PAJRI
PAN-AFRICAN JOURNAL OF RESEARCH AND INNOVATION

Pan-African Journal of Research and Innovation in Medical, Health and Clinical

EISSN: 3156-7053 | Vol. 1, Issue 2 | www.pajri.com | DOI: https://doi.org/10.0000/0000

Antifungal Susceptibility Profile and Virulence Factors of *Candida* Species Isolated from Door Handles of a University Campus in Owerri, Imo State, Nigeria.

EchetaM.O.[1*], Obi-Adumanya G.A[2], Udochukwu U.[3], Oyem I.M.[4], Onyeukwu R.U.[5], Tony-Nze C.P.[6], Ezekwueche S.N.[7], Itubochi C.A.[8], Nwokoro A.B.[9], Korie M.C.[10], Nzeagwu M.O.[11], Onuoha N.C.[12], Nsoha J.C.[13]

[1, 3, 5, 6, 7, 13] *Department of Microbiology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.*

[4]*Department of Microbiology, University of Delta, Agbor, Nigeria.*

[8]*Department of Microbiology, Kingsley Ozumba Mbadiwe University, Ideato, Imo State*

[2,9] *Department of Biology, University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria.*

[10, 11, 12]*Department of Science Laboratory Technology, DR. B.U. Nzeribe State Polytechnic, Awomamma, Imo, State, Nigeria.*

* Corresponding author: maryrose.echeta@uaes.edu.ng

Received: 2026-10-09	Accepted: 2026-10-21	Published: 2026-10-27

ABSTRACT

Candida species are opportunistic yeasts capable of causing infections, especially in immunocompromised individuals. This study evaluated the occurrence, virulence factors, and antifungal susceptibility profile of Candida species isolated from door handles of the University of Agriculture and Environmental Sciences, Umuagwo, Owerri, Imo State, Nigeria. Swab samples were collected from high-touch door handles and cultured on chromogenic Candida agar to enhance Candida species identification relying on colony appearance. Germ tube test and chlamydospore production were done for confirmatory tests of the Candida species. The isolates were subjected to a series of virulence tests, including phospholipase, protease, and hemolytic activity tests using standard plate methods. Pure cultures of Candida albicans, C. parapsilosis, C. glabrata, C. tropicalis, and C. krusei were successfully isolated. Every isolate exhibited at least one virulence factor, with C. albicans displaying the strongest enzymatic and hemolytic activity. Antifungal susceptibility tests revealed broad sensitivity to polyene antifungals but inconsistent resistance to azoles, especially in Candida parapsilosis. These results suggest that door handles in shared spaces harbor potentially multidrug-resistant Candida species. The study shows the value of rigorous hygiene protocols and regular environmental surveillance to curb the dissemination of opportunistic fungal pathogens in public and institutional environments. Overall, the findings enhance insights into environmental Candida niches and emphasize the urgency of targeted interventions to address related public health threats.

KEYWORDS: *Candida, Antifungal susceptibility profile, Virulence factors, Door handles*

How to Cite

Echeta, M., Obi-Adumanya, G., Udochukwu, U., Oyem, I., Onyeukwu, R., Tony-Nze, C., Ezekwueche, S., Itubochi, C., Nwokoro, A., Korie, M., Nzeagwu, M., Onuoha, N., & Nsoha, J. (2026). Antifungal Susceptibility Profile and Virulence factors of Candida Species Isolated from Door Handles of a University Campus in Owerri, Imo State, Nigeria. *Pan-African Journal of Research and Innovation in Medical, Health and Clinical Sciences, 1(1-2), 77-85.*

1. Introduction

Infections caused by *Candida* genus have become a significant public health problem in recent times. *Candida* species are common yeasts that form part of the normal microbiota of humans, colonizing sites such as the oral cavity, gastrointestinal tract, vagina, and skin (**Fróis-Martins, *et al*.,** 2024). In typical circumstances, these microbes live alongside their human hosts without causing damage. Yet, when host

