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Assessment of *Aspergillus* species isolated from different soil samples in Jos Metropolis for protease, amylase, lipase and cellulase enzymes production potential

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ABSTRACT

Aspergillus is a genus of filamentous and cosmopolitan fungi that includes important species used in the pharmaceutical and fermentation industries, medical mycology, food production, basic research, and agro-industry. Soil represents an important reservoir of these filamentous fungi, with considerable potential for the production of industrially relevant extracellular enzymes. This study assessed *Aspergillus* species isolated from different soil environments in Jos Metropolis, Plateau State, Nigeria, for their potential to produce protease, amylase, lipase, and cellulase. Soil samples were collected in triplicate from ten distinct environments, including cultivated, garden, abattoir, industrial, mechanic workshop, and oil-contaminated soils. Fungal isolates were recovered using the serial dilution plate technique on chloramphenicol-supplemented Potato Dextrose Agar, purified, and identified based on their macroscopic and microscopic characteristics. Enzyme production was screened using substrate-specific agar media, and enzyme activity was evaluated by measuring the zones of hydrolysis. Thirty-six *Aspergillus* isolates were recovered, with *A. niger* being the most predominant species (41.7%), followed by *A. fumigatus* (36.1%), *A. flavus* (19.4%), and *A. nidulans* (2.8%). Amylase activity was highest in *A. niger* isolate HG (45.50 ± 2.43 mm), while cellulase activity was highest in *A. flavus* isolate AE (70.00 ± 1.96 mm). Lipase activity was comparatively low, with the highest activity recorded in *A. niger* isolate ND (4.50 ± 0.37 mm). Lipase activity was not detected in several isolates, and no protease activity was detected in any of the cultures. The results demonstrate considerable isolate-dependent variation in extracellular enzyme production, with cellulolytic activity generally exceeding amylolytic and lipolytic activity. The study concludes that indigenous *Aspergillus* species from Jos Metropolis, particularly selected *A. niger* and *A. flavus* isolates, have potential for industrial enzyme production.

Keywords: *Aspergillus*, soil fungi, extracellular enzymes, amylase, cellulase, lipase, enzyme production, Jos Metropolis.

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INTRODUCTION

Soil is a complex and highly diverse ecosystem that harbours a wide range of microorganisms with considerable ecological and biotechnological importance. Among these microorganisms, filamentous fungi of the genus *Aspergillus* are particularly important because of their ability to secrete large quantities of extracellular hydrolytic enzymes (de Souza et al, 2015). These enzymes enable fungi to degrade complex organic substrates present in soil and make *Aspergillus* species valuable organisms in industrial biotechnology. Enzymes such as proteases, amylases, lipases, and cellulases have extensive applications in the food, pharmaceutical, detergent, textile, leather, paper, agricultural, and biofuel industries. The production of these enzymes is influenced by fungal species, strain characteristics, substrate availability, and environmental conditions. Consequently,

the isolation and screening of indigenous *Aspergillus* species from different soil environments provide an important approach for identifying fungal strains with useful enzyme-producing capabilities (Khokhar et al., 2011; El-Gendy et al., 2021).

Proteases, amylases, lipases, and cellulases are among the most important industrially relevant enzymes produced by fungi. Proteases hydrolyse proteins into peptides and amino acids and are widely used in detergent production, food processing, leather production, and the pharmaceutical industry (Naveed et al., 2021; Ashraf et al., 2023). Amylases degrade starch into simpler sugars and are important in baking, brewing, starch processing, and bioethanol production. Lipases catalyse the hydrolysis of triglycerides and have applications in food processing, detergent formulation, biodiesel production, and the pharmaceutical industry, whereas cellulases hydrolyse cellulose and contribute significantly to the conversion of lignocellulosic biomass into fermentable sugars (Ramesh et al., 2020). *Aspergillus* species are recognized as efficient producers of several of these enzymes because of their extensive hyphal growth, capacity for extracellular enzyme secretion, and adaptability to diverse substrates. Studies have demonstrated that *Aspergillus* isolates can exhibit multiple hydrolytic activities, although the level of enzyme production may vary considerably among species and individual strains. This strain-dependent variation makes systematic screening essential for selecting isolates with superior enzyme-producing potential (Morilla et al., 2023).

