3) was recorded when the grinding mills were not in operation was recorded in the afternoon (Table 4).

Table 5. Fungal Load Obtained in Samples from Shop E

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{39}	Not Active	8am-9am	Morning	1930
2	SDA_{42}	Not Active	9am-10am	Morning	3421
3	SDA_{24}	Not Active	1pm-2pm	Afternoon	3246
4	SDA_{07}	Not Active	2pm-3pm	Afternoon	2588
5	SDA_{28}	Active	4pm-5pm	Evening	4474
6	SDA_{50}	Active	5pm-6pm	Evening	4649

Note: OS= Operation status; CFU= Colony Forming Unit

In shop E, the fungal loads recorded when the grinding mills were in operation ranged between 4474 and 4649 CFU/m^3 while it ranged between 1930 and 3421 CFU/m^3 when the grinding mills were not in operation (Table 5).

Table 6. Fungal Load Obtained in Samples from Shop F

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{43}	Not Active	8am-9am	Morning	3860
2	SDA_{26}	Active	9am-10am	Morning	5877
3	SDA_{22}	Active	1pm-2pm	Afternoon	4649
4	SDA_{04}	Not Active	2pm-3pm	Afternoon	4430
5	SDA_{01}	Not Active	4pm-5pm	Evening	2456
6	SDA_{51}	Active	5pm-6pm	Evening	4649

Note: OS= Operation status; CFU= Colony Forming Unit

In shop F, when the grinding mills were in operation, the highest fungal load recorded was 5877 CFU/m^3 while the lowest fungal load deduced when the grinding mills were in operation was 2456 CFU/m^3 (Table 6).

Table 7. Fungal Load Obtained in Samples from Shop G

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{37}	Not Active	8am-9am	Morning	1667
2	SDA_{21}	Active	9am-10am	Morning	4737
3	SDA_{16}	Active	1pm-2pm	Afternoon	4035
4	SDA_{40}	Not Active	2pm-3pm	Afternoon	2281
5	SDA_{38}	Not Active	4pm-5pm	Evening	2149
6	SDA_{52}	Not Active	5pm-6pm	Evening	2456

Note: OS= Operation status; CFU= Colony Forming Unit

During indoor air sampling in shop G, the fungal loads ranged between 4035 and 4737 CFU/m^3 when the grinding mills were in operation while it ranged between 1667 and 2456 CFU/m^3 when the grinding mills were not in operation (Table 7).

Table 8. Fungal Load Obtained in Samples from Shop H

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{34}	Active	8am-9am	Morning	3947
2	SDA_{33}	Not Active	9am-10am	Morning	3553
3	SDA_{12}	Active	1pm-2pm	Afternoon	4474
4	SDA_{14}	Not Active	2pm-3pm	Afternoon	3026
5	SDA_{02}	Not Active	4pm-5pm	Evening	3158
6	SDA_{53}	Active	5pm-6pm	Evening	4035

Note: OS= Operation status; CFU= Colony Forming Unit

When there was no grinding operation going on in shop H, fungal loads detected ranged between 3026 and 3553 CFU/m^3 whereas the fungal loads recorded when there was grinding activity going on ranged between 3947 and 4474 CFU/m^3 (Table 8).

Table 9. Fungal Load Obtained in Samples from Shop I

Sample	Label	OS	Time	Period	CFU/m^3
1	SDA_{44}	Active	8am-9am	Morning	4211
2	SDA_{05}	Active	9am-10am	Morning	4123
3	SDA_{15}	Not Active	1pm-2pm	Afternoon	3465
4	SDA_{29}	Active	2pm-3pm	Afternoon	4781
5	SDA_{19}	Active	4pm-5pm	Evening	5351
6	SDA_{54}	Active	5pm-6pm	Evening	4474

Note: OS= Operation status; CFU= Colony Forming Unit

However, in shop I, the highest fungal load obtained during grinding operation in the afternoon was 4781 CFU/m^3 while the lowest fungal load recorded in the absence of grinding operation in the afternoon was 3465 CFU/m^3 (Table 9). It can be observed that the indoor air sampling of the grinding mills was done in the morning (8-10 am), afternoon (1-3 pm), and evening (4-6 pm). When the grinding mill was in operation in the morning, the highest (4035 CFU/m^3) fungal load recorded in shop A was obtained on SDA_{25} (Table 1). However, when the grinding mill was not in operation, the lowest (2018CFU/m^3) fungal load was obtained on SDA_{17} in the evening (Table 1). When the grinding mill was in operation in the afternoon, the highest (5614 CFU/m^3) fungal load recorded in shop B was obtained on SDA_{31} (Table 2). Conversely, when the grinding mill was not in operation, the lowest (3421CFU/m^3) fungal load was obtained on SDA_{41} in the afternoon (Table 2).