immunity weakens, they turn pathogenic, acting as opportunistic threats. The worldwide health sector views *Candida* infections as especially concerning, as they represent a major share of global fungal illnesses (**Katsipoulaki** *et al.,* 2024). The Centers for Disease Control and Prevention (CDC, 2024) reports that *Candida* species rank among the top triggers of bloodstream infections in hospital patients, leading to extended stays, higher medical expenses, and elevated death rates even more alarming, emerging non-albicans *Candida* species like *C. glabrata*, *C. parapsilosis*, and *C. krusei* have been documented to trigger serious illnesses, frequently displaying strong resistance to standard antifungal drugs. The shift from a benign commensal to a pathogenic entity is driven by an array of specialized processes called virulence factors. These factors such as phospholipases, hemolysins, and proteases allow *Candida* species to attach to host and non-living surfaces, penetrate tissues, evade immune defenses, and withstand antifungal therapies (Ferreira *et al*., 2026). Grasping these virulence processes is vital, especially in environmental research, where strains from high-contact areas like door handles can act as sources for opportunistic infections in populations (Talpko *et al.,* 2021). While antifungal medications like azoles and polyenes have formed the mainstay of therapy, resistance strategies including efflux pump upregulation, biofilm production, and target protein modifications have reduced their efficacy (Shorts *et al*., 2019). The World Health Organization (WHO, 2022) has classified *Candida albicans*, *C. auris*, and various non-albicans *Candida* species as among the most urgent fungal threats needing immediate worldwide investigation and monitoring. Recognizing their presence in routine surroundings and their resistance profiles is key to developing measures that lower infection hazards. This dovetails directly with the current study, which examines *Candida* species isolated from commonly handled surfaces such as door handles.

While bacterial contamination of door handles has been widely investigated, no targeted data exists on *Candida* species in non-clinical settings within a university environment in Imo State. Door handles in busy areas can shelter virulent and antifungal-resistant *Candida* strains, yet their prevalence, species makeup, and antifungal susceptibility profiles remain largely unexplored. This knowledge gap hinders the development of evidence-based strategies for infection prevention and control in institutional environments. The study thus examined the main *Candida* species linked to door handles at the University of Agriculture and Environmental Sciences, Umuagwo, Imo State, and assessed their antifungal resistance patterns and the virulence factors responsible for their antifungal resistance.

2. Materials and Methods

2.1 Sample Collection

Samples were collected by swabbing the door handles using sterile cotton swabs moistened with distilled water. A total of thirty (30) samples were collected from different door handles in the three distinct buildings (Administrative block, Faculty of science and computing and Faculty of arts). Ten (10) samples each were collected from each building. These buildings were selected because there is high frequency of people's movement in these places. All samples were immediately transported to the Microbiology laboratory of the department of Microbiology under cold chain conditions to preserve the viability of the microorganisms for analysis. Upon arrival, samples were homogenized by vortexing and subjected to ten-fold serial dilution using sterile distilled water, following standard microbiological procedures. Aliquots from the 10^3 and 10^4 dilutions were plated in triplicate onto prepared Chromatic agar *Candida* plates using the streak plate method to ensure isolation of discrete colonies. The inoculated plates were incubated at 37°C for 48 hours to allow for the growth and identification of *Candida* species based on their colony morphology and chromogenic reactions. Germ tube test was used to confirm for *Candida albicans* and chlamydospore production for all the isolates. The colonies were sub-cultured until pure cultures were obtained.

2.2 Screening for Virulence Factors

2.3 Protease Activity

Protease production was assessed using skim milk agar (SMA) following the protocol of Ghosh & Chatterjee, 2022) with slight modification). Isolates were spot-inoculated onto SMA agar plates triplicates and incubated at $37^o \pm 2^oC$ for 72 h. Clear zones of proteolysis around the colonies signified active proteinase secret ±ion.

2.4 Phospholipase Production

The production of phospholipase was carried out on egg yolk agar following the method of (Sun *et al,* 2022) with slight modification. Following incubation at 37°C ± 2°C for 72 h, colonies with surrounding precipitation zones were deemed phospholipase positive. The zone diameter was recorded to quantify enzymatic activity. The inoculation was done in triplicates.

2.5 Hemolysin Test

The hemolysin test was done using the method of Makled *et al,* 2024). Ten microliters of *Candida* isolate suspension, adjusted to turbidity of 0.5 McFarland standards was inoculated onto human blood-SDA plates in triplicates. All the plates were aerobically incubated at 37°C ± 2 for 72 h. After incubation, transparent zones around the colonies were observed and considered positive for production of hemolysis.

