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Microbial diversity of fruit and vegetable market dumpsite soils in Yola, Adamawa State, Nigeria

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Abstract

A study was conducted to study the bacterial and fungal biodiversity in fruit and vegetable dumpsite soils of the main fruit and vegetable market in Yola, Adamawa State Nigeria. The dumpsites were chosen based on their significant contribution to the local waste disposal system in the market. The biological properties of the dumpsite soils were assessed by investigating microbial abundance and diversity of bacteria and fungi only. Plate count was carried out to quantify their population in the samples and statistical analysis using Dunnett's test revealed that there were significant ($P < 0.05$) differences in bacterial and fungal counts between the fruit and vegetable dumpsite soils. Bacterial count in the fruit dumpsite soil was 7.23 X 10^5 Cfu/g while in the vegetable dumpsite it was 5.63 X 10^5 Cfu/g and 1.50 X 10^5 Cfu/g in the control pot. The fungal count was 5.14 X 10^5 Cfu/g, 4.14 X 10^5 Cfu/g and 1.40 X 10^5 Cfu/g for fruit dumpsite soil, and vegetable dumpsite soil and control respectively. Based on the combination of biochemical characteristics, different isolates of bacteria were identified such as *Escherichia coli*, *Klebsiella sp*., *Pseudomonas sp*. and *Proteus sp* while some fungal isolates such as *Aspergillus niger*, *Mucor species, Aspergillus flavus, Penicillium species, Aspergillus fumigates* and *Fusarium species* were identified in both of the dumpsites. The present study has revealed some of the bacteria and fungi that thrive in the market dumpsite known to be associated with organic waste degradation however, the presence of potential pathogens like *Escherichia coli* and Aspergillus *flavus* raises concern for more caution in organic waste disposition especially near waterways and its subsequent use in Nigeria.

Keywords: *Fruit, vegetable, bacteria, fungi, dumpsite soil*

Introduction

A dumpsite soil is soil found in areas designated for the deposition of waste materials, which can include household, industrial, market and/or institutional refuse. These sites may be open or covered with soil and can significantly impact the surrounding environment, particularly through groundwater contamination and soil pollution due to leachate from the waste (Igboama et al., 2022). The composition of dumpsite soil is often altered by the types of waste deposited, leading to changes in microbial communities and soil properties, such as increased heavy metal concentrations and variations in pH and electrical conductivity (Halász et al., 2022; Ramaswamy et al., 2021; Agbeshie et al., 2020). Like most developing economies, Nigeria wastes are disposed of on open dumpsites with no regard for suitable waste management techniques (Adewumi et al., 2019). Research indicates that soil in and around dumpsites can exhibit distinct characteristics, including a predominance of certain bacterial phyla, which may have implications for bioremediation efforts (Selvarajan et al., 2022).
The diversity of bacteria and fungi in fruit and vegetable dumpsite soils is notably rich and varied, as evidenced by studies. Research indicates that dumpsite soils are predominantly enriched with bacterial phyla such as Actinobacteria, Proteobacteria, and Firmicutes, with specific genera like Nocardioides, Bacillus, and Pseudomonas frequently isolated (Selvarajan et al., 2022); Varier, 2019). Fungal diversity is also significant in dumpsite soils, with common genera including Aspergillus, Mucor, and Fusarium identified in these environments (Mgbeze and Osazee, 2014). The microbial communities in these soils exhibit distinct functional potentials, particularly in biodegradation, which can be harnessed for bioremediation efforts (Selvarajan, 2022; Bassey et al., 2021). However, the presence of potential pathogens, such as Escherichia and Klebsiella, raises concerns regarding food safety and the health implications of utilizing such soils for agricultural purposes (Bassey et al., 2021). While the microbial diversity in dumpsite soils presents opportunities for ecological applications, careful management is essential to mitigate health risks associated with pathogenic organisms.
The diversity of bacteria and fungi in fruit and vegetable dumpsite soils in Nigeria is notably influenced by the specific environmental conditions and waste composition at these sites. Research indicates that dumpsites in Ondo and Lagos states exhibit significant microbial populations, with Epe dumpsite showing higher bacterial (122.0 × 10^6 cfu/ml) and fungal counts (25.5 × 10^6 cfu/ml) compared to Laje dumpsite (Simon-Oke et al., 2023) because

