

## International Journal of Multidisciplinary Research in Biotechnology, Pharmacy, Dental and Medical Sciences (IJMRBPDMS)

# Biodegradation Potential of Indigenous Fungal Isolates on Potato (*Solanum tuberosum* L.) Waste: A Case Study of Dumpsites in Bwari, Abuja.

Anslem S. Maichiki<sup>1</sup>, Anthonia Oyegue O.<sup>1</sup>, Izevbigie R. Adesuwa<sup>1</sup>

<sup>1</sup>Department of Microbiology, Veritas University, Abuja, Nigeria

Corresponding Author: Anslem A. Maichiki, Department of Microbiology, Veritas University, Abuja, Nigeria

Email: anslemmaichiki@gmail.com

### ABSTRACT

#### Introduction:

Wastes are unwanted by-products from daily activities like consumption and production, which are no longer useful. Improper disposal, especially open dumping, poses immediate health risks and long-term environmental threats, including greenhouse gas emissions. The accumulation of organic waste like potato peels in dumpsites leads to foul odors and the spread of pathogens. This study aimed to screen the biodegradation potential of fungal species isolated from dumpsites at Bwari, Abuja, Nigeria, for the management of potato waste.

#### Methods

A total of six soil samples were collected from three major dumpsites within the Bwari Area Council, FCT, Abuja. Standard microbiological techniques, including serial dilution and plating on Potato Dextrose Agar (PDA), were used to isolate and enumerate fungi. Isolates were characterized and identified based on macroscopic and microscopic morphological features. The biodegradation potential of the identified fungal isolates was assessed using a 7-day weight loss experiment in a minimal salt broth medium, and the percentage weight loss was calculated.

#### Results

The physicochemical analysis of the soil revealed a temperature range of 28–31°C and pH values ranging from 7.19 to 9.12. The heterotrophic fungal count ranged from  $5 \times 10^{-4}$  to  $12 \times 10^{-4}$  CFU/g. Morphological characterization led to the identification of three dominant genera: *Aspergillus flavus* (40.00% prevalence), *Aspergillus niger* (33.33%), and *Penicillium* sp. (26.67%). The single isolate with the highest degradation efficiency was *A. niger* (82.0% weight loss), followed by *A. flavus* (75.0%) and *Penicillium* sp. (70.0%). Notably, the consortium of *A. flavus* and *A. niger* achieved the highest overall degradation of 90.0%, demonstrating a synergistic effect. A drop in pH (from alkaline to near-neutral/acidic) was observed in all treatment setups, indicating microbial metabolic activity.

#### Conclusion

This study demonstrates that indigenous fungal species, particularly *Aspergillus niger* and its consortium with *Aspergillus flavus*, possess significant potential for the rapid biodegradation of potato waste. These findings support the feasibility of utilizing native fungal strains as low-cost, eco-friendly agents for organic waste management, contributing to pollution reduction in urban and academic settings.

**Keywords:** Biodegradation; Potato waste; *Aspergillus niger*; *Aspergillus flavus*; *Penicillium* sp.; Dumpsite; Mycoremediation; Sustainable waste management.

#### Article Info

Received: 05 January 2026, received in revised form: 15 January 2026, accepted: 20 January 2026, available online: 30 January 2026; Volume: 2; Issue: 1; Pages: 28-34.

**Citation:** Maichiki A. A., 2026. Biodegradation Potential of Indigenous Fungal Isolates on Potato (*Solanum tuberosum* L.) Waste: A Case Study of Dumpsites in Bwari, Abuja. *International Journal of Multidisciplinary Research in Biotechnology, Pharmacy, Dental and Medical Sciences (IJMRBPDMS)* 2(1): 28-34.

