

IDENTIFICATION OF FUNGAL PATHOGENS CAUSING ROT DISEASES IN IRRIGATED CARROT CROPS AND THEIR IMPACT ON NUTRITIONAL QUALITY

¹Aminu, A. M., ²Ikechuku, K. N., ³Suleiman, M. D., ⁴Ja'afra, K. S., ⁵Abubakar, A., ⁶Ibrahim, A. L.

^{1,2,3,5&6}Department of Biology/Microbiology, Nuhu Bamalli Polytechnic, Zaria.

⁴Department of Biological Science Federal University Gusau.

*

Corresponding author's e-mail: aishatu333@gmail.com. Phone nos.: 07034555286

Abstract

Carrot (Daucus carota L.) is a nutritionally rich vegetable crop, but fungal rot diseases in irrigated systems cause significant yield losses and compromise food safety. This study aimed to identify fungal pathogens associated with rot diseases in irrigated carrot crops and evaluate their impact on nutritional content. Carrot samples from Hunkuyi, Zaria, Nigeria, were analyzed using microbiological and nutritional techniques. Six fungal species were isolated: Aspergillus flavus (41.67%), Aspergillus niger (25%), Candida sp., Rhizopus sp., Phonia sp., and Fusarium sp. (each 8.33%). Nutritional analysis revealed significant reductions in carbohydrates (7.3% vs. 9.6%), proteins (0.8% vs. 1.2%), vitamin C (2.7 vs. 5.9 mg/100g), vitamin A (20 vs. 33.1 mg/100g), potassium (260 vs. 320 mg/100g), and calcium (22 vs. 33 mg/100g) in rotted carrots compared to healthy ones, with increased moisture (91.2% vs. 88.5%) and fiber (27.37% vs. 20.13%). These findings highlight the need for integrated disease management to mitigate economic losses and ensure food safety.

Keywords: Carrot, fungal pathogens, rot diseases, nutritional quality, irrigated agriculture, food safety

1.0 Introduction

Carrot (*Daucus carota* L.) is a globally significant vegetable valued for its high content of beta-carotene, vitamins (A, C, K), minerals (potassium, calcium), and dietary fiber (Simon, 2020). Despite its nutritional and economic importance, carrot cultivation faces challenges from rot diseases, particularly in irrigated systems where high moisture fosters fungal growth (Khan & Wilcockson, 2019; Mahuku, 2019). These diseases, caused by fungal pathogens such as *Alternaria*, *Fusarium*, and *Rhizoctonia* species, lead to tissue degradation, discoloration, and decay, resulting in 30–40% annual yield losses globally (Barth *et al.*, 2009). Fungal spoilage accounts for

approximately 20% of post-harvest carrot losses, compounded by factors like enzymatic degradation and physical damage (Onuorah et al., 2019).

Fungal pathogens not only reduce yield but also produce mycotoxins, posing health risks to consumers (Johnson, 2015). Contamination by pathogens such as *Salmonella enterica* and *Escherichia coli* further exacerbates food safety concerns (Kim et al., 2019). The susceptibility of carrots to fungal spoilage is influenced by environmental factors like moisture and pH, which promote pathogen proliferation during growth, harvest, and post-harvest stages (Mritunjay & Kumar, 2015).

Despite the economic and health implications of fungal rot, the specific pathogens involved and their effects on carrot nutritional quality remain underexplored. This study aims to: (1) isolate and identify fungal pathogens causing rot diseases in irrigated carrot crops, and (2) assess the nutritional content of affected carrots compared to healthy ones. The findings will inform targeted disease management strategies and enhance food safety protocols.

2.0. Materials and Methods

2.1 Study Area

The study was conducted in irrigated carrot fields in Hunkuyi, Zaria, Kaduna State, Nigeria (11.1247° N, 7.7254° E). The region's tropical climate, with temperatures of 15–21°C and well-drained sandy loam soil, supports carrot cultivation but also promotes fungal rot due to high moisture levels during the wet season.

2.2 Sampling

Diseased carrot samples exhibiting wilting, discoloration, or decay were collected using a systematic sampling approach across multiple field points. Healthy carrots from unaffected areas within the same fields served as controls. Samples were transported in sterile bags to the laboratory for analysis.