of the differences in the types of wastes being deposited in those dumpsites. Similarly, a study in Lagos identified various fungal species, including Penicillium chrysogenum and Aspergillus flavus, indicating a rich fungal diversity in the soil (Ewekeye et al., 2023). In Ogun State, a predominance of keratinophilic fungi was noted, with a Shannon index of diversity around 1.98, suggesting a diverse fungal community (Thomas et al., 2021).

Materials and Methods

Dumpsite soil samples were collected separately from the fruit and vegetable dumpsites of the fruit and vegetable market in Yola Adamawa State.

Sample Collection

Dumpsite soil samples were collected from the fruit and vegetable dumpsites located in the *Kasuwan Gwari* market Yola, Adamawa State Nigeria using a systematic random sampling method. Four (4) composite samples were collected at a depth of approximately 0-20 cm (2m x 2m) to ensure representation of the microbial community present in the soil and also for routine soil physical and chemical analysis. The soil samples were sorted into organic and inorganic parts by sorting to remove stones. The samples were air-dried at room temperature and sieved using a 2-mm mesh to remove any coarse particles and homogenize the soil. The biological properties of the dumpsite soil were assessed by investigating microbial abundance and diversity. Plate count analysis was performed to quantify the population of bacteria and fungi present in the soil samples. For this purpose, serial dilutions of the soil suspensions were plated onto nutrient agar and PDA for bacteria and fungi count respectively, followed by incubation under suitable conditions. The colony-forming units (CFUs) were counted and expressed as log CFU/g soil.

All isolates were subjected to morphological characterization and identification, using seven-day-old growing cultures on appropriate media at 25 ± 2 ºC. Each culture plate was opened and viewed under a light microscope. Fungal colony colour and texture were studied while several numbers septa, shapes, and sizes of fungal spores were also studied and recorded under the compound light microscope (Nikon, ECLIPSE E200).

Data Analysis

The collected data were analysed using one way analysis of of variance and Dunnett's test was used to test significant difference between the population of the microbes between the 2 dumpsite soils and a control using statistical analysis software (SAS) version 9.4

Results and Discussion

Physical and chemical properties of dumpsite soils of fruit and vegetable market in Yola, Adamawa State Nigeria

Table 1 presents the results for various physical and chemical properties of the fruit and vegetable dumpsite soils. A pH of 6.10 and 6.15 recorded for the fruit and vegetable dumpsite soils respectively is an indication that the dumpsite soils are acidic in nature, and are not within the ideal range of 6.5-7.5 required for optimal plant growth. This pH level is close to the optimal range (6.0-6.5) for many crops, including citrus, suggesting that nutrient availability may be favourable for plant growth (Mohammed and Mohammed, 2012). Ogbemudia and Mbong, (2013) observed that dumpsite soils mostly have high levels of heavy metals which easily become bioavailable posing health risks when being taken up by plants during growth and development. The pH can also influence the mobility and solubility of these metals, potentially increasing their uptake by plants (Nta et al., 2020). However, these are fruit and vegetable market dumpsite soils and the heavy metal load will not be expected to be high. Therefore, while a pH of 6.10 may support crop growth, it is crucial to monitor heavy metal concentrations to ensure food safety and soil quality (Jadoun and Singh, 2014). Singh (2017) reported that slightly acidic soils can support the growth of various crops, including vegetables. Crops like chilli and tomato can thrive in acid soils with appropriate management practices like liming and/or integrated nutrient management. This is because liming by raising the pH makes available more nutrient release which consequentially increases crop productivity (Abdi, 2024).

The mean EC of 0.30 and 0.29 dSm-1 for fruit and vegetable dumpsites respectively is considered moderate, suggesting a low concentration of soluble salts in the dumpsite soil. This is favourable for plant growth as high salinity can negatively impact plant health and water uptake. The electrical conductivity (EC) levels of 0.30 and 0.29 dSm-1 in fruit and vegetable dumpsites can also significantly influence microbial communities and nutrient cycling. These levels indicate a moderate salinity, which can affect microbial diversity and nutrient availability.