The soil environment represents an important reservoir for the discovery of novel enzyme-producing fungi because it contains diverse organic materials that exert selective pressure on microorganisms to produce enzymes capable of degrading complex substrates. Differences in soil origin, vegetation, organic matter content, pH, moisture, and human activities may therefore influence the distribution and enzymatic characteristics of *Aspergillus* species (Riedling et al., 2025). Research on soil-derived *Aspergillus* has shown that isolates may exhibit substantial differences in their ability to produce amylase, cellulase, protease, and lipase. For example, studies have reported the isolation of multiple *Aspergillus* species from soil and demonstrated their capacity to produce extracellular hydrolytic enzymes, with enzyme activity varying according to the isolate and substrate used for screening (Khokhar et al., 2011; Mustafa et al., 2022). Similarly, investigations of *Aspergillus* section *Nigri* isolated from soil and plant litter have demonstrated considerable potential for amylase, protease, and cellulase production, emphasizing the importance of environmental sampling in the search for industrially useful fungal strains (Mustafa et al., 2022).

Jos Metropolis contains a variety of soil environments influenced by residential development, agricultural activities, vegetation, waste disposal, and other anthropogenic factors (Wuave, 2023). These different environments may support distinct fungal communities and potentially select for *Aspergillus* species with different enzymatic capabilities. However, the enzyme-producing potential of *Aspergillus* species isolated from different soil samples within Jos Metropolis remains insufficiently characterized. Therefore, assessing *Aspergillus* species isolated from different soil environments for protease, amylase, lipase, and cellulase production is scientifically important because it may reveal indigenous fungal isolates with valuable biotechnological properties. Comparative evaluation of these isolates will provide information on their species distribution and enzyme-producing profiles while also identifying promising strains for further optimization, characterization, and possible industrial applications (Al Sharif et al., 2025; Kumari et al., 2026). This study was therefore designed to assess *Aspergillus* species isolated from different soil samples in Jos Metropolis for their potential to produce protease, amylase, lipase, and cellulase enzymes.

METHODOLOGY

Study area and soil sample collection

Soil samples were collected from ten different sampling locations within Jos Metropolis, Plateau State, Nigeria. The selected sites represented different anthropogenic environments, including gardens, automobile mechanic workshops, industrial areas, abattoirs, and palm oil-selling areas, to capture the diversity of *Aspergillus* species associated with different soil ecosystems. At each sampling location, three independent soil samples (triplicates) were collected, giving a total of 30 soil samples. Prior to sampling, surface debris, stones, leaves, and other extraneous materials were carefully removed from the soil surface. Using sterile disposable gloves and sterile sampling tools, soil was aseptically collected from a depth of approximately 3 cm, where fungal propagules are more abundant and less susceptible to transient environmental contamination. Approximately 100 g of soil was transferred into sterile polyethylene bags, appropriately labelled according to the sampling site, and transported immediately to the Microbiology Laboratory for mycological analysis. All samples were processed within 24 h of collection to minimize changes in the indigenous fungal population.

Isolation of *Aspergillus* species

Isolation of fungal species was performed using the serial dilution plate technique as described by Raja et al. (2017), with slight modifications. Briefly, 1.0 g of each soil sample was aseptically transferred into a sterile test tube containing 9.0 mL of sterile distilled water to obtain a 10^{-1}

dilution. The suspension was vigorously vortexed for 2–3 min to ensure uniform dispersion of fungal spores and mycelial fragments. Ten-fold serial dilutions were subsequently prepared up to 10^{-3}. Thereafter, 0.5 mL aliquots from the appropriate dilution were aseptically inoculated onto sterile Potato Dextrose Agar (PDA) plates using the pour-plate technique. The inoculum was evenly distributed by gently swirling the Petri dishes before the medium solidified. To minimize bacterial contamination, the PDA medium was supplemented with chloramphenicol (50 mg/L) before inoculation. The inoculated plates were incubated aerobically at 30 ± 2°C for 5 days, after which emerging fungal colonies exhibiting morphological characteristics typical of *Aspergillus* species were selected for further purification and identification.