**DOI:**

### Introduction

The global generation of waste, a by-product of routine human activities such as consumption and production, has escalated into a critical environmental and public health concern [1]. Traditional disposal methods, including open dumping and incineration, have proven insufficient, leading to soil, water, and air pollution, and contributing to climate change through the emission of greenhouse gases [2]. In many developing nations like Nigeria, waste management practices are often inefficient, with open dumpsites remaining prevalent in urban areas [3]. The potato

(*Solanum tuberosum* L.), a high-yielding global crop, contributes significantly to this organic waste stream. The food processing industry generates substantial quantities of potato peels, which, if left unmanaged, lead to decay, odor, and the proliferation of pathogens [4].

Microorganisms play a crucial role in the natural degradation of organic matter. Dumpsite soils harbor a diverse array of bacteria and fungi that can utilize organic constituents like cellulose and starch as nutrient sources, facilitating detoxification through metabolic processes [5,6]. Among these, fungi are particularly promising for bioremediation due to their potent enzymatic machinery, including cellulases, amylases, and pectinases, which enable them to break down complex plant polymers [7]. While the biodegradation of various wastes has been studied, the specific potential of fungal communities native to local dumpsites in Abuja for degrading potato waste remains underexplored. Harnessing this indigenous microbial potential offers a pathway to develop cost-effective, sustainable waste management strategies.

Therefore, this study was designed to isolate, characterize, and screen fungi from dumpsites at Bwari, FCT, Abuja, for their ability to biodegrade potato waste. The specific objectives were: (i) to isolate and enumerate fungi from the dumpsite soil; (ii) to characterize and identify the isolates using morphological techniques; (iii) to determine the frequency distribution of the isolates; and (iv) to screen the biodegradation potential of the isolates on potato waste under controlled conditions.

## Materials and Methods

### Study Area and Sample Collection

The study was conducted within the Bwari Area Council of the Federal Capital Territory (FCT), Abuja, Nigeria. A total of six soil samples were aseptically collected from three major dumpsites (designated DS1, DS2, and DS3). At each site, surface debris was removed, and subsurface soil (10 cm depth) was collected using a sterile trowel. The pH and temperature were measured in situ. Samples were transported on ice to the Microbiology Laboratory of Veritas University for analysis [8].

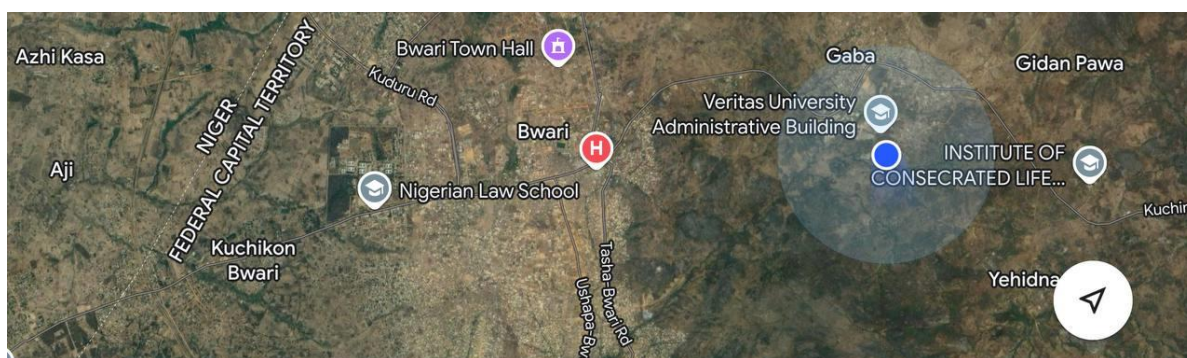


Figure 1: Geographical location of Bwari [8]

### Soil Treatment and Physicochemical Analysis

Soil samples were air-dried, homogenized, and sieved (2 mm mesh) to remove stones and debris. The pH and temperature were recorded, and soil type was determined using the hand texture method [9].