Table 1: Physical and Chemical Properties of Dumpsite Soils

Parameter	Fruit dumpsite soil	Vegetable dumpsite soil
pH	6.10±0.34	6.15±0.21
EC (dSm^{-1})	0.30±0.29	0.29±0.12
Organic carbon (%)	1.36±0.09	1.35±0.14
Organic matter (%)	2.35±0.14	2.33±0.24
Total nitrogen ($g\ kg^{-1}$)	0.14±0.01	0.14±0.01
Available phosphorus ($mg\ kg^{-1}$)	11.87±3.46	10.29±2.16
Calcium (cmol (+)/kg)	5.71±1.77	7.24±2.20
Magnesium (cmol (+)/kg)	2.39±0.74	2.18±0.90
Sodium (cmol (+)/kg)	0.28±0.15	0.31±0.14
Potassium (cmol (+)/kg)	0.59±0.14	0.62±0.16
TEB (cmol (+)/kg)	8.99±1.72	10.36±2.10
TEA (cmol (+)/kg)	3.15±0.69	3.27±0.85
Effective CEC (cmol (+)/kg)	12.13±1.92	13.63±2.51
Percent base saturation	73.86±5.76	75.85±4.87
Sand (%)	77.44±4.66	80.27±3.52
silt (%)	16.03±4.20	12.4±2.93
Clay (%)	6.53±2.81	7.33±1.83
Bulk density ($Mg\ m^{-3}$)	1.65±0.06	1.63±0.04
Total porosity (%)	37.93±2.37	38.6±1.55

Elevated EC can enhance nutrient solubility, impacting the cycling of essential elements like nitrogen and phosphorus, which are crucial for plant growth (Gyabaah et al. 2023). Fungal spores released from decomposing organic matter in dumpsites contribute to nutrient cycling, although their activity may vary with EC levels (Arigela et al., 2023). While moderate EC levels can support microbial activity and nutrient cycling, excessive salinity may lead to detrimental effects on plant health and soil quality, highlighting the need for careful management of dumpsite environments.

The organic carbon content of 1.36 and 1.35 % and organic matter contents of 2.35 and 2.33 % for fruit and vegetable dumpsites respectively indicate their moderate levels in the dumpsites. Organic matter plays a crucial role in nutrient retention, soil structure, and microbial activity, which are beneficial for plant growth. In a study by Musa et al. (2021) they observed that organic matter improves soil structure, enhancing moisture retention and aeration, which are vital for root development while Asare & Száková (2023) added that higher organic carbon content supports a favourable C/N ratio, facilitating effective mineralization and nutrient cycling.

The mean total nitrogen content of 0.14% is low compared to the ratings of Landon (2014). However, a study conducted by Chokor & Agbai. (2022) revealed that dumpsite nitrogen levels can be as high as 1.48% at the surface but decrease with depth and distance from the dumpsite. The phosphorus content of 11.08 mg/kg in dumpsite soil can be considered moderate compared to various soil nutrient level studies. The assessment of soil from different dumpsites reveals a range of phosphorus concentrations, indicating variability based on location and contamination levels. Ogoko & Ijeoma (2016) reported a range of 5.10 to 15.10 mg/kg across different dumpsites in Aba, Nigeria while a study carried out by Obianefo et al. (2017) in Port Harcourt Rivers state, Nigeria reported phosphorus levels between 0.041 and 4.07 mg/kg, suggesting that the 11.08 mg/kg value is significantly higher than some sites but lower than the maximum observed in the present study. In contrast, Amos-Tautua (2014) reported available phosphorus levels that ranged from 35.00 to 84.20 mg/kg, which is considerably higher than the 11.08 mg/kg found in the current study. These are all indications that the nutrient content of dumpsite soil is always a function of the type and amount of waste being deposited. The mean values for calcium, magnesium, sodium, and potassium fall within the typical ranges for agricultural soils. The total exchangeable base (TEB) of 9.67 cmol/kg and percent base saturation (BS) of 74.85% indicates a moderate level of base saturation. This suggests good buffering capacity against soil acidification. The high sand content (78.85%) indicates a sandy loam texture, which is well-drained but has a low water-holding capacity. This could pose challenges for plant growth in dry periods. The bulk density of 1.63 g/cm^3 is within the typical range for agricultural soils, indicating good aeration and root penetration. The total porosity of 38.27% is also within the recommended range for good drainage and aeration, further supporting the suitability of the soil texture for plant growth.