Purification of fungal isolates

Distinct fungal colonies presumptively identified as *Aspergillus* were purified by repeated subculturing onto freshly prepared Potato Dextrose Agar (PDA) plates using the hyphal-tip technique. Individual colonies were aseptically transferred onto fresh media and incubated at 30 ± 2°C for 3–5 days. Successive subculturing was carried out until morphologically uniform colonies free from contamination were obtained. Pure cultures were subsequently maintained on PDA slants at 4°C for further morphological characterization and identification.

Identification of *Aspergillus* species

Identification of the purified fungal isolates was based on standard macroscopic and microscopic characteristics following the taxonomic keys of Raja et al. (2017), Samson et al. (2014), and de Vries and Visser (2001). Macroscopic examination included assessment of colony characteristics such as colony diameter, texture, pigmentation, topography, margin characteristics, and pigmentation of the reverse surface after incubation on Potato Dextrose Agar. Microscopic characterization was performed using the lactophenol cotton blue staining technique. A small portion of the fungal mycelium was mounted on a clean glass slide containing a drop of lactophenol cotton blue stain, covered with a coverslip, and examined under a compound light microscope using a ×100 objective lens.

Screening of *Aspergillus* isolates for extracellular enzyme production

Amylase production

Amylase production was screened using a starch-supplemented agar medium, based on the principle that amylolytic fungi hydrolyse starch into smaller soluble products that do not form the characteristic blue-black complex with iodine. The medium consisted of KH_2PO_4 (7.0 g L^{-1}), K_2HPO_4 (2.0 g L^{-1}), $MgSO_4 \cdot 7H_2O$ (0.1 g L^{-1}), $(NH_4)_2SO_4$ (1.0 g L^{-1}), yeast extract (0.6 g L^{-1}), soluble starch (10.0 g L^{-1}), and agar (10.0 g L^{-1}). The medium was sterilized, poured into sterile Petri dishes, and allowed to solidify. Each plate was inoculated with a standardized inoculum of the test *Aspergillus* isolate and incubated for 2–5 days. Following incubation, the plates were flooded with iodine solution and subsequently rinsed with sterile distilled water. Amylase production was indicated by the formation of a clear halo surrounding the fungal colony against the dark blue or blue-black background resulting from the starch–iodine reaction. The diameter of the hydrolysis zone was measured as an indication of amylolytic activity (de Souza et al., 2015; Khokhar et al., 2011).

Cellulase production

Cellulase production was evaluated using an agar medium supplemented with carboxymethyl cellulose (CMC) as the cellulose substrate. The medium contained KH_2PO_4 (7.0 g L^{-1}), K_2HPO_4 (2.0 g L^{-1}), $MgSO_4 \cdot 7H_2O$ (0.1 g L^{-1}), $(NH_4)_2SO_4$ (1.0 g L^{-1}), yeast extract (0.6 g L^{-1}), carboxymethyl cellulose (10.0 g L^{-1}; 1% w/v), and agar (15.0 g L^{-1}). After sterilization and solidification, the medium was inoculated with the test *Aspergillus* isolates and incubated for 2–5 days. Following incubation, the plates were flooded with Congo red solution to stain the undegraded cellulose substrate, after which excess stain was removed by rinsing the plates with distilled water. Cellulase production was indicated by the formation of a distinct clear hydrolysis zone surrounding the fungal colony. The diameter of the clear zone was recorded as an indicator of cellulolytic activity (Khokhar et al., 2011; Raja et al., 2017).

Protease Production

Protease production was screened using skimmed milk agar medium, in which casein serves as the principal protein substrate for detecting extracellular proteolytic activity. The medium was prepared by incorporating skimmed milk as the protein substrate into an agar-based medium containing 2% agar. The prepared medium was sterilized appropriately, poured into sterile Petri dishes, and allowed to solidify before inoculation. The plates were inoculated with the test *Aspergillus* isolates and incubated for 2–5 days. Proteolytic activity was detected by hydrolysis of the casein present in the skimmed milk, resulting in the formation of a transparent or clear zone surrounding the fungal colony. The diameter of the clear

zone was measured as an indication of extracellular protease production (de Souza et al., 2015; Ashraf et al., 2023).

Lipase Production

Lipase production was evaluated using a medium supplemented with groundnut oil as the lipid substrate. The test *Aspergillus* isolates were inoculated onto the prepared medium and incubated for 2–5 days under suitable growth conditions. Following incubation, lipase activity was detected using Sudan III as an indicator dye. The formation of a visible hydrolysis zone or alteration in the staining pattern surrounding the fungal colony was considered evidence of extracellular lipase activity. The diameter of the zone of activity was measured to provide a qualitative assessment of the lipolytic potential of the isolates (de Souza et al., 2015; Ashraf et al., 2023).