### Isolation and Enumeration of Fungi

A ten-fold serial dilution (up to  $10^{-10}$ ) was performed for each soil sample. From dilutions  $10^{-3}$  and  $10^{-4}$ , 1 mL aliquots were aseptically plated onto Potato Dextrose Agar (PDA) plates supplemented with chloramphenicol to inhibit bacterial growth. The plates were incubated at  $28 \pm 2^\circ\text{C}$  for 5-7 days. After incubation, distinct fungal colonies were counted (CFU/g) and subcultured onto fresh PDA plates to obtain pure cultures [10].

### Characterization and Identification

Fungal isolates were identified based on their macroscopic and microscopic characteristics. Macroscopic features included colony color, texture, diameter, and pigmentation. Microscopic examination was performed using the Lactophenol Cotton Blue (LPCB) staining technique, and structures such as hyphae, conidiophores, vesicles, and conidia were observed under a compound microscope. Identification was done by comparing observed features with standard taxonomic keys [11,12, 13].

### Biodegradation Experiment

The biodegradation potential of the isolates was assessed using a weight loss method. Potato peels were collected, washed, dried, and ground. One gram (1g) of potato peel was added to a 50 mL minimal salt broth (MSB) in 250 mL conical flasks. The Mineral Salt Broth was prepared by first dissolving  $(\text{NH}_4)_2\text{SO}_4$  (1.0 g/L),  $\text{CaCl}_2$  (0.02 g/L),  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  (0.2g/L),  $\text{K}_2\text{HPO}_4$  (1.0g/L),  $\text{NaNO}_3$  (2.0g/L),  $\text{KCl}$  (0.8g/L),  $\text{Na}_2\text{PO}_4$  (2.0g/L) and  $\text{KH}_2\text{PO}_4$

(1.0 g/L) in distilled water. FeSO<sub>4</sub>.7H<sub>2</sub>O was dissolved separately in distilled water and added to the media [14, 15]. The final volume and pH of the MS broth was adjusted to 7.0 with K<sub>2</sub>HPO<sub>4</sub>. The mixture was then be heat-stirred on a hot plate and autoclaved. The flasks were inoculated with 1 mL of a standardized spore suspension (approximately 10<sup>6</sup> spores/mL) of the respective fungal isolates. Six treatment setups were prepared: (CFB1) *A. flavus*, (CFB2) *Penicillium* sp., (CFB3) *A. niger*, (CFB4) *A. flavus* + *A. niger*, (CFB5) *Penicillium* sp. + *A. niger*, (CFB6) *A. flavus* + *Penicillium* sp. A control setup (no fungal inoculum) was also maintained. All flasks were incubated in a shaking incubator at 28°C and 150 rpm for 7 days. After incubation, the residual potato waste was retrieved, centrifuged to remove biofilm, shade-dried, and reweighed [14]. The percentage weight loss (biodegradation) was calculated using the formula:

% Degradation = (Initial weight - Final weight) / Initial weight × 100 [14,15]

The pH and temperature of the culture medium were recorded before and after the 7-day period.

## Results

**Physicochemical Properties of the Soil:** The physicochemical analysis of the six soil samples (A1, A2, B1, B2, C1, C2) is presented in Table 1. The soil types were predominantly loamy and sandy. The temperature ranged from 28°C to 31°C. The pH values ranged from slightly acidic to highly alkaline, with B2 recording the highest pH of 9.12 and A2 the lowest at 7.19.

**Table 1: Physicochemical Analysis of Soil Samples from Dumpsites**

Sample Code	Soil Type	Temperature	pH at 30°C
A1	Loamy	29°C	7.46
A2	Loamy	28°C	7.19
B1	Loamy	28°C	7.53
B2	Loamy	28.5°C	9.12
C1	Sandy	31°C	8.40
C2	Sandy	30°C	8.63

**Key:** A1& A2= Kuduru Dumpsite soils, B1 & B2= Zuma dumpsite soils, C1 & C2= Kogo dumpsite soils

**Heterotrophic Fungal Count:** The total heterotrophic fungal counts on PDA ranged from 5 × 10<sup>-4</sup> CFU/g (sample B2) to 12 × 10<sup>-4</sup> CFU/g (sample B1). The results are shown in Table 2.