Total Heterotrophic Microbial Counts in Fruit and Vegetable Dump Soil Sites

The total heterotrophic microbial counts in fruit and vegetable dump soil sites is presented in Table 2. Data obtained reveal that the results are significantly different ($P < 0.05$) between the dumpsites in comparison to the control soil. The Bacterial count in fruit dumpsite soil is 7.22×10^5 cfu/g while in the vegetable dumpsite soil it is 5.63×10^5 cfu/g, with a value of 1.50×10^5 cfu/g in the control. This suggests a relatively diverse bacterial

population across the dump soil sites. However, notable differences exist between fruit and vegetable dumpsites, with fruit dumpsite showing consistently higher bacterial counts than vegetable dumpsite. This could be attributed to factors like type of waste generated, organic matter content, pH, or moisture availability, which differ between the two sites and influence bacterial growth. This highlights the elevated microbial activity in the dumpsite areas, likely due to the abundance of organic matter and nutrients from decomposing fruit and vegetable wastes.
Fungal counts is 5.14 x 10^5 cfu/g in the fruit dumpsite soil while it is 4.14 x 10^5 cfu/g in the vegetable dumpsite, with the control soil recording 1.40 x 10^5 cfu/g. This indicates a lower fungal diversity compared to bacteria across the samples. Similar to bacteria, plots within the same site tend to have comparable fungal counts. However, unlike bacteria, the difference in fungal counts between the two sites less pronounced. This suggests that factors influencing fungal growth might be more evenly distributed across the two sites. As with bacteria, both dumpsite soil samples have higher fungal counts than the control soil. This could indicate that while the dumpsite soil provides a suitable habitat for fungi as well, specific factors might be limiting their growth to a greater extent than for bacteria. In all samples, the bacterial counts are consistently higher than the fungal counts, indicating a general dominance of bacteria in the dumpsite soil microbial communities. This is a common observation in soil environments, as bacteria tend to have faster growth rates and utilize organic matter more efficiently than fungi. While bacterial dominance is evident, the ratio of bacteria to fungi remains relatively constant across the samples. This suggests a potentially balanced ecosystem where both bacterial and fungal populations contribute to the decomposition process and nutrient cycling within the dumpsite soil.

Table 2: Total Heterotrophic microbial counts in fruit and vegetable dump soil sites

Dumpsite	Bacteria (Cfu/g) 10^5	Fungi (Cfu/g) 10^5
Fruit dumpsite	7.23a	5.14a
Vegetable dumpsite	5.63b	4.14b
Control	1.50c	1.40c

The higher total heterotrophic microbial counts in dump soil compared to the control (Table 2) highlight the increased microbial activity fueled by the abundant organic matter in the dump site. This indicates a potentially active and diverse ecosystem, but also raises concerns about potential pathogen presence and potential for odor generation. Wastes in some tropical fruits like durian and jackfruit can be as high as 60% (Sagar et al., 2018) and such wastes can increase waste being generated in the markets. In addition, approximately 48.6% of fruits and vegetables are discarded as wastes after processing in a study at Rio de Janeiro, Brazil (de Brito Nogueira et al., 2020). Increase in consumption of fruits and vegetables will come with its attendant consequence of increasing waste to dispose and odour generation.