2.6 Antifungal Susceptibility Testing

Antifungal susceptibility testing of the isolated *Candida* species was performed in triplicate using the disk diffusion method following the Clinical and Laboratory Standards Institute (CLSI) guidelines (2020). The test was carried out on Mueller-Hinton Agar supplemented with 2 % glucose and 0.5 g/mL methylene blue (GM-MHA). The antifungal agents tested included: Caspofungin (5µg), Fluconazole (100µg), Voriconazole (1µg), Amphotericin B (100µg), Ketoconazole (15µg), Clotrimazole (2µg), and Nystatin (100µg). A standardized inoculum of each *Candida* isolate (adjusted to 0.5 McFarland Standard) was swabbed uniformly over the entire surface of the Mueller-Hinton agar plates and the discs aseptically placed onto the surface of the inoculated plates. The plates were incubated at 37°C ± 2°C for 72 h and the zones of inhibition measured with meter rule. Negative control was done with sterile distilled water. Standard deviation [SD] was calculated to assess intra-assay variability using the sample standard deviation formula for variability. Data were expressed as mean standard deviation. Disk diffusion was done per CLSI M44-A2/M60 on GM-MHA in triplicate [n=3], zones expressed as Mean ± SD [sample SD, n-1]. CLSI provides no disk breakpoints for ketoconazole, amphotericin B, nystatin and clotrimazole; therefore zones were interpreted using HiMedia/literature criteria: ketoconazole S ≥28 mm, nystatin/clotrimazole S ≥20 mm, amphotericin B ≥10 mm = S [requires MIC confirmation per CLSI.

2.7 Ethical Approval

The study does not need ethical approval hence no clinical samples were used.

3. Results

The results of the distribution of occurrence of *Candida* species across from door handles are shown in Table 1. A total of 197 *Candida* isolates were recovered from the door handles. The most dominant species was *Candida albicans* with 113 isolates (57.4%), followed by *C. parapsilosis* with 38 isolates (19.3%), *C. glabrata* with 30 isolates (15.2%), *C. krusei* with 11 isolates (5.6%), and *C. tropicalis* with 5 isolates (2.5%). The distribution and percentage occurrence of the isolated *Candida* species from the door handles is as represented in table 1.

The antifungal susceptibility of the *Candida* isolates to selected antifungal agents (such as Caspofungin, Fluconazole, Voriconazole, Amphotericin B, ketoconazole, Clotrimazole, and Nystatin) revealed *Candida parapsilosis* as only species susceptible to Amphotericin B, Nystatin, Clotrimazole and Ketoconazole showing clear diameter zones of inhibition of 12mm, 26mm, 30mm, and 30mm respectively. *C. glabrata* was resistant to all antifungal agents used. *C. tropicalis*, *Candida albicans* and *C. krusei* were all resistant to all the antifungal agents. A summary of the antifungal susceptibility patterns of the *Candida* isolates is presented in Table 3 and plate 2.

Table 1. Distribution and Percentage Occurrence of *Candida* Species isolated from Door Handles of the University of Agriculture and Environmental Sciences, Umuagwo, Imo, State, Nigeria.

S/N	*Candida* species	Number of Isolates	% Occurrence
1	*C. albicans*	113	57.4%
2	*C. parapsilosis*	38	19.3%
3	*C. glabrata*	30	15.2%
4	*C. krusei*	11	5.6%
5	*C. tropicalis*	5	2.5%
	Total	**197**	**100%**

Table 2 below presents the virulence factors exhibited by the *Candida* isolates. *Candida albicans* showed negative phospholipase activity, beta hemolysis, and positive protease. *Candida glabrata* exhibited positive phospholipase activity, alpha hemolysis, and negative protease test. *Candida krusei* showed negative phospholipase activity, alpha hemolysis, and negative protease activity. *Candida tropicalis* showed positive phospholipase activity, alpha hemolysis, and negative protease activity, while *Candida parapsilosis* exhibited negative phospholipase activity, alpha hemolysis, and positive protease activity. Of the five *Candida isolates,* all 5 (100%) exhibited hemolytic activity on sheep blood agar. Complete [β] hemolysis was demonstrated by only 1 isolate (20%), identified as *Candida albicans,* while incomplete [α] hemolysis was demonstrated by 4 isolates [80%] *(Candida glabrata, C. krusei, C. tropicalis* and *C. parapsilosis).* No γ-hemolysis [non-hemolytic] activity was recorded.