Generally, it can be observed across all the shops that irrespective of the sampling time, fungal loads obtained when grinding mills were in operation were always more than the fungal loads

obtained when the grinding mills were not in operation (Tables 1-9). During air sampling, it was observed that workers in the grinding mils had no protective device on. This implies that more of these fungal aerosols were more likely to be inhaled during this space of time. Table 10 depicts the results of the mean fungal load obtained during air sampling in the shops.

Table 10. Mean Fungal Load Obtained during Air Sampling in the Shops

Mean fungal load (CFU/m^3)		
Morning	Afternoon	Evening
4084	3818	3867

CFU= Colony Forming Unit

Results obtained indicate that depending on the sampling period and operation status of the grinding mills, all the sampling points examined were heavily contaminated with total mean fungal load in the morning (4085 CFU/m^3), evening (3866 CFU/m^3), and afternoon (3818 CFU/m^3) (Table 10).

Colonial and Microscopic Characteristics of the Isolated Fungi

The colonial attributes and microscopic characteristics of the isolated fungi are depicted in (Table 11).

Table 11. Colonial and Microscopic Characteristics of the Identified Fungi

Colonial Attributes	Microscopic Characteristics	Fungi Identified
Fairly distinct, blackish flat and coarse colonies	Septate hyphae with a large sporangiosphore	*Aspergillus niger*
Yellow to green colonies which later turned brown	Septate hyphae with filamentous structure	*Aspergillus flavus*
Candy like colonies, whitish, turned brown at the center	Septate hyphae with macro conidia growing on sporangiosphore	*Fusarium* spp.
Fast growing colonies, white to grey cotton candy, and darkening	Non Septate hyphae with sporangiosphore	*Mucorplambeaus*
Colonies having green fluffy mycelia with white sporangiosphore	Septate hyphae with filamentous structure	*Penicillium* spp.

It can be seen that four (4) airborne fungi ranging from *Aspergillus niger* and *Penicillium* spp. were isolated and identified in the grinding mills (Table 11). The detection of these fungi in this study corroborates the findings of Amengialue *et al*. (2017) who reported the isolation of *Penicillium* spp., *Aspergillus* spp., *Aspergillus niger,* and *Mucorplambeus* at the University of Benin. The results obtained in this study are also in agreement with that of Sekulska *et al*. (2007) who detected some strains of *Fusarium, Penicillium,* and *Rhizopus* in University rooms. The occurrence frequency of the fungi isolated from the sampled air is presented in Table 12**.**

Table 12. Occurrence Frequency of the Isolated Fungi

Fungi Isolates	Number of Isolates	Frequency (%)
Aspergillus flavus	9	16.67
Mucorplambeus	12	22.22
Fusarium spp.	12	22.22
Aspergillus niger	11	20.37
Penicilliumspp.	10	18.52
Total	54	100

The most frequent fungal isolates were *Mucorplambeus* and *Fusarium* spp. with a percentage frequency of 22.22 % and 22.22 % respectively while the least occurred fungal isolate was *Aspergillus flavus* with a percentage frequency of 16.67% (Table 12). The results of the present study agree with the reports of Würtz *et al.* (1999); Meklin (2002) who isolated molds belonging to the

genera *Penicillium* and *Aspergillus* from the indoor air of some Norwich schools and Danish schools respectively. It also agrees with the report of Kumari *et al.* (2015); Canha *et al.* (2015) on the detection of *Penicllium* spp., Yeasts, and *Aspegillus* spp. In their study area. The findings in this current study equally coincide with the report of Dacarro *et al.* (2005) on the detection of *Aspergillus* spp., *Penicillium* spp. in an Italian grind mill. These authors implicated mycetes of *Aspergillus* genus as the main threat causing pathologies connected with dust particles emanating from organic sources. Naga *et al.* (2015) equally reported the occurrence of *Aspergillus* spp., *Penicillium* spp., and *Rhizopus* spp. as the dominant fungal isolates in an indoor environment.