**Table 2: Heterotrophic Fungal Count (CFU/g) on Potato Dextrose Agar**

Sample Code	Plate 1	Plate 2	Mean plate count
A1	9 × 10 <sup>-3</sup>	3 × 10 <sup>-4</sup>	6 × 10 <sup>-4</sup>
A2	10 × 10 <sup>-3</sup>	4 × 10 <sup>-4</sup>	7 × 10 <sup>-4</sup>
B1	15 × 10 <sup>-3</sup>	9 × 10 <sup>-4</sup>	12 × 10 <sup>-4</sup>
B2	2 × 10 <sup>-3</sup>	8 × 10 <sup>-4</sup>	5 × 10 <sup>-4</sup>
C1	12 × 10 <sup>-3</sup>	6 × 10 <sup>-4</sup>	9 × 10 <sup>-4</sup>
C2	7 × 10 <sup>-3</sup>	11 × 10 <sup>-4</sup>	9 × 10 <sup>-4</sup>

**Key:** A1& A2= Kuduru Dumpsite soils, B1 & B2= Zuma dumpsite soils, C1 & C2= Kogo dumpsite soils

**Identification and Prevalence of Fungal Isolates:** Morphological and microscopic characterization led to the identification of three distinct fungal genera: *Aspergillus flavus*, *Aspergillus niger*, and *Penicillium* sp. (Table 3). *Aspergillus flavus* was the most prevalent isolate, constituting 40.00% of the total occurrences, followed by *A. niger* (33.33%) and *Penicillium* sp. (26.67%) (Table 4).

**Table 3: Morphological and Microscopic Characteristics of Fungal Isolates**

Suspected Isolate	Colony Color & Texture	Microscopic Features
<i>Aspergillus niger</i>	Black to dark brown, powdery to granular	Septate hyphae; conidiophores ending in globose vesicles with radiating phialides; black rough-walled conidia
<i>Aspergillus flavus</i>	Yellow-green, powdery to	Septate hyphae; rough conidiophores terminating in

	velvety	a vesicle with both uniseriate and biseriate phialides; rough conidia
<i>Penicillium sp.</i>	Blue-green, velvety to powdery	Septate hyphae; branched conidiophores with brush-like (penicillus) arrangements of phialides; chains of round conidia

**Table 4: Prevalence Distribution of Fungal Isolates**

Isolate	DS1	DS1	DS2	DS2	DS3	DS3	Frequency of Occurrence	Percentage Prevalence (%)
	Sample A	Sample B	Sample A	Sample B	Sample A	Sample B		
<i>Aspergillus niger</i>	1 (6.67%)	1 (6.67%)	1 (6.67%)	1 (6.67%)	0 (0%)	1 (6.67%)	5	33.33
<i>Aspergillus flavus</i>	1 (6.67%)	1 (6.67%)	1 (6.67%)	2 (13.33%)	1 (6.67%)	0 (0%)	6	40.00
<i>Penicillium sp</i>	0 (0%)	1 (6.67%)	0 (0%)	1 (6.67%)	1 (6.67%)	1 (6.67%)	4	26.67
Total							15	100

Biodegradation of Potato Waste: The results of the 7-day biodegradation experiment showed significant weight loss in all fungal treatments compared to the control (0% loss). Among the single isolates, *Aspergillus niger* had the highest degradation (82.0%), followed by *A. flavus* (75.0%) and *Penicillium sp.* (70.0%). The combination of *A. flavus* and *A. niger* (CFB4) exhibited the highest overall degradation of 90.0%, indicating a synergistic effect. The *Penicillium sp.* + *A. niger* consortium also performed well (80.0%), while the *A. flavus* + *Penicillium sp.* combination showed the least degradation among the consortia (72.0%) (Table 5).