Table 2: Virulence Factors of *Candida* Isolates.

***Candida* spp**	**Phospholipase**	**Hemolysin**	**Protease**
C. albicans	(-)	β	(+)
C. glabrata	(+)	α	(+)
C. krusei	(-)	α	(-)
C. tropicalis	(+)	α	(-)
C. parapsilosis Footnote: + =Positive	(-) - =Negative, α	α =Alpha hemolysis , β	(+) = Beta-hemolysis

Table 3: Antifungal susceptibility Patterns of *Candida* isolates with their Zones of Inhibition (mm).

Isolates	**Ca (5µg)**	**Flu (100 µg)**	**Keto (15 µg)**	**Vo (1 µg)**	**AmB (20 µg)**	**Nys (100 µg)**	**Clo (2 µg)**
Candida albicans	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Candida glabarata	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Candida parapsilosis	**R**	**R**	**28.33 ±1.53**	**R**	**14.33 ± 2.08**	**23.67 ± 2.52**	**32.00 ± 2.00**
Candida tropicalis	**R**	**R**	**R**	**R**	**R**	**R**	**R**
Candida krusei	**R**	**R**	**R**	**R**	**R**	**R**	**R**

Key: Ca (Caspofungin). Flu (Fluconazole), Keto (Ketoconazole), Vo (Voriconazole), AmB (Amphothericin B), Nys (Nystatin) and Clo (Clotrimazole).
R means resistant to antifungal agents.



Plate 1

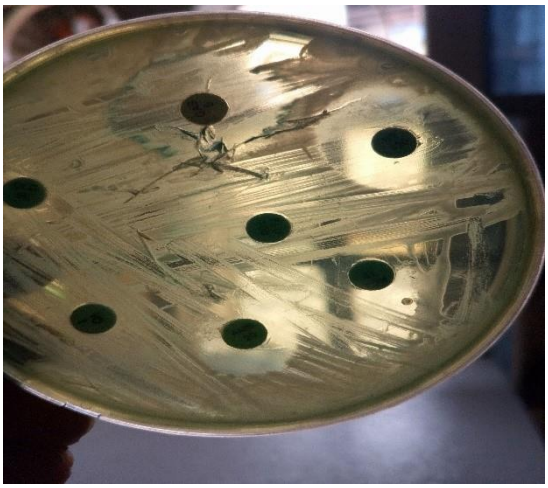


Plate 2

Plate 1 :Pure culture and morphological feature of *Candida albicans* on Chromatic Agar *Candida.*
Plate 2: Zones of Inhibition of *Candida parapsilosis* to ketoconazole, Nystatin, Amphothericin B and Clotirmazole.

4. Discussion

The novel finding in this study is the recovery of five clinically important, virulent *Candida species* from door handles in a Nigerian university environment, with 100% of isolates retaining pathogenic potential outside the host. Easily touched surfaces such as door handles are likely to serve as a powerful route for the transmission of microbes. The present study observed that *Candida albicans* was the common species on door handles, with 113 (57.4%), followed by *C. parapsilosis* 38 (19.3%) *C. glabrata* 30 (15.2%), *C. krusei* 11 (5.6%) and *C. tropicalis* 5 (2.5%). This evidence shows that *C. albicans* is present everywhere in the environment, corroborating its consistent with its classification as a predominant opportunistic pathogen in both humans and the environment (Sule *et al*., 2025). The high prevalence of *C. albicans* may be attributed to its ability to survive under diverse environmental conditions, including the variable temperatures and humidity present in indoor and outdoor environments of the university buildings. These findings are in agreement with (Appiah, 2025) who recorded that high-touch surfaces, particularly door handles, serve as reservoirs for *Candida* species. The results are in concordance with Nwinyi & Boluwatife (2024) who recorded the presence of *Candida* species and bacteria on door handles of school hostels. Interestingly, the relatively lower counts of C. *tropicalis* and *C. krusei* may reflect species-specific environmental tolerances or competition for resources among *Candida* species. While *C. parapsilosis* was present in moderate amounts, its survival may be enhanced by its known affinity for plastic surfaces, which aligns with our observation that door handles were both metallic and plastic. Studies have shown that *C. parapsilosis* often colonizes medical and environmental surfaces, highlighting the potential risk of surface-mediated transmission (Singh, *et al.,* 2020)
These findings suggest that high-touch surfaces, particularly door handles, serve as reservoirs for *Candida* species, facilitating the potential spread of opportunistic fungal pathogens. Our results are largely consistent with (Kramer *et al,* 2024; Dire *et al*., 2023) who reported environmental colonization by *C. albicans* as the most dominant species on frequently used surfaces. However, the slightly higher occurrence of *C. glabrata* in our study compared to previous reports may reflect the specific environmental conditions in the sampled buildings, such as indoor humidity, human traffic, and surface material, which are known to influence fungal survival and proliferation (Dire *et al*., 2023). The ability of *Candida* species to be pathogenic and virulent is as a result of some virulence factors. The existence of phospholipase, haemolysin and protease producing *Candida* isolates in the present study reaffirms the report of (Saha, 2018; Akinjogunla, et al, 2019; Corbu *e t al.,* 2024; Deorukhkar (2014) who stated that the ability of *Candida* to invade and damage the cellular content of the host cell is attributable to the production of phospholipase.