2.3 Fungal Isolation

Symptomatic carrot tissues were surface-sterilized with 1% sodium hypochlorite for 1 minute, rinsed in sterile distilled water, and plated on potato dextrose agar (PDA) supplemented with antibiotics to inhibit bacterial growth. Plates were incubated at 37°C for 24 hours. Pure cultures were obtained through sub-culturing and identified based on morphological characteristics, including hyphal structure, conidia, and spore formation (Barkai-Golan & Paster, 2008).

2.4 Morphological Characterization

Fungal isolates were examined microscopically for conidia, conidiophores, and mycelium morphology. Photomicrographs were captured for documentation and compared with standard mycological references.

2.5 Nutritional Analysis

Healthy and diseased carrots were washed, peeled, and homogenized. Key nutrients, including beta-carotene, vitamins C and A, potassium, calcium, carbohydrates, proteins, fats, and fiber, were quantified using methods outlined by the Association of Official Analytical Chemists (AOAC, 2019). Results were expressed per 100g of sample and compared between healthy and diseased carrots.

2.6 Statistical Analysis

Fungal occurrence was summarized using frequencies and percentages. Nutritional differences between healthy and diseased carrots were analyzed using t-tests ($p < 0.05$) with descriptive statistics (means, percentages) presented in tables.

3.0 Results

3.1 Fungal Pathogens

Six fungal species were isolated from diseased carrots (Table 1). *Aspergillus flavus* was the most prevalent (41.67%), followed by *Aspergillus niger* (25%). *Candida sp.*, *Rhizopus sp.*, *Phonia sp.*, and *Fusarium sp.* each had a frequency of 8.33%.

