



Fungi Responsible for Storage Rot of Carrot (*Daucus carota* L.)

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Authors' contributions

This work was carried out in collaboration among all authors. Author YKO conceived the study and drafted it in its entirety. All authors read and approved the final manuscript.

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ABSTRACT

Introduction: Carrot (*Daucus carota* L.) is mainly cultivated for its edible taproot, as a fresh or cooked vegetable. It is an excellent source of vitamin A, fiber and bioactive compounds such as β -carotene, which offer several health benefits, the root vegetable with the highest economic value (and the most consumed worldwide).

However, it is subject to fungal attack during storage, resulting in numerous losses. This study aims at identifying the fungi responsible for symptoms on carrots during storage.

Location and Duration of Study: Côte d'Ivoire, March to June 2022.

Methodology: Samples of apparently healthy carrots marketed in three municipalities of Abidjan were collected and stored at room temperature (around 25°C). The phytosanitary condition of these stored carrots was assessed, and the fungi associated with symptoms were isolated on PDA medium and identified. A pathogenicity test was subsequently carried out with these different fungi.

Results: Black and white rot and grey soft rot were the symptoms identified after storage. Grey rot was the most recurrent symptom, with a prevalence of 40.46%. From symptomatic carrots, 11 fungi

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in 5 genera were isolated. These included *Aspergillus*, *Botrytis*, *Colletotrichum*, *Geotrichum* and *Rhizopus*. Pathogenicity test revealed that *Botrytis* sp. causing white rot and *Rhizopus* sp. causing black rot are pathogenic to carrots in storage.

Conclusion: This study enables us to envisage methods for controlling these post-harvest carrot fungi.

Recommendations: This study enables us to envisage methods for controlling the fungi responsible for losses on carrots during storage.

Keywords: Carrot; fungi; storage; rot.

1. INTRODUCTION

Carrot (*Daucus carota* L.) is mainly cultivated for its edible taproot, as a fresh or cooked vegetable (Wzamy, 2022). It is an essential agricultural product for many countries worldwide. Carrot is a root vegetable of global importance due to its high nutritional quality and wide application in food (Basso et al., 2021). It is attractive for human consumption due to its soft texture and pleasant taste. Carrot is an excellent source of vitamin A, fiber and bioactive compounds such as β -carotene, which offer several health benefits (Resende et al., 2016; Gomes et al., 2019). It is the root vegetable with the highest economic value (Carvalho et al., 2018; Patkowska et al., 2020) and the most consumed worldwide (Ding, 2024).

Like all fresh vegetables, carrots are subject to several factors that can reduce their post-harvest quality and shelf life. These include abiotic and biotic factors. Among biotic factors, plant diseases play a major role in yield reduction and carrot deterioration (Qiao et al., 2022). These diseases are due to the action of phytopathogenic agents, namely: bacteria, nematodes, viruses, and fungi (Ahmed et al., 2019). Fungi are the most formidable of all these agents. They not only reduce yield during cultivation, but also degrade product quality during transport and, above all, in storage conditions (Tanbir et al., 2020). During the storage period, carrots are vulnerable to numerous diseases and in-store losses of carrots vary between 10 and 40% (Franke, 2013) and can reach 50 to 60% (Bond, 2016). Several fungi have already been isolated on carrots in storage, the most abundant of which are *Mycocentrospora acerina*, *Cylindrocarpon* spp. *Dictyostelium* spp. and *Fusarium* spp. (Rizan, 2021). The negative influence of these fungi on the nutritional and commercial values of carrots is a real problem. This study aims therefore at identifying the fungi responsible for storage diseases of carrots.

2. MATERIALS AND METHODS

2.1 Material

The material used consisted of two different varieties of carrot, commonly known as Lapin and 5 Doigts, collected from three markets in the Autonomous District of Abidjan (Côte d'Ivoire), notably the markets in the municipalities of Yopougon, Abobo and Adjamé. These different batches of carrots were contained in hermetically sealed packages and were available for sale.

2.2 Assessment of the Phytosanitary Condition of Carrots in Storage

Three batches of carrots per variety were stored for 21 days at laboratory room temperature ($\pm 25^{\circ}\text{C}$) to observe the possible appearance of symptoms. Symptomatic carrots were then grouped depending on symptom types and municipalities of collection, and described according to their appearance, color and shape.