Antifungal susceptibility testing revealed that only *C. parapsilosis* exhibited sensitivity to selected

Amphotericin B, Nystatin , Clotrimazole, and Ketoconazole. This is in contrast to (Corbu *et al.,* 2024) who reported that *C. parapsilosis* was resistant to Clotrimazole. The remaining species, *C. albicans*, *C. krusei*, *C. tropicalis*, and *C. glabrata* demonstrated multi-drug resistance to all antifungal agents tested. This is not in concordance with Deorukhkar (2014) and Ogba (2014) who reported that all their isolates were sensitive to fluconazole. It concurs with (Ogba, 2014) who recorded that *C. glabrata* was resistant to Amphothericin B. The persistence of resistant strains in the environment is consistent with reports identifying environmental reservoirs of antifungal-resistant *Candida* (Piedrahita *et al*., 2017). These results are consistent with the findings of (Kramer, 2024) who reported high resistance rates among environmental *Candida* isolates, particularly *C. albicans*, to commonly used antifungals. Resistance in *C. albicans* is particularly concerning because it limits treatment options if environmental transmission leads to opportunistic infections. The observed susceptibility of *C. parapsilosis* aligns with its known pattern of being less resistant compared to other *Candida* species, particularly in environmental isolates. Tis is concordance with Zhang *et al,* (2023)who reported tha C. parapsolosis was susceptible to the tested antifungal agents. However, resistance in species like *C. glabrata* and *C. krusei* emphasizes the importance of ongoing surveillance of environmental surfaces for antifungal-resistant strains, as they represent potential risks for resistant infections.

The presence of antifungal-resistant *Candida* species on high-touch surfaces, such as door handles in university buildings, raises significant public health concerns. Individuals who frequently contact these surfaces especially students, staff, and visitors may serve as vectors for the spread of these opportunistic pathogens. This is particularly critical for persons with low immunity, who are at higher risk of *Candida* infections (Ibe *et al.*, 2025). Environmental colonization by resistant *Candida* species highlights the need for rigorous hygiene practices, including frequent cleaning and disinfection of door handles and other high-touch surfaces. Silva *et al,* (2024) emphasized that surface-mediated transmission is a key pathway for environmental *Candida* species to reach susceptible hosts. Our findings reinforce this assertion and highlight the potential for door handles, often overlooked in routine sanitation practices, to act as reservoirs for pathogenic fungi.

Unlike previous Nigerian studies that focused on clinical isolates or bacterial contamination of fomites, this study integrates species distribution with three virulence markers and antifungal profiling. Our observation of azole resistance in environmental *Candida albicans* and non-albicans species mirrors recent clinical trends in Africa and suggests community circulation of resistant strains.