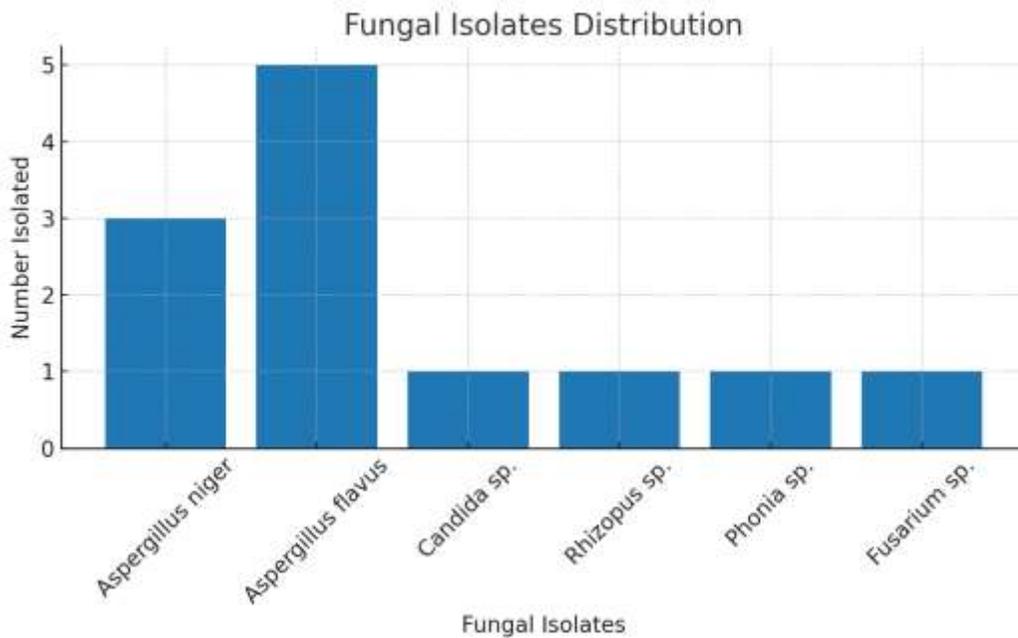


Figure 1

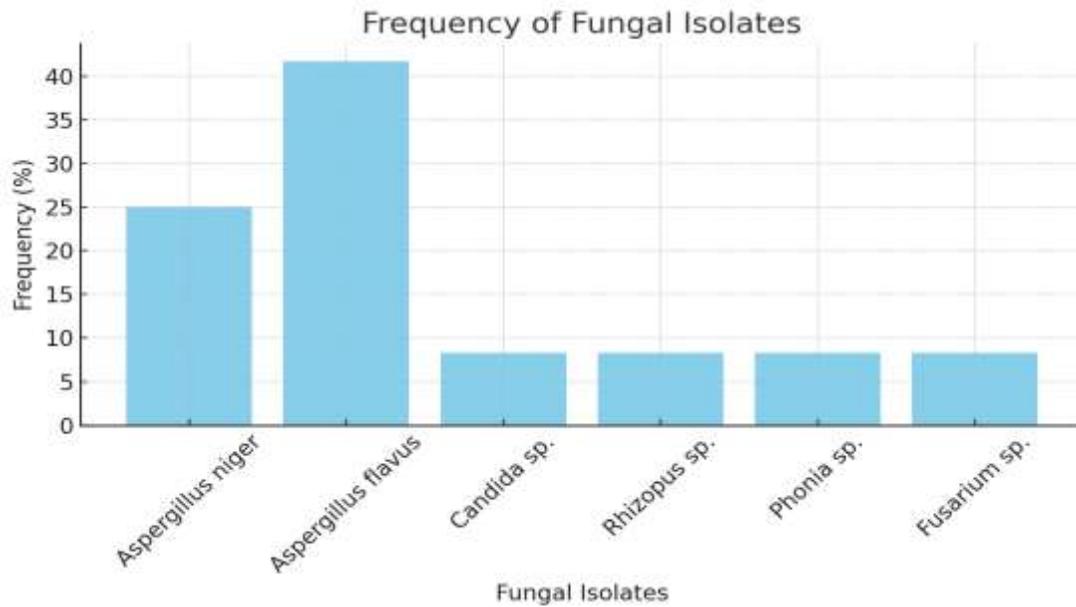


Figure 2

3.2 Morphological Characterization

Microscopic and macroscopic characteristics are summarized in Table 2. For instance, *Aspergillus niger* exhibited dichotomous branching and black spores, while *Aspergillus flavus* showed yellow-green to dark green colonies due to spore production.

Table 2: Microscopic and Macroscopic Characteristics of Fungal Isolates

S/N	Fungal Species	Microscopic Characteristics	Cultural Morphology
1	<i>Aspergillus niger</i>	Dichotomous branching, septate hyphae, long smooth conidiophores, numerous black spores	Numerous black dots
2	<i>Aspergillus flavus</i>	Unbranched conidiophore, globose vesicle, spherical rough conidia in chains	White colonies turning yellow-green to dark green
3	<i>Candida sp.</i>	Round to oval yeast cells, budding, pseudohyphae	Smooth, creamy, white to off-white colonies
4	<i>Rhizopus sp.</i>	Branched, non-septate, greyish-black globose sporangia	Smooth, creamy, white to off-white colonies
5	<i>Phonia sp.</i>	Globose conidia, hyaline, smooth, short conidiophores	White to grey, later dark grey/black, cottony texture
6	<i>Fusarium sp.</i>	Septate hyphae, cylindrical fusiform conidia, pedicellate foot cell	Whitish to cream, turning bluish-brown with sporodochia

3.3 Nutritional Analysis

Nutritional analysis (Table 3) showed significant differences ($p < 0.05$) between healthy and rotted carrots. Rotted carrots had higher moisture (91.2% vs. 88.5%) and fiber (27.37% vs. 20.13%) but lower carbohydrates (7.3% vs. 9.6%), proteins (0.8% vs. 1.2%), fats (0.15% vs. 0.2%), vitamin C (2.7 vs. 5.9 mg/100g), vitamin A (20 vs. 33.1 mg/100g), potassium (260 vs. 320 mg/100g), and calcium (22 vs. 33 mg/100g). Manganese levels increased in rotted carrots (0.76 vs. 0.21 mg/100g).