**Table 5: Percentage Weight Loss of Potato Peels After 7 Days of Incubation**

Isolate	Initial Day 1	Final Day 7	Weight Loss(g)	Percentage
	<b>Weight in grams (g)</b>			
<i>Aspergillus flavus</i>	1.0g	0.25g	0.75g	75.0%
<i>Penicillium sp.</i>	1.0g	0.30g	0.70g	70.0%
<i>Aspergillus niger</i>	1.0g	0.18g	0.82g	82.0%
<i>Aspergillus flavus</i> + <i>Aspergillus niger.</i>	1.0g	0.10g	0.90g	90.0%
<i>Penicillium sp</i> + <i>Aspergillus niger</i>	1.0g	0.2g	0.8g	80.00%
<i>Aspergillus flavus</i> + <i>Penicilium sp.</i>	1.0g	0.28g	0.72g	72.0%
Control	1.0g	1.0g	0	0

Changes in pH and Temperature: The temperature remained stable (27-28°C) across all setups. In contrast, the pH decreased in all treatments from an initial alkaline range (7.52-8.61) to a near-neutral or acidic range (4.53-7.24). The most notable drop in pH was recorded for the *A. flavus* + *Penicillium sp.* combination, which fell to 4.53 (Table 6).

**Table 6: pH and Temperature Before and After 7-Day Incubation**

Isolate	Ph		Temperature	
	Initial at	Final at	Initial at Day	Final at Day

	Day 1	Day 7	1	7
<i>Aspergillus flavus</i>	8.5	7.11	27	28°C
<i>Penicillium sp</i>	8.32	7.24	27	28°C
<i>Aspergillus niger</i>	8.61	7.03	28	28°C
<i>Aspergillus flavus</i> + <i>Aspergillus niger</i>	8.43	7.19	27	28°C
<i>Penicillium sp</i> + <i>Aspergillus niger</i>	8.10	6.90	28	28°C
<i>Aspergillus flavus</i> + <i>Penicillium sp</i>	7.52	4.53	28	28°C

## Discussion

This study successfully isolated three dominant fungal genera, *Aspergillus niger*, *Aspergillus flavus*, and *Penicillium sp.* from dumpsite soils in Abuja and demonstrated their significant potential for the biodegradation of potato waste. The findings offer a promising, eco-friendly alternative to traditional waste disposal methods. The identification of *Aspergillus* and *Penicillium* as the predominant genera is consistent with earlier studies on microbial communities in organic waste-rich environments [13,14]. The high prevalence of *A. flavus* (40%) can be attributed to its well-documented saprophytic nature, rapid sporulation, and ability to produce a broad spectrum of hydrolytic enzymes, including amylases, cellulases, and proteases, which are essential for breaking down the complex carbohydrates, proteins, and lipids found in potato peels [15]. The presence of *A. niger* and *Penicillium sp.* further supports the diverse enzymatic potential within these dumpsite soils, making them a valuable reservoir for isolating potent biodegrading agents [16].

The experiment revealed that *A. niger* was the most efficient single degrader (82.0%), followed by *A. flavus* (75.0%) and *Penicillium sp.* (70.0%). The superior performance of *A. niger* aligns with the findings of Miya et al. [17], who reported over 80% degradation of cassava peel, another starchy substrate, by the same species. This high efficiency is likely due to *A. niger*'s well-characterized and potent amylolytic and pectinolytic enzyme systems, which facilitate the rapid breakdown of potato peels into simple sugars that can be easily assimilated [18]. *A. flavus*, while slightly less efficient, also demonstrated strong degradation, corroborating its known ability to thrive on a wide variety of organic substrates. *Penicillium sp.*, although effective, showed the lowest rate among the single isolates, which may be due to differences in the specific composition and regulation of its extracellular enzyme cocktail [19].