RESULTS AND DISCUSSION

The findings of this study revealed that soils from different environmental settings within Jos Metropolis harboured diverse *Aspergillus* species, with *Aspergillus niger* being the predominant isolate, accounting for 15 (41.7%) of the total isolates, followed by *Aspergillus fumigatus* (13; 36.1%), *Aspergillus flavus* (7; 19.4%), and *Aspergillus nidulans* (1; 2.8%) (Figure 1). The predominance of *A. niger* corroborates previous studies that identified this species as one of the most ubiquitous saprophytic fungi in soil, owing to its exceptional ecological adaptability, efficient spore production, and ability to utilize a wide range of organic substrates (Samson et al., 2014; Klich, 2002). The high frequency of *A. niger* in cultivated soils, abattoir soils, and industrial effluent sites suggests that environments enriched with decomposing organic matter and anthropogenic wastes provide favourable conditions for its proliferation (Table 1). Similarly, the widespread occurrence of *A. fumigatus*, particularly in industrial effluent and organically contaminated soils, may be attributed to its thermotolerant nature and ability to colonize composting organic materials, animal wastes, and decaying vegetation (Latgé and Chamilos, 2019).

The relatively lower occurrence of *A. flavus* agrees with reports by Pitt and Hocking (2009), who noted that although *A. flavus* is a common soil inhabitant, its distribution is often influenced by climatic conditions, soil moisture, nutrient availability, and competition with other fungal species. The isolation of *A. nidulans* from only one garden soil sample indicates its comparatively low prevalence in the study area, possibly reflecting its narrower ecological niche compared with the more dominant *Aspergillus* species. Furthermore, the highest numbers of fungal isolates recovered from cultivated soils and industrial effluent sites (19.4% each) emphasize the influence of organic enrichment and human activities on soil fungal diversity. In contrast, the comparatively lower recovery from mechanic workshop and oil-contaminated soils may be associated with the toxic effects of petroleum hydrocarbons and heavy metals, which can suppress the growth of susceptible fungal species while selecting for more tolerant microorganisms (Atlas and Bartha, 1998).

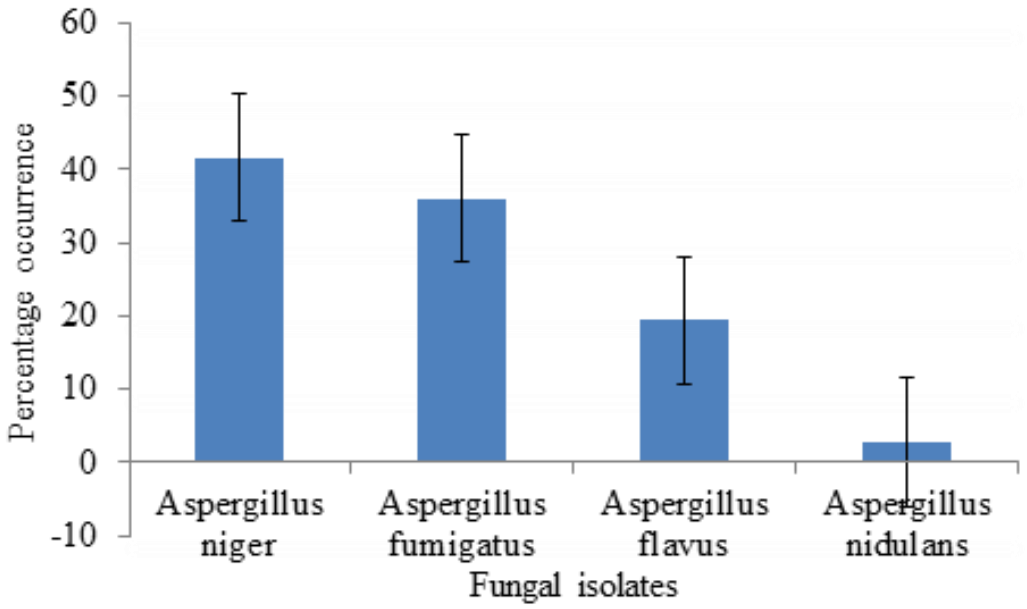


Figure 1. Overall frequency of *Aspergillus* species isolated from soil samples.