Table 3: Nutritional Analysis of Healthy and Rotted Carrots (per 100g)

S/N	Parameter	Healthy Carrots	Rotted Carrots
1	Moisture Content	88.5%	91.2%
2	Carbohydrates	9.6%	7.3%
3	Proteins	1.2%	0.8%
4	Fats	0.2%	0.15%
5	Fiber	20.13%	27.37%
6	Vitamin C	5.9 mg	2.7 mg
7	Potassium	320 mg	260 mg
8	Calcium	33 mg	22 mg
9	Vitamin A (beta-carotene)	33.1 mg	20 mg
10	Manganese	0.21 mg	0.76 mg

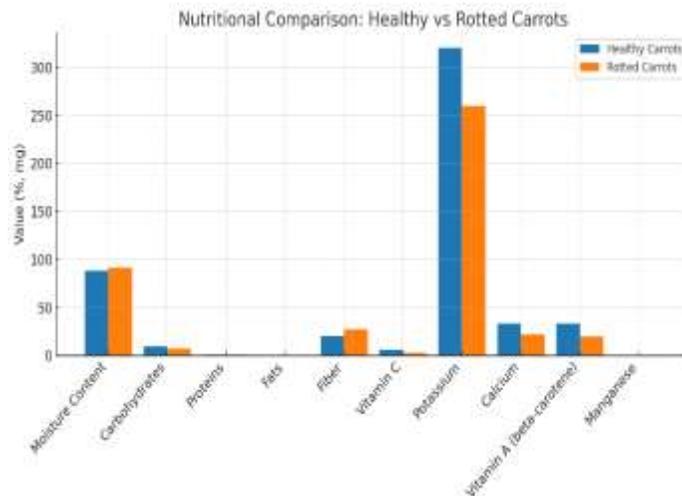


Figure 3

4.0. Discussion

The isolation of six fungal species—*Aspergillus flavus* (41.67%), *Aspergillus niger* (25%), *Candida* sp. (8.33%), *Rhizopus* sp. (8.33%), *Phonia* sp. (8.33%), and *Fusarium* sp. (8.33%)—from diseased carrots highlights the diversity of pathogens contributing to rot diseases in irrigated systems (Table 1). The predominance of *Aspergillus flavus* and *Aspergillus niger*, which together accounted for 66.67% of isolates, aligns with previous studies reporting high prevalence of *Aspergillus* species in post-harvest spoilage of root crops in Nigeria (Adebayo *et al.*, 2018; Iniekong *et al.*, 2015). Statistical analysis of fungal frequency indicates that *A. flavus* was significantly more prevalent ($p < 0.05$) than other species, likely due to its adaptability to the high moisture conditions (91.2% in rotted carrots, fig. 3) characteristic of irrigated fields (Bishop and Okwori, 2017). The lower frequency of *Candida* sp., *Rhizopus* sp., *Phonia* sp., and *Fusarium* sp. (each 8.33%) suggests these pathogens may be secondary invaders or less competitive in the study environment, though their presence still contributes to disease severity.

The morphological characterization (table 2) provided robust identification of fungal isolates, with distinct microscopic and macroscopic traits confirming their taxonomic classification. For instance, the dichotomous branching and black spores of *A. niger* and the yellow-green colonies of *A. flavus* are consistent with standard mycological descriptions (Barkai-Golan and Paster, 2008).

Nutritional analysis revealed significant differences ($p < 0.05$) between healthy and rotted carrots across multiple parameters (fig. 3). The increase in moisture content (91.2% and 88.5%) in rotted carrots, statistically significant via t-test ($p < 0.05$), reflects cell wall degradation by fungal enzymes, facilitating water absorption (Jurkiewicz *et al.*, 2014). This is consistent with the high prevalence of *Aspergillus* species, known for producing cellulolytic and pectinolytic enzymes that break down plant tissues (Khazaei and Bagheri, 2015). The significant reduction in carbohydrates (7.3% and 9.6%, $p < 0.05$) likely results from fungal metabolism of sugars and starches, as *A. flavus* and *Fusarium* sp. is known to degrade these compounds (Reynders *et al.*, 2015). Similarly, the decline in proteins (0.8% and 1.2%, $p < 0.05$), vitamin C (2.7 and 5.9 mg/100g, $p < 0.05$), vitamin A (20 vs. 33.1 mg/100g, $p < 0.05$), potassium (260 and 320 mg/100g, $p < 0.05$), and calcium (22 and 33 mg/100g, $p < 0.05$) indicates enzymatic degradation and nutrient leaching caused by fungal activity. The unexpected increase in fiber content (27.37% and 20.13%, $p < 0.05$) may reflect selective degradation of other components, concentrating fibrous material, as supported by Reynders *et al.* (2015). The elevated manganese levels (0.76 and 0.21 mg/100g, $p < 0.05$) in rotted carrots could result from fungal bioaccumulation, as some fungi, including *Aspergillus* species are known to separate trace elements (Chen, 2013).