A crucial finding of this study is the enhanced degradation observed in the *A. flavus* and *A. niger* consortium, which achieved a remarkable 90% weight loss in just seven days. This synergistic effect suggests that the two species complement each other's enzymatic activities. For instance, one species may initiate the breakdown of complex polymers, creating intermediate compounds that are more easily utilized by the other, or they may produce a broader and more effective array of enzymes acting on different components of the potato peel [20]. This supports the widely accepted concept that a mixed microbial consortium often outperforms single strains in biodegradation due to collaborative metabolic networks and reduced feedback inhibition [21,22]. This result is of significant biotechnological interest, as it demonstrates the potential for developing a defined, highly effective fungal consortium for waste treatment. Conversely, the combination of *A. flavus* and *Penicillium sp.* resulted in lower degradation (72.0%) than either species alone or in other combinations. This indicates possible antagonism or intense competition for limited nutrients. The production of inhibitory secondary metabolites by one species against the other, a common phenomenon in microbial ecology, could explain this antagonistic effect [23]. This underscores the importance of not just selecting any combination of fungi, but rather identifying consortia that exhibit true metabolic synergy.

The consistent drop in pH across all treatments, from an initial alkaline range (up to 8.61) to a near-neutral or acidic range (as low as 4.53), is a clear indicator of active fungal metabolism. The acidification is primarily attributed to the excretion of organic acids (e.g., citric, oxalic, gluconic acid) as by-products of the rapid utilization of the carbohydrate-rich substrate [34]. *Aspergillus niger* is particularly renowned for its industrial production of citric acid [25]. The sharpest pH drop (to 4.53) was seen in the *A. flavus* + *Penicillium sp.* combination, which surprisingly had one of the lower degradation rates. This suggests that while intense acid production occurred, the specific organic acids produced or the rapid shift in pH may have been suboptimal for the overall enzymatic activities of these two species, potentially contributing to the observed antagonism. The temperature remained stable within the optimal mesophilic range (27-28°C), confirming that the incubation conditions were suitable for the growth and metabolic activity of all isolates [26].

In conclusion, the discussion of these results strongly supports the conclusion that native *Aspergillus* and *Penicillium* isolates, particularly *A. niger* and the synergistic consortium of *A. niger* and *A. flavus*, are highly

effective agents for the biodegradation of starchy potato waste [27]. [28][29]The study highlights the value of screening local microbial resources for application in sustainable waste management.

### Conclusion

This study successfully demonstrated that indigenous fungal species isolated from dumpsites in Abuja possess significant potential for the biodegradation of potato waste. *Aspergillus niger* was identified as the most efficient single degrader, while the consortium of *A. niger* and *Aspergillus flavus* exhibited remarkable synergistic activity, achieving a 90% reduction in waste mass within seven days. The observed drop in pH confirmed active microbial metabolism. The research highlights that harnessing native fungal diversity, particularly in strategic consortia, offers a low-cost, environmentally friendly, and highly effective strategy for managing starchy organic waste. These findings provide a strong scientific foundation for developing mycoremediation-based solutions to mitigate environmental pollution caused by food waste in urban settings like Abuja, thereby contributing to more sustainable and circular economy models for waste management.

### Recommendations

Future studies should employ molecular techniques, such as ITS sequencing of rDNA, to provide definitive identification and phylogenetic analysis of the potent fungal isolates. It is essential to conduct quantitative assays for key hydrolytic enzymes (amylase, cellulase, pectinase, protease) during the degradation process. This will help elucidate the specific mechanisms behind the observed synergy and antagonism. The biodegradation process of organic contaminants should be optimized by evaluating different environmental parameters (pH, temperature, aeration, moisture) and nutrient conditions (C:N ratio) to maximize degradation rates for the most promising isolates and consortia. The ability of the *A. niger* + *A. flavus* consortium should be tested on a wider range of organic wastes to assess its potential for use in a centralized composting facility. Since the isolates include *A. flavus* (which can produce aflatoxins), a thorough safety and toxicity assessment of the final compost product is necessary before it can be recommended as a biofertilizer or soil amendment. Relevant government agencies should be encouraged to support and integrate microbial-based biodegradation technologies into national solid waste management policies and guidelines.

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