4. Conclusion

This study has provided a comprehensive assessment of *Candida* species contamination on door handles within the university buildings, with particular focus on their occurrence, virulence factors and antifungal susceptibility patterns. The findings show that high- touch surfaces, such as door handles in a university campus harbor pathogenic *Candida* species, including *C. albicans*, *C. parapsilosis*, *C. krusei*, *C. glabrata*, and *C. tropicalis*. The study also established that *C. albicans* was the most predominant species across all sampled door handles, followed by *C. parapsilosis* and *C. glabrata*. The occurrence of *C. albicans* compared to non-albicans species suggests not only a higher environmental contamination but also a serious risk of infection. Some of the *Candida* isolates exhibited some virulent potential which may help them ppathogenicity. Antifungal susceptibility testing revealed resistance patterns, particularly among *C. albicans*, *C. glabrata* and *C. tropicalis* which exhibited multidrug-resistance to all the antifungal agents. It was only *C. parapsilosis* that exhibited sensitivity to Amphotericin B, ketoconazole, fluconazole, Nystatin, clotrimazole and resistance to Caspofungin, fluconazole and voriconazole. This differential susceptibility show the need for proper surveillance, monitoring, education of the public on the risk associated with poor hygienic practices observed in environmental settings such as door handles. It also reinforces the global concern regarding rising antifungal resistance, emphasizing that environmental reservoirs may contribute to the persistence and dissemination of resistant strains. Institutions, particularly universities and offices, should practice routine cleaning of high touch surfaces including door handles, with strong disinfectants to prevent transmission of pathogenic fungi like the *Candida* species which are highly resistant to antifungal agents. Also, institutions of higher learning can install doors with sensors to avoid touching of these surfaces which will reduce direct contact and possible contamination.

5. Recommendation

Based on the findings of this study, the following recommendations were made:

- University management should establish and enforce routine cleaning and disinfection of high-touch surfaces, particularly door handles, using appropriate disinfectants with proven antifungal activity. Cleaning schedules should be increased in heavily used buildings and during periods of increased disease risk.
- Students, staff, visitors, cleaners, and other members of the university community should be educated on the importance of proper hand hygiene and environmental cleanliness. Regular handwashing with soap and water or the use of appropriate alcohol-based hand sanitizers should be encouraged, particularly after contact with frequently touched surfaces.
- Periodic microbiological surveillance of high-touch surfaces should be conducted to monitor the presence and distribution of *Candida* species and other potentially pathogenic microorganisms. Particular attention should be given to detecting non-*albicans Candida* species and isolates with reduced susceptibility to commonly used antifungal agents.
- Where *Candida* isolates are recovered, antifungal susceptibility testing should be considered to identify resistant strains and monitor changes in resistance patterns. This information can support appropriate infection-control measures and contribute to the broader surveillance of emerging antifungal resistance.
- Universities should consider installing automatic, sensor-operated, push-button, or other touch-free door-opening systems, particularly at entrances to high-traffic buildings. Such measures could reduce the frequency of hand contact with door handles and consequently reduce opportunities for environmental contamination and transmission.
- Appropriate infection-prevention measures should be emphasized in university clinics, laboratories, hostels, and other areas where individuals who may be immunocompromised could be present. Suspected fungal contamination in such settings should receive prompt attention because opportunistic *Candida* infections can cause serious disease in susceptible individuals.
- Cleaning and environmental-health personnel should receive regular training on appropriate cleaning techniques, disinfectant preparation and application, contact times, personal protective equipment, and the importance of targeting high-touch surfaces such as door handles.
- Further studies should investigate the persistence and survival of *Candida* species on different environmental surfaces, the effectiveness of commonly used disinfectants against resistant isolates, and the potential relationship between environmental contamination and human colonization or infection. Larger studies involving multiple universities and different environmental settings are also recommended to establish the broader epidemiological significance of these findings.

6. Declarations

Data Availability:

The data supporting the findings of this study are not publicly accessible due, but may be made available by the corresponding author upon demand.

Funding:

The study received no external funding and was financed collectively by the authors..

Conflict of Interest:

The authors declare that there are no conflicts of interest associated with this study.

Authors' contributions

Conceptualization and study design: Echeta M.O., Obi-Adumanya G.A., Udochukwu U., and Oyem I.M. Supervision and Study Design: Romanus Onyeukwu R.U., Tony-Nze C.P., Ezekwueche S.N., and Itubochi C.A. Methodology and Data Collection: Nwokoro A.B., Korie M.C., Nzeagwu M.O., and Onuoha N.C., Data Analysis: Nsoha J.C., Echeta M.O., Udochukwu U., and Korie M.C. Writing – Original Draft: Obi-Adumanya G.A., Oyem I.M., Romanus Onyeukwu R.U., and Nzeagwu M.O. Writing, Review and Editing: Tony-Nze C.P., Ezekwueche S.N., Itubochi C.A., Nwokoro A.B., and Onuoha N.C., Final Review and Approval: All authors reviewed, revised, and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Acknowledgements
The authors sincerely appreciate the undergraduate students of the University of Agriculture and Environmental Sciences, Umuagwo, Imo State, Nigeria, who helped in collecting the samples.