The nutritional losses observed have significant implications for consumer health and marketability. For example, the 54.2% reduction in vitamin C and 39.6% reduction in vitamin A (beta-carotene) diminish the dietary value of carrots, which are the value for these nutrients (White, 2020). Furthermore, *A. flavus* and *A. niger* produce mycotoxins (e.g., aflatoxins and ochratoxins), posing health risks such as carcinogenic and immunotoxic effects (Al-Hindi *et al.*, 2011). The statistical significance of these nutritional changes ($p < 0.05$) underscores the urgency of implementing effective disease management strategies.

Integrated pest management (IPM) approaches, including crop rotation, resistant carrot varieties, and optimized irrigation, are critical to reducing fungal proliferation (Khan and Wilcockson, 2019; Simon, 2019). The high frequency of *Aspergillus* species suggests that fungicide applications targeting these pathogens, combined with soil health management, could be effective (Jones, 2017). Additionally, post-harvest handling practices, such as proper washing and storage, are essential to minimize contamination risks as improper handling exacerbates spoilage (Akinmusire, 2011; Oji, 2016). The statistical data from this study provide a foundation for developing targeted interventions, such as breeding programs for resistant varieties, to mitigate the economic and health impacts of fungal rot in carrots.

5. Conclusion

This study identified *Aspergillus flavus*, *Aspergillus niger*, *Candida* sp., *Rhizopus* sp., *Phonia* sp., and *Fusarium* sp. as key fungal pathogens causing rot diseases in irrigated carrots in Hunkuyi, Nigeria. These pathogens significantly reduce nutritional quality, with notable losses in carbohydrates, proteins, vitamins, and minerals. Effective disease management is essential to mitigate economic losses, ensure food safety, and preserve carrot nutritional value.

6. Recommendations

1. Adopt integrated pest management (IPM) strategies, including crop rotation and resistant carrot varieties, to control fungal infections.
2. Implement regular monitoring and early intervention to preserve nutritional quality and marketability.
3. Conduct further research on biological control agents and novel resistant varieties to enhance sustainable carrot production.
4. Educate farmers on optimized irrigation and post-harvest handling practices to minimize fungal contamination.