2.3 Determining Symptom Prevalence

Depending on the municipality of collection, the prevalence of each symptom was calculated using the following formula of Bernardo (2014):

$$P(\%) = \frac{Ni}{Nt} \times 100$$

P: prevalence;

Ni: number of carrots showing one type of symptom;

Nt: total number of carrots

2.4 Determining Symptom Severity

Symptom severity was determined according to the 0 to 4 severity scale of Kora et al. (2005), with: 0: no symptoms; 1: symptom observed on 1% to 25% of the carrot surface; 2: symptom observed on 26% to 50% of the carrot surface; 3: symptom observed on 51% to 75% of the carrot

surface; 4: symptom observed on 76% to 100% of the carrot surface.

Severity indices were calculated using the formula of Kobriger and Hagedorn (1983):

$$Is = \frac{\sum(Ni \times Xi)}{Nt \times 4} \times 100$$

Is: severity index;

Nt: total number of carrots in a batch;

Ni: number of carrots having the same severity score in the batch;

Xi: severity score

2.5 Isolation of Fungi Associated with Symptoms

Isolation of fungi associated with symptoms observed on carrots was carried out on Potato Dextrose Agar (PDA) culture medium. Explants from symptomatic carrots were inoculated onto PDA media in Petri dishes. Several purifications were then carried out to obtain pure strains.

2.6 Identification of Fungal Strains

Fungal strains were identified macroscopically based in characteristics such as color, growth pattern of fungal colonies, and microscopically by observation of mycelia and conidia. The Botton et al. (1990) identification key was also used.

2.7 Assessment of the Pathogenicity of Isolated Fungi

Three batches of apparently healthy carrots were collected. The carrots were then washed with water containing 10% bleach, rinsed with water and wiped dry with paper towels. These carrots were disinfected again with 70° alcohol. 5 mm-diameter circular openings were then made in these carrots, and 7-day-old fungi strains were individually introduced into the openings, and subsequently covered with cling film. Finally, they

were incubated at 25°C for 10 days to observe possible symptoms.

After 10 days of incubation, the symptoms observed were described and the fungi associated with such symptoms were isolated and identified as described above. After isolation and identification of these fungi, they were compared with those previously inoculated, along with the symptoms they caused, to confirm that they were indeed responsible for the symptoms observed on the carrots.

2.8 Statistical Analyses

All the data obtained were subjected to statistical analysis using R software version 4.3.0. Bartlett's homogeneity of variance test was performed to determine the homogeneity of variances.

The one-way ANOVA test was used to compare the mean prevalence and mean symptom severity index depending on the municipality of collection. In the event of a significant difference at the 5% threshold, Fisher's LSD test was used to establish homogeneous groups.

3. RESULTS

3.1 Symptoms Observed on Carrots in Storage

The main symptom developed on stored carrots was rot, which appeared in three different forms: grey soft rot, whitish soft rot, and black rot.

Gray soft rot was characterized by decomposition of carrot epidermis and fleshy mass, with a moist appearance and alternating colors ranging from brown to gray (Fig. 1a); soft rot of carrot tissue covered with a whitish cottony mycelial mat (Fig. 1b); and black rot with moist lesions (Fig. 1c).

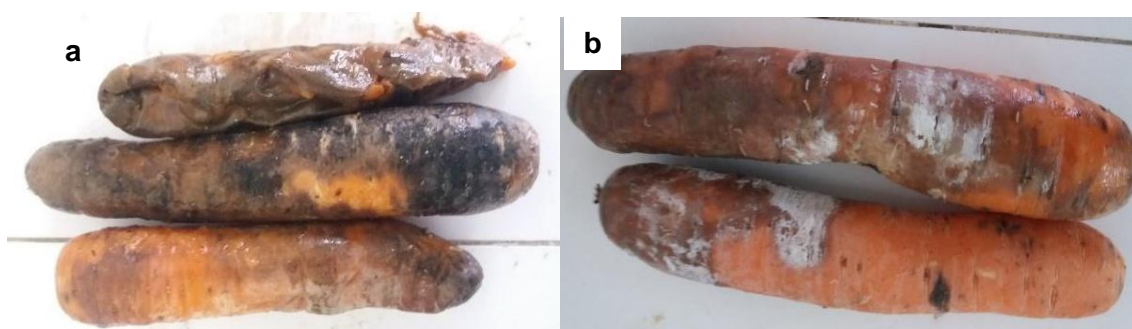




Fig. 1. Symptoms of rot observed on carrots in storage
A: grey soft rot; b: whitish soft rot; c: black rot

3.2 Prevalence and Severity of Symptoms Observed

Symptom prevalence ranged from 5.53 to 40.46. Thus, the highest prevalence was observed in carrots showing grey rot symptoms, while those affected by black rot showed the lowest prevalence. Statistical analyses showed a significant difference between prevalence of these different symptoms (Table 1).