Biochemical Characteristics and Identification of the Bacterial Isolates obtained from Vegetable and Fruit Dump Sites

The biochemical characteristics of bacterial isolates obtained from fruit and vegetable dump sites is presented in Table 3. All isolates are Gram-negative, indicating their affiliation with the Proteobacteria phylum. This is a common group of bacteria known for their metabolic diversity and presence in various environments, including soil. The majority of isolates (5 out of 8) are positive for citrate utilization, indicating their ability to utilize this organic acid as a carbon source. This suggests their potential contribution to the breakdown and recycling of organic matter in the dumpsite. Three isolates show positive indole production, a characteristic of some tryptophan-degrading bacteria. This ability allows them to break down tryptophan, an amino acid found in organic matter, and utilize it for growth. All isolates exhibit an "acid/acid" reaction on TSIA, indicating their ability to ferment both glucose and lactose. This further confirms their metabolic versatility and potential role in organic matter degradation. Four isolates display gas production, a characteristic of some fermentative bacteria. This ability contributes to the release of carbon dioxide, which can impact the soil's gas composition and potentially influence other microbial populations. Three isolates show positive urease activity, indicating their ability to hydrolyze urea and utilize the resulting ammonia as a nitrogen source. This capability could be crucial for their survival in environments with limited nitrogen availability Based on the combination of these biochemical characteristics, five isolates were identified as *Escherichia coli*, two as *Klebsiella sp*., and one each as *Pseudomonas sp*. and *Proteus sp*. These are common bacterial genera found in soil and known for their ability to thrive in organic-rich environments. The biochemical profiles reveal a diverse range of metabolic capabilities among the isolated bacteria. Their ability to utilize different carbon and nitrogen sources suggests their active role in the decomposition and nutrient cycling processes within the dump soil ecosystem. The presence of *Escherichia coli and Klebsiella sp*., which can be opportunistic pathogens, also highlights the potential public health concerns associated with these environments. The biochemical profiles of the bacterial isolates (Table 2) reveal their varied metabolic capabilities. The dominance of Escherichia coli and Klebsiella sp. aligns with previous studies on dump sites (Odum et al., 2020), suggesting their adaptation to organic-rich environments.

Table 3: Biochemical characteristics and identification of the bacterial isolates obtained from vegetable and fruit dump site soils

S/No	Isolates identification	Grams Reaction	Citrate	Indole	TSIA	Gas production	Urease	Isolate identification
1.	A	-	-	+	Acid/Acid	+	-	*Escherichia coli*
2.	A	-	+	-	Acid/Acid	+	+	*Klebsiella* sp.
3.	A	-	+	-	Acid/Acid	-	+	*Pseudomonas* sp.
4.	A	-	-	+	Acid/Acid	+	-	*Escherichia coli*
5.	B	-	-	+	Acid/Acid	+	-	*Escherichia coli*
6.	B	-	+	-	Acid/Acid	+	+	*Klebsiella* sp.
7.	B	-	+	+	Alkaline/Alkaline	+	+	*Proteus* sp.
8.	B	-	+	-	Acid/Acid	-	+	*Pseudomonas* sp.

Key: A- bacteria isolate from fruit dumpsite soil, B- bacteria isolate from vegetable dumpsite soil

The ability of some isolates to utilize citrate, indole, and gas production indicates their potential contribution to organic matter decomposition and nutrient cycling (Madigan et al., 2009). However, the presence of Escherichia coli raises concerns about potential faecal contamination and associated public health risks.

Morphological characteristics of isolated fungi

Table 4 presents the morphological characteristics of fungal isolates obtained from fruit and vegetable dump sites. Fungal isolate A1 showed a black and powdery-like appearance suggesting a filamentous fungus with abundant spore production. This description is consistent with *Aspergillus niger*, a common saprobic fungus known for its ability to degrade organic matter. Fungal isolate A2 showed a whitish/light cotton-like appearance indicating a fast-growing fungus with aerial mycelia. This aligns with *Mucor species*, which are known for their rapid growth and efficient degradation of organic matter.