Many authors (Bünger *et al*., 2000; Douwes *et al*., 2003; Viegas *et al*., 2015) have reported aspergillosis in immunosuppressed individuals exposed to bio-aerosols in their workplace. M*ucorplambeus, Penicillium* spp., *Fusarium* spp., *Aspergillus flavus,* and *Aspergillus niger* isolated in this current study have been implicated as opportunistic pathogens for humans and often associated with clinical manifestations of allergy, rhinitis, asthma, cancer, and conjunctivitis. Also, these fungi are considered potential candidates involved in the establishment of sick building syndromes (Sa'id and Salihu, 2018). Sundaram *et al.* (2002) has attributed pneumoconiosis which is known as flour mill lung to inhalation of dusts generated from grains.

In reference to the Commission of the European Communities (CEC), American Conference of Governmental Industrial Hygienists (ACGIH), and Occupational Safety and Health Administration (OSHAA) standards and groupings (Kim *et al.*, 2018), the indoor air of grains grinding mills of ultra-modern market Dutse, generally showed a high level of fungal contamination levels as the identified fungi recorded in the grinding mills fell in the range of the recommended fungal counts ($>10^3$ CFU/m^3) as against the earlier findings of Adeleye *et al.* (2018). Even though Bragoszewska and Biedron (2018) did report difficulty in the characterization of work-related risks associated with airborne pathogens, the risks attributable to the isolated and identified fungi in this study should be a source of concern as workers and people that come in contact with the bioaerosols detected in the grinding mills are potentially exposed to such and may be susceptible to its associated ill health effects after all.

Results generated from air sampling indicated that the mean fungal loads obtained in the morning from shops A (3290 CFU/m^3), B (3882 CFU/m^3), D (4496 CFU/m^3), E (2676 CFU/m^3), F (4869 CFU/m^3), G (3202 CFU/m^3), H (3750 CFU/m^3) and I (4167 CFU/m^3) were not significantly ($p> 0.05$) different from each other. However, the mean fungal load obtained in the morning from shop C (6426 CFU/m^3) was significantly ($p< 0.05$) different from the fungal loads obtained in other shops (Table 13).

Table 13. Variations in the Mean Fungal Loads during Sample Collection

	Fungal Load (CFU/m^3)		
Shop	Morning	Afternoon	Evening
A	3290^{bc}	3728^{bc}	2720^{bc}
B	3882^{bc}	4518^{abc}	4474^{abc}
C	6426^{a}	3991^{bc}	3868^{bc}
D	4496^{abc}	3640^{bc}	4802^{ab}
E	2676^{bc}	2917^{bc}	4562^{abc}
F	4869^{ab}	4540^{abc}	3553^{bc}
G	3202^{bc}	3158^{bc}	2302^{c}
H	3750^{bc}	3750^{bc}	3597^{bc}
I	4167^{abc}	4123^{abc}	4913^{ab}

Note: Means with the same letters in each column are not significantly different using Duncan multiple range test (DMRT) ($p >0.05$).

In the afternoon, the mean fungal loads recorded in all the shops were significantly ($p > 0.05$) different from each other. The same trend was witnessed in the evening as the mean fungal loads recorded across all the shops were not significantly ($p>0.05$) different from each other (Table 13).

CONCLUSION

In this study, *Mucorplambeaus, Aspergillus flavus, Aspergillus niger, Fussarium* spp., and *Penicillium* spp. Were isolated across all the air sampling points using the simple staining technique. The fungi isolated in this study have been established as causative agents of several fungal infections which can be potentially and readily picked up by the workers and customers that come in contact with the indoor air of the grinding mills. Specifically, allergies, rhinitis, asthma, cancer, and conjunctivitis are the reported diseases synonymous with the fungi isolated from the grains' grinding mills. The results obtained in this study have clearly indicated that depending on the time of the day and operation status of the various shops housing the grinding mills, the indoor environment allows fungal aerosols to build up which could serve as potential reservoirs of fungal infections. The concentrations of aero flora above the permissive standard recorded in this study, underscore the importance of this microenvironment for high exposure of humans to bio-aerosols.

Based on the findings recorded in this study, it is therefore recommended that a proper ventilation system should be provided to allow the movement of air in and out of the grinding mills. Proper control measures have to be taken to prevent the environmental factors which facilitate the growth and proliferation of pathogenic fungi in the workplace. Disinfection of floors should be performed routinely and dust from the grinding process should be prevented to the barest minimum. Workers and customers that visit the grinding mills should be mandated to wear face masks for their safety. Finally, as this study focused on the isolation of fungal airborne pathogens, future studies may be required to isolate bacterial pathogens which could be a good source of air-borne pathogens in the grinding mills.

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