Table 1. Distributions and percentage occurrence of *Aspergillus* species isolated from different soil environments in Jos Metropolis.

Sampling site	No. of Samples	*A. niger* n (%)	*A. fumigatus* n (%)	*A. flavus* n (%)	*A. nidulans* n (%)	Total Isolates (%)
Abattoir soil (AE)	3	3 (100)	2 (66.7)	1 (33.3)	0	6 (16.7)
Cultivated soil (HG)	3	3 (100)	2 (66.7)	2 (66.7)	0	7 (19.4)
Garden soil (MG)	3	1 (33.3)	1 (33.3)	0	1 (33.3)	3 (8.3)
Industrial waste (IA)	3	2 (66.7)	2 (66.7)	1 (33.3)	0	5 (13.9)
Industrial effluent (ND)	3	3 (100)	3 (100)	1 (33.3)	0	7 (19.4)
Mechanic workshop 1 (KM1)	3	0	1 (33.3)	1 (33.3)	0	2 (5.6)
Mechanic workshop 2 (KM2)	3	2 (66.7)	0	1 (33.3)	0	3 (8.3)
Mechanic workshop 3 (KM3)	3	0	1 (33.3)	0	0	1 (2.8)
Vegetable oil soil (KO)	3	1 (33.3)	0	0	0	1 (2.8)
Terminus oil soil (TO)	3	0	1 (33.3)	0	0	1 (2.8)
Total	30	15 (41.7)	13 (36.1)	7 (19.4)	1 (2.8)	36 (100)

The cultural and microscopic characteristics observed in Table 2 confirmed the identification of the isolated *Aspergillus* species based on their distinct morphological features. *Aspergillus niger* was characterized by rapid growth, white colonies that developed into black, dense powdery conidial heads, with septate hyphae and globose vesicles bearing radiating chains of conidia. *A. fumigatus* exhibited blue-green, suede-like colonies with short conidiophores, conical terminal vesicles and globose to subglobose conidia, while *A. flavus* produced yellow-green to olive colonies with granular texture and rough conidiophores terminating in globose vesicles. These cultural and microscopic features are consistent with the characteristic morphological descriptions commonly used for the identification of *Aspergillus* species, demonstrating that colony colour, texture, conidiophore structure, vesicle shape and arrangement of conidia are useful diagnostic characteristics for differentiating the isolates.

The present study demonstrated substantial variation in the amylase-producing potential of *Aspergillus* species isolated from different soil environments in Jos Metropolis. The highest amylolytic activity was recorded for *A. niger* isolate HG, which produced a hydrolysis zone of 45.50 ± 2.43 mm, followed by *A. nidulans* isolate MG (41.50 ± 1.37 mm) and *A. niger* isolate ND (34.40 ± 0.95 mm). In contrast, *A. flavus* isolate AE exhibited relatively low amylolytic activity (5.50 ± 0.59 mm), while *A. niger* isolates KG, IA, and KO produced smaller hydrolysis zones of 2.50 ± 0.28, 2.50 ± 0.19, and 4.25 ± 0.82 mm, respectively. No detectable amylase activity was observed in *A. fumigatus* isolate TO (Table 3). The pronounced differences observed among isolates, including isolates belonging to the same species, indicate that amylase production was strongly strain-dependent. This observation is consistent with the findings of Khokhar et al. (2011), who reported variation in the amylase-producing abilities of *Aspergillus* and *Penicillium* isolates screened on starch-containing media. Similarly, *A. niger* isolates have been reported to produce extracellular amylase, although the magnitude of production varies among individual strains and is influenced by culture conditions and substrate composition (Abdel-Rahman et al., 2021). The high amylolytic activity recorded by the HG isolate therefore suggests that this indigenous *A. niger* strain may possess considerable potential for further amylase production and optimization. The use of a clear zone of starch hydrolysis as an indicator of amylase production is also consistent with previous studies that have employed starch agar and iodine-based visualization for the preliminary screening of amylase-producing fungi (Khokhar et al., 2011; Grillo et al., 2025).