As for the symptom severity index, it ranged from 5.38 to 5.74. Statistical analyses revealed no significant difference between them (Table 1).

3.3 Fungi Associated with Symptoms Observed on Carrots

Eleven fungi in 5 genera were isolated from symptomatic carrots. These included the genera *Aspergillus*, *Botrytis*, *Colletotrichum*, *Geotrichum* and *Rhizopus*. Thus, for carrots stored at room temperature, eleven fungi were associated with the different symptoms observed. Two strains of *Colletotrichum*, two of *Rhizopus* and one strain of *Aspergillus* were isolated from black rot. For soft rot, one *Colletotrichum* and one *Aspergillus* strain were isolated. As for white rot, two strains of *Botrytis*, one of *Geotrichum* and one strain of *Aspergillus* were associated with this symptom. Pathogenicity of isolated fungi.

3.4 Symptoms Induced by Inoculated Fungi and Identification of Pathogenic Fungi

The symptoms observed on carrots after inoculation were the following: black rot identifiable by blackening of the surfaces, color rot with whitish cottony mycelium covering the carrot tissue, and rot with a cottony appearance.

Botrytis and *Rhizopus* fungi, which respectively caused symptoms of white soft rot and black rot similar to those initially observed, and which were re-isolated from these symptoms with the same characteristics as the fungi previously inoculated, were identified as pathogens of carrot in storage.

4. DISCUSSION

A diversity of symptoms was observed on carrots in storage. This can be explained by the fact that the fungi associated with carrot diseases in storage can develop at different temperatures. In contrast, these would have optimal growth at low temperatures. Indeed, according to Niankan (2016), carrots are vulnerable to pathogens during storage, as they can develop at low temperatures and high relative humidity.

Among the symptoms observed, black rot was preponderant in all cases. It thus represents one of the major constraints involved in the deterioration of the nutritional and commercial value of carrots in storage. This symptom has been identified by a several authors on stored carrots in several countries. Indeed, Michel (2004), in his work on carrot disease identification and management in California, identified numerous diseases on stored carrots. He suggested that black rot is one of the most significant diseases involved in the deterioration of carrots in storage, leading to significant economic losses. Similarly, Heller et al. (2007) also pointed out that black rot is one of the main causes of deterioration in carrot quality during distribution.

Our study revealed that several fungal genera are associated with symptoms observed on carrots in storage, notably *Aspergillus*, *Botrytis*, *Colletotrichum*, *Geotrichum* and *Rhizopus*.

Table 1. Prevalence and severity index of symptoms observed on stored carrots

Fungal symptoms	Prevalence	Severity index
Black rot	5.5 ± 0.61 c	5.70 ± 1.47 a
Grey rot	40.46 ± 3.78 a	5.74 ± 1.54 a
White rot	35.34 ± 1.49 b	5.38 ± 1.57 a
F	4.36	10.17
P	0.11	0.10

This shows that there is a diversity of fungal genera associated with symptoms on stored carrots. Rizan (2021) also reported that during the storage period, carrots are vulnerable to many fungal diseases. However, of the fungal genera isolated during this study, only *Botrytis* and *Rhizopus* were recognized as pathogenic to carrot in storage. The same results were obtained by Hermansen et al. (2012). They isolated and identified several fungal genera pathogenic to carrots, including *Botrytis* and *Rhizopus*. Indeed, according to Ben-Yephet (1993), the *Botrytis* genus is highly polyphagous and attacks many vegetable crops by developing abundant white mycelia in the form of sclerotia. Similarly, Onuorah et al. (2016) isolated *Rhizopus stolonifer* from spoiled carrots in Nigeria.

5. CONCLUSION

This study revealed a diversity of symptoms on stored carrots. Rot was the main symptom observed. It appeared in three forms: grey soft rot, black wet rot and whitish soft rot. Five fungal genera were associated with these symptoms. These included *Aspergillus*, *Botrytis*, *Geotrichum*, *Rhizoctonia* and *Rhizopus*. Moreover, only the genera *Botrytis* and *Rhizopus* were pathogenic to carrots in storage. This study enables us to envisage methods for controlling the fungi responsible for losses on carrots during storage.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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