References

Akinjogunla, O. J., Divine-Anthony, O., Akpan, M. M., & Ogbonna, F. C. (2019). Virulence markers and antifungal susceptibility of vaginal yeast isolates from contraceptive and non-contraceptive users in Uyo, Nigeria. Journal of ExperimentalResearch, 7(1),33-40.

Appiah, P. O., Odoom, A., Tetteh-Quarcoo, P. B., Kotey, F. C. N., & Donkor, E. S. (2025). Microbial contamination of door handles: A global systematic review and meta-analysis of public and healthcare settings. *Environmental Heath Insights*,19, 11786302251328550. https://doi.org/10.1177/11786302251328550

Centers for Disease Control and Prevention. (2024). Data and statistics on candidemia*. https://www.cdc.gov/candidiasis/data-research/facts-stats/

Clinical and Laboratory Standards Institute. (2020). Performance standards for antifungal susceptibility testing of yeasts (2nd ed., CLSI supplement M60-Ed2). *Clinical and Laboratory Standards Institute.*

Corbu, V. M., Georgescu, A.-M., Marinas, I. C., Pericleanu, R., Mogos, D. V., Dumbravă, A. Ș., Marinescu, L., Pecete, I., Vassu-Dimov, T., Czobor Barbu, I., Csutak, O., Ficai, D., & Gheorghe-Barbu, I. (2024). Phenotypic and genotypic characterization of resistance and virulence markers in *Candida* spp. isolated from community-acquired infections in Bucharest, and the impact of AgNPs on the highly resistant isolates. *Journal of Fungi*, 10(8), 563. https://doi.org/10.3390/jof10080563

Deorukhkar, S. C., Saini, S., & Mathew, S. (2014). Virulence factors contributing to pathogenicity of *Candida tropicalis* and its antifungal susceptibility profile. *International Journal of Microbiology*, 456878. https://doi.org/10.1155/2014/456878

Dire, O., Ahmad, A., Duze, S. T., & Patel, M. (2023). Survival of *Candida auris* on environmental surface materials and low-level resistance to disinfectant. *Journal of Hospital Infection*, 137, 17–23. https://doi.org/10.1016/j.jhin.2023.04.007

Ferreira, P. A. A., Roso, L. D. C., Freitas, D. A., Bressani, A. P. P., Ferreira, P. H. C., Bodevan, E. C., Moura, C. L., Magalhães-Guedes, K. T., & Ramos, C. L. (2026). Species identification, virulence factors, and antifungal resistance in clinical *Candida* isolates from ICU patients. Microorganisms, 14(1), 241. https://doi.org/10.3390/microorganisms14010241

Fróis-Martins, R., Lagler, J., & LeibundGut-Landmann, S. (2024). *Candida albicans* virulence traits in commensalism and disease. *Current Clinical Microbiology Reports*, 11, 231–240. https://doi.org/10.1007/s40588-024-00235-8

Ghosh, A. K., & Chatterjee, S. (2022). Assessing pH-dependent activities of virulence factors secreted by *Candida albicans*. Frontiers in Cellular and Infection Microbiology, 12, 1008685. https://doi.org/10.3389/fcimb.2022.1008685

Ibe, C., Otuc, A., & Pohl, C. H. (2025). Mechanisms of resistance to cell wall and plasma membrane targeting antifungal drugs in *Candida species* isolated in Africa. *Expert Review of Anti-infective Therapy*, 23(1), 91–104. https://doi.org/10.1080/14787210.2024.2448844

Katsipoulaki, M., Stappers, M. H. T., Malavia-Jones, D., Brunke, S., Hube, B., & Gow, N. A. R. (2024). *Candida albicans* and Candida glabrata. Global priority pathogens. *Microbiology and Molecular Biology Reviews,* 88(2), e00021-23. https://doi.org/10.1128/mmbr.00021-23