Cellulase activity was generally more pronounced than amylase activity among the *Aspergillus* isolates examined. The highest cellulolytic activity was recorded for *A. flavus* isolate AE (70.00 ± 1.96 mm), followed by *A. niger* isolate ND (68.50 ± 2.41 mm) and *A. nidulans* isolate MG (67.50 ± 2.75 mm). Other *A. niger* isolates, including HG, KG, IAa, and IAb, also demonstrated substantial cellulolytic activity, producing hydrolysis zones ranging from 56.50 ± 1.18 to 61.00 ± 1.83 mm. However, markedly lower activities were observed in *A. niger* isolate KO (4.25 ± 0.88 mm) and *A. fumigatus* isolate TO (7.85 ± 1.35 mm) (Table 4). The considerable variation among isolates may be associated with differences in strain-specific genetic capacity for cellulase synthesis, enzyme secretion, and adaptation to the environmental conditions of the soils from which the isolates were obtained. The present findings are consistent with Khokhar et al. (2011), who demonstrated cellulase production among filamentous fungal isolates, although the magnitude of activity varied considerably among isolates. Similarly, Ahmad et al. (2021) reported cellulase production by several soil-derived fungal isolates, including *A. flavus*, *A. niger*, and *A. fumigatus*, using carboxymethyl cellulose agar and zone-of-hydrolysis assays. The strong cellulolytic activity observed in the present study, particularly among isolates AE, ND, and MG, further supports the importance of soil-derived *Aspergillus* species as potential sources of cellulases. This is of considerable biotechnological

Table 2. Cultural and microscopic features of *Aspergillus* species isolated from soil samples in Jos Metropolis (on PDA).

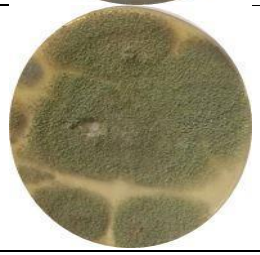
Isolates	Cultural characteristics	Morphology	Macroscopic	Microscopy ×100	Organism
1	Colonies showed rapid growth, initially white becoming black with dense powdery conidial heads; texture granular; reverse pale yellow	Septate hyphae; erect conidiophores with globose vesicles bearing radiating chains of conidia			*Aspergillus niger*
2	On PDA, colonies showed typical bluegreen surface pigmentation with a suede-like surface consisting of a dense felt of conidiophores. Texture was powdery and the colour on the reverse side was yellow	Septate hyphae with thin-walled Conidiophore stipes are short, smoothwalled and had conical-shaped terminal vesicles. Conidia were produced in basipetal succession forming long chains and are globose to subglobose			*Aspergillus Fumigatus*
3	Colonies showed rapid growth, yellow-green to olive with granular texture; reverse gold to reddish	Septate hyphae; rough conidiophores terminating in globose vesicles with chains of conidia			*Aspergillus flavus*

Table 3. Amylase activity of *Aspergillus* species isolated from different soil environments in Jos Metropolis.

Sampling location	Identified species	Zone of hydrolysis (mm)
MG	*Aspergillus nidulans*	41.50 ± 1.37
HG	*Aspergillus niger*	45.50 ± 2.43
ND	*Aspergillus niger*	34.40 ± 0.95
AE	*Aspergillus flavus*	5.50 ± 0.59
KG	*Aspergillus niger*	2.50 ± 0.28
IA	*Aspergillus niger*	2.50 ± 0.19
TO	*Aspergillus fumigatus*	ND
KO	*Aspergillus niger*	4.25 ± 0.82

Values are presented as mean ± standard error of the mean (SEM) based on replicate measurements. ND = not detected.

Table 4. Cellulase activity of *Aspergillus* species isolated from different soil environments in Jos Metropolis.

Sampling location	Identified species	Zone of hydrolysis (mm)
MG	*Aspergillus nidulans*	67.50 ± 2.75
HG	*Aspergillus niger*	61.00 ± 1.83
ND	*Aspergillus niger*	68.50 ± 2.41
AE	*Aspergillus flavus*	70.00 ± 1.96
KG	*Aspergillus niger*	56.50 ± 1.18
IAa	*Aspergillus niger*	58.50 ± 1.32
IAb	*Aspergillus niger*	57.00 ± 1.83
KO	*Aspergillus niger*	4.25 ± 0.88
TO	*Aspergillus fumigatus*	7.85 ± 1.35

Values are presented as mean ± standard error of the mean (SEM) based on replicate measurements.

significance because cellulases are important in the hydrolysis of lignocellulosic biomass and have applications in food, feed, biofuel, and other industrial processes (Ma et al., 2024).