Table 4: Morphological characteristics of Fungal Isolated

Isolates	Macroscopy	Microscopy	Organism (s)
A1	Black and powdery like	Conidiophores smooth walled and non-septate	Aspergillus niger
A2	Whitish/ Light Cotton like	Round, Conidia non – Septate	Mucor species
A3	Light green and powdery light	Long, erect septate, condiophores	Aspergillus flavus
B1	Brown and cottony-like	Long erect conidiophores round-shape conidia	Penicillium species
B2	Gray–green fluggy colonies	Long erect non septate conidiophores	Aspergillus fumigates
B3	Yellow pink creamy colonies	Cylindrical to ovoid conidia, curved septate conidiophores	Fusarium species

Key: A -fruit dumpsite soil, B- vegetable dumpsite soil

Fungal isolate A3 showed a light green and powdery-light appearance suggesting another Aspergillus species, possibly Aspergillus flavus, known for its green conidia and potential to produce mycotoxins.
Fungal isolate B1 obtained from the vegetable dumpsite soil showed a Brown and cotton-like appearance could indicate *Penicillium species*, another common soil fungus known for its ability to degrade organic matter and produce antibiotics. Fungal isolate B2 showed Gray-green fluggy colonies suggesting Aspergillus fumigatus, a ubiquitous fungus known for its ability to cause respiratory infections in humans and animals. Fungal isolate B3 showed Yellow-pink creamy colonies with curved septate conidia pointing towards a Fusarium species, a diverse group of fungi with saprobic and pathogenic lifestyles.
In addition, Fungal isolate A1 showed Smooth-walled and non-septate conidiophores that are characteristic features of *Aspergillus niger*. This confirms the macroscopic identification. Fungal isolate A2 showed a Round, non-septate conidia that are consistent with Mucor species. This further corroborates the initial identification. Fungal isolate A3 showed a Long, erect septate conidiophores support the identification of Aspergillus flavus. However, additional tests might be needed for definitive confirmation. Fungal isolate B1 showed a Long, erect conidiophores with round-shaped conidia that are typical of Penicillium species. This strengthens the macroscopic identification. Fungal isolate B2 showed Long erect non-septate conidiophores that are consistent with Aspergillus fumigatus. This observation aligns with the macroscopic features. Fungal isolate B3 showed a Cylindrical to ovoid

conidia with curved septate conidiophores that are characteristic of Fusarium species, this confirms the initial identification.

The morphological characterization revealed a diverse range of fungal isolates, including saprobic species like *Aspergillus niger, Mucor species, and Penicillium species*, which play crucial roles in organic matter decomposition and nutrient cycling. Additionally, the presence of *Aspergillus flavus* and *Fusarium species* highlights the potential presence of mycotoxin-producing fungi, which could pose human health concerns. The identified fungal isolates (Table 4) – *Aspergillus niger, Mucor species, Penicillium species, Aspergillus flavus, and Fusarium species* – are commonly found in soil environments and dumpsites too (Owhonka et al., 2024). Their presence indicates a diverse fungal community with potential roles in organic matter degradation, nutrient cycling, and even antibiotic production (Gadd, 2011). However, the presence of Aspergillus flavus and Fusarium species necessitates further investigation due to their potential to produce mycotoxins, which pose human health risks.

Conclusion

The dumpsite soils exhibited a slightly acidic pH, moderate organic matter content, low electrical conductivity, and sandy loam texture. Diverse fungal and bacterial communities were identified, including species like *Aspergillus niger*, *Mucor sp.*, *Penicillium sp.*, *Escherichia coli*, and *Klebsiella sp.* The bacterial isolates displayed varied metabolic capabilities, suggesting their involvement in organic matter decomposition and nutrient cycling. Total heterotrophic microbial counts were significantly higher in the dump soil compared to the control, indicating increased microbial activity. The dumpsite soil supports an active and diverse microbial community, but the slightly acidic pH, presence of potential pathogens like *Escherichia coli* and mycotoxin-producing fungi like *Aspergillus flavus*, and the potential for odor generation raise concerns about environmental and public health risks and raises concern for more caution in organic waste disposition especially near waterways and its subsequent use in Nigeria. Molecular techniques can be employed for precise microbial identification, evaluating pathogen presence and risk, investigate bioremediation potential, and explore soil amendment strategies.

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