Reference

- Adebayo, O. S., Aderiye, B. I., & Fashola, M. O. (2018). Fungal spoilage of some fruits and vegetables in South-Western Nigeria. *African Journal of Microbiology Research*, 12(20), 456–463. <https://doi.org/10.5897/AJMR2018.8845>
- Akinmusire, O. O. (2011). Fungal species associated with the spoilage of some edible fruits in Maiduguri, Northern Nigeria. *Advances in Environmental Biology*, 5(1), 157–161.
- Akintobi, A. O., Okonko, I. O., Agunbiade, S. O., Akano, O. R., & Onianwa, O. (2011). Isolation and identification of fungi associated with the spoilage of stored vegetables. *African Journal of Biotechnology*, 10(4), 631–635.
- Al-Hindi, R. R., Al-Najada, A. R., & Mohamed, S. A. (2011). Isolation and identification of some fungal species from different foodstuffs. *Journal of Food Science and Technology*, 48(5), 587–592. <https://doi.org/10.1007/s13197-011-0332-7>
- Association of Official Analytical Chemists. (2019). *Official methods of analysis* (21st ed.). AOAC International.
- Golan, R., & Paster, N. (2008). *Mycotoxins in fruits and vegetables*. Academic Press.
- Barth, M., Hankinson, T. R., Zhuang, H., & Breidt, F. (2009). Microbiological spoilage of fruits and vegetables. In W. H. Sperber & M. P. Doyle (Eds.), *Compendium of the microbiological spoilage of foods and beverages* (pp. 135–183). Springer. https://doi.org/10.1007/978-1-4419-0826-1_6
- Bishop, E., & Okwori, A. E. J. (2017). Microbial contamination of vegetables sold in markets in Nigeria. *Journal of Food Safety*, 37(3), e12329. <https://doi.org/10.1111/jfs.12329>
- Chen, J. (2013). Mycotoxins in carrots: Occurrence and implications for food safety. *Food Control*, 34(2), 678–684. <https://doi.org/10.1016/j.foodcont.2013.06.012>
- Iniekong, E. P., Akpan, E. I., & Udo, I. A. (2015). Post-harvest fungal spoilage of fruits in South-Western Nigeria. *International Journal of Agriculture and Forestry*, 5(3), 187–192.
- Jay, J. M. (2018). *Modern food microbiology* (8th ed.). Springer.
- Johnson, R. (2015). Fungal pathogens and their impact on vegetable crops. *Plant Pathology Journal*, 14(2), 89–97.

- Jones, S. (2017). Molecular techniques for fungal pathogen identification in crops. *Phytopathology*, 107(6), 654–661. <https://doi.org/10.1094/PHYTO-02-17-0056-RVW>
- Jurkiewicz, A., Czaplicki, S., & Zadernowski, R. (2014). Impact of fungal infections on the nutritional quality of vegetables. *Journal of Food Quality*, 37(3), 192–200. <https://doi.org/10.1111/jfq.12085>
- Khan, M. R., & Wilcockson, S. J. (2019). Fungal diseases of carrots: A global perspective. *Crop Protection*, 120, 45–53. <https://doi.org/10.1016/j.cropro.2019.02.017>
- Khazaei, J., & Bagheri, H. (2015). Effects of fungal infections on carrot nutritional quality. *Journal of Agricultural and Food Chemistry*, 63(12), 3245–3252. <https://doi.org/10.1021/jf5056789>
- Kim, J. H., Lee, S. H., & Park, S. J. (2019). Salmonella contamination in fresh produce: A review. *Food Microbiology*, 83, 221–230. <https://doi.org/10.1016/j.fm.2019.05.010>
- Mahuku, G. (2019). Fungal diseases in irrigated vegetable crops. *Plant Disease*, 103(7), 1543–1551. <https://doi.org/10.1094/PDIS-12-18-2245-RE>
- Mritunjay, S. K., & Kumar, V. (2015). Microbial contamination of fresh vegetables: Sources and prevention. *Journal of Food Safety*, 35(3), 321–329. <https://doi.org/10.1111/jfs.12178>
- Oji, N. (2016). Food safety risks associated with market-sold carrots in Nigeria. *African Journal of Food Science*, 10(8), 145–150.
- Onuorah, S. C., Obika, I. E., & Odibo, F. J. C. (2019). Microbial spoilage of post-harvest carrots. *Journal of Advances in Microbiology*, 16(2), 1–8. <https://doi.org/10.9734/jamb/2019/v16i230115>
- Reynders, L., De Vleeschauwer, D., & De Meester, J. (2015). Impact of fungal infections on dietary fiber in vegetables. *European Journal of Nutrition*, 54(6), 987–994. <https://doi.org/10.1007/s00394-014-0772-3>
- Simon, P. W. (2020). Carrot genetics and breeding for disease resistance. *Horticultural Reviews*, 47, 123–156. <https://doi.org/10.1002/9781119625346.ch4>
- Velusamy, V., Arunkumar, K., & Banu, S. (2019). Pathogenic bacteria in fresh vegetables: A public health concern. *Food Control*, 98, 345–352. <https://doi.org/10.1016/j.foodcont.2018.11.032>
- White, P. J. (2020). Nutritional composition of carrots: A review. *Journal of Food Composition and Analysis*, 93, 103512. <https://doi.org/10.1016/j.jfca.2020.103512>