In contrast to the relatively high amylolytic and cellulolytic activities, lipase production was comparatively limited among the isolates tested. The highest lipolytic activity was recorded in *A. niger* isolate ND (4.50 ± 0.37 mm), followed by *A. nidulans* isolate MG (3.00 ± 0.74 mm), while *A. niger* isolate HG and *A. flavus* isolate AE each produced hydrolysis zones of 2.00 ± 0.18 and 2.00 ± 0.42 mm, respectively (Table 5). Lipase activity was not detected in isolates KG, IA, KO, and TO. The low level of lipase activity and the absence of detectable activity in several isolates indicate considerable variation in the expression of extracellular lipolytic enzymes under the conditions employed in this study. Similar strain-dependent variation in lipase production has been reported among soil-derived fungi, including *A. niger* and *A. flavus*, with differences in hydrolysis zones observed among fungal species and isolates (Makut and Bemgba, 2017). The comparatively low lipase activity observed in the present study may also reflect the influence of the lipid substrate, indicator system, incubation conditions, and other nutritional factors on enzyme expression, since fungal lipase production is known to be affected by culture conditions and medium composition (Abdel-Rahman et al., 2021). Nevertheless, the relatively higher activity of *A. niger* isolate ND suggests that it may serve as a promising candidate for subsequent optimization of lipase production. No protease activity was detected (Table 6).

Table 5. Lipase activity of *Aspergillus* species isolated from different soil environments in Jos Metropolis.

Sampling location	Identified species	Zone of hydrolysis (mm)
MG	*Aspergillus nidulans*	3.00 ± 0.74
HG	*Aspergillus niger*	2.00 ± 0.18
ND	*Aspergillus niger*	4.50 ± 0.37
AE	*Aspergillus flavus*	2.00 ± 0.42
KG	*Aspergillus niger*	ND
IA	*Aspergillus niger*	ND
KO	*Aspergillus niger*	ND
TO	*Aspergillus fumigatus*	ND

Values are presented as mean ± standard error of the mean (SEM) based on replicate measurements. ND = not detected.

Overall, the results demonstrate that the *Aspergillus* isolates recovered from the different soil environments in Jos Metropolis exhibited distinct extracellular enzyme profiles, with cellulase production generally being the most pronounced, followed by amylase, whereas lipase production was comparatively weak and restricted to fewer isolates. The observed variation highlights the importance of screening multiple indigenous isolates when selecting fungal strains for potential industrial enzyme production (Khokhar et al., 2011, Abdel-Rahman et al., 2021).

CONCLUSION

The study demonstrated that soils from different

Table 6. Protease activity of *Aspergillus* species isolated from different soil environments in Jos Metropolis.

Sampling location	Identified species	Zone of hydrolysis (mm)
MG	*Aspergillus nidulans*	ND
HG	*Aspergillus niger*	ND
ND	*Aspergillus niger*	ND
AE	*Aspergillus flavus*	ND
KG	*Aspergillus niger*	ND
IA	*Aspergillus niger*	ND
KO	*Aspergillus niger*	ND
TO	*Aspergillus fumigatus*	ND

ND = not detected.

environments within Jos Metropolis harbour diverse *Aspergillus* species with considerable extracellular enzyme-producing potential. *A. niger* was the predominant species, while the isolates exhibited marked variation in enzyme production. Cellulase activity was generally the highest, followed by amylase, whereas lipase activity was comparatively low, and no protease activity was detected under the conditions employed. These findings indicate that indigenous *Aspergillus* isolates, particularly selected strains of *A. niger* and *A. flavus*, show potential for industrial enzyme production.

RECOMMENDATION

Further studies should focus on optimizing culture conditions, including pH, temperature, incubation period, substrate concentration, and nutrient composition, to enhance enzyme production by the most promising isolates. Quantitative enzyme assays, molecular identification of the isolates, enzyme purification, and biochemical characterization should also be conducted to confirm their industrial potential and determine their suitability for applications in food processing, biotechnology, biofuel production, and other relevant industries.

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