Kramer, A., Lexow, F., Bludau, A., Köster, A. M., Misailovski, M., Seifert, U., Eggers, M., Rutala, W., Dancer, S. J., & Scheithauer, S. (2024). How long do bacteria, fungi, protozoa, and viruses retain their replication capacity on inanimate surfaces? A systematic review examining environmental resilience versus healthcare-associated infection risk by “fomite-borne risk assessment.” *Clinical Microbiology Reviews,* 37(4), e00186-23. https://doi.org/10.1128/cmr.00186-23

Makled, A. F., Ali, S. A. M., Labeeb, A. Z., Salman, S. S., Shebl, D. Z. M., Hegazy, S. G., & Sabal, M. S. (2024). Characterization of *Candida* species isolated from clinical specimens: Insights into virulence traits, antifungal resistance and molecular profiles. *BMC Microbiology*, 24, 388. https://doi.org/10.1186/s12866-024-03515-x

Nwinyi, O. C., & Boluwatife, A. (2024). Antibiogram of fungal and bacterial isolates associated with toilet

door handles in the students' residential hall at a Nigerian university. *Covenant Journal of Health and Life Sciences*, 2(1), 12.

Ogba, O. M., Chidinma, B.-O. D., Inah, I. O., Ogba, R. O., Akpan, N. G., Nyambi, E. S., & Ifu, U. L. (2024). Catheter associated candiduria among in-patients accessing care in a tertiary health institution in Calabar, Nigeria. *Sokoto Journal of Medical Laboratory Science,* 9(3), 227–236. https://doi.org/10.4314/sokjmls.v9i3.24

Piedrahita, C. T., Cadnum, J. L., Jencson, A. L., Shaikh, A. A., Ghannoum, M. A., & Donskey, C. J. (2017). Environmental surfaces in healthcare facilities are a potential source for transmission of *Candida auris* and other *Candida* species. *Infection Control & Hospital Epidemiology*, 38(9), 1107–1109. https://doi.org/10.1017/ice.2017.127

Saha, S. (2018). Species distribution, virulence factors and antifungal susceptibility profile of *Candida* isolates from various clinical samples*. Indian Journal of Basic and Applied Medical Research*, 7(3), 206–212.

Short, B., Brown, J., Delaney, C., Sherry, L., Williams, C., Ramage, G., & Kean, R. (2019). *Candida auris* exhibits resilient biofilm characteristics in vitro: Implications for environmental persistence. Journal of Hospital Infection, 103(1), 92–96. https://doi.org/10.1016/j.jhin.2019.06.006

Singh, A., Verma, R., Murari, A., and Agrawal, A. (2020). Oral candidiasis: An overview. *Journal of Oral and Maxillofacial Pathology,* 24(1), 178–183. https://doi.org/10.4103/jomfp.JOMFP_152_19

Silva, I., Miranda, I. M., & Costa-de-Oliveira, S. (2024). Potential environmental reservoirs of *Candida auris*: A systematic review. *Journal of Fungi,* 10(5), 336. https://doi.org/10.3390/jof10050336

Sule, H., & Abdulkadir, A. I. (2025). Isolation and identification of fungi and bacteria associated with contamination of tap and door handles in Faculty of Allied Health Sciences, Bayero University, Kano-Nigeria. Arid Zone *Journal of Basic and Applied Research*, 4(5), 9–14. https://doi.org/10.55639/607.02010064

Sun, A.-M., Wang, Y.-X., Hu, G.-X., Li, L., & Wang, R.-R. (2023). Polyphyllin I effects *Candida albicans* via inhibition of virulence factors. Evidence-Based Complementary and Alternative Medicine, 5645500. https://doi.org/10.1155/2023/5645500

Talapko, J., Juzbašić, M., Matijević, T., Pustijanac, E., Bekić, S., Kotris, I., & Škrlec, I. (2021). *Candida albicans*: The virulence factors and clinical manifestations of infection. *Journal of Fungi*, 7(2), 79. https://doi.org/10.3390/jof7020079

World Health Organization. (2022). WHO fungal priority pathogens list to guide research, development and public health action. World Health Organization.https://www.who.int/publications/i/item/9789240060241

Zhang, W, Zhan, M., Wang, N., Fan J., Han, X., Li, C., Liu, J., Hou, Y., Wang, X., & Zhang, Z., (2023). In vitro susceptibility profiles of Candida parapsilosis species complex subtypes from deep infections to nine antifungal drugs. Journal of Medical Microbiology, 72(3),001640. https://doi.org/10.099/jmm. 001640