

Antagonistic Activity of *Pseudomonas fluorescens* CI on Fungal Contaminants of Groundnut (*Arachis hypogaea* L.) Seeds During Sale in Côte d'Ivoire

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Received September 27, 2023; Revised November 02, 2023; Accepted November 14, 2023

Abstract Post-harvest groundnut commonly used for many culinary preparations are most often subject to fungal contamination during storage in shops. In the perspective of designing an integrated control strategy for fungal spoilage contaminants in groundnut seeds, the objective of this work was to identify them and to evaluate the inhibitory capacity of the bacterium *Pseudomonas fluorescens* CI against these fungal contaminants. Thus, 27 samples of 500 g each of groundnut seeds were collected in the markets of three communes of Abidjan, namely Abobo, Adjamé and Yopougon. Five fungal genera including *Absidia* (one strain), *Mucor* (two strains), *Rhizopus* (two strains), *Aspergillus* (five strains) and *Trichophyton* (three strains) were isolated from collected groundnut seeds and subsequently pathogenicity tests of isolated fungal strains were applied to healthy groundnut seeds surface disinfected with a chlorine solution (2%). Subsequently, tests of biocontrol antagonists of *P. fluorescens* CI were also demonstrated by direct in vitro confrontation of *P. fluorescens* CI and fungal strains of isolated groundnut seeds. The results indicate that all fungal strains isolated caused partial or total spoilage of groundnut seeds within two weeks. The most significant spoilage was caused by *Rhizopus* sp. and *Absidia* sp. which caused soft rot of the seeds. However, the in vitro antifungal activity of *Pseudomonas fluorescens* CI showed strong inhibition of the growth of all the spoilage fungal strains when *Pseudomonas fluorescens* CI was inoculated 72 h before the fungal strains. These inhibition rates ranged from $52.63 \pm 3.73\%$ to $80.42 \pm 0.42\%$. This indicates that *Pseudomonas fluorescens* CI has antifungal properties that could be used during groundnut seeds storage.

Keywords: groundnut seeds, storage, fungal contamination, antagonistic activity, *Pseudomonas fluorescens* CI

Cite This Article: Zamblé Bi Irié Abel Boli, Wahauwouélé Hermann Coulibaly, Rokiatou Bamba, Koffi Maïzan Jean-Paul Bouatenin, and W. Aimée Mireille Alloue-Boraud, "Antagonistic Activity of *Pseudomonas fluorescens* CI on Fungal Contaminants of Groundnut (*Arachis hypogaea* L.) Seeds During Sale in Côte d'Ivoire." American Journal of Microbiological Research, vol. 11, no. 4 (2023): 88-96. doi: 10.12691/ajmr-11-4-1.

1. Introduction

Introduced to Africa in the 16th century, groundnut with its scientific name *Arachis hypogaea* L. is an annual legume that is among the most important oil crops in the world [1]. With an estimated global production of 46.81 million tonnes in 2019, groundnut has seen an increase to 47.73 million tonnes in the period 2020-2021 [2]. In Côte d'Ivoire, groundnut production has also increased in recent years, from 93.5 thousand tons in 2012 [2] to 210 thousand tons in the 2020-2021 period. Post-harvest groundnuts seeds or groundnut seeds obtained after harvest at the producer level intended to supply the city of Abidjan often face numerous constraints. In recent years, many post-harvest losses groundnut seeds have been recorded during storage and the majority of losses are due to the effect of moulds [3-4]. Natural contaminants of food products, in

particular peanuts, the incriminating moulds are the mycotoxin-producing fungi during the drying process, storage until sale [5]. Mycotoxin contamination of foodstuffs affects both natural and processed products including cereals, dried fruits and oilseeds [6]. Previous studies on the case of groundnut processed into paste for sale in the markets of the city of Abidjan intended for culinary preparations revealed the presence of various pathogenic fungal genera and mycotoxins, in particular aflatoxin B1 [7-8]. Furthermore, the work of [9] revealed that the level of exposure to aflatoxin B1 of consumers of peanut paste sold in the markets of the city of Abidjan varies between 2.072 ng/kg/day and 2.193 ng/kg/day. Statistical modelling of the data from this work using @RISK software led to an estimated population at risk of between 10.1 and 15.6% compared to the tolerable daily intake of 1 ng/kg/day. This means that there is a cancer risk when considering the margin of exposure values for cancer which are well above the threshold value of 10,000.

This implies that post-harvest peanut seeds sold during storage in shops would be subject to fungal and mycotoxic contaminants.

The use of chemicals to control the growth of pathogens in food can result in possible carcinogenic action and high residual toxicity to consumers. The application of high concentrations of synthetic chemicals for post-harvest food control increases the risk of toxic residues in food products [10]. Due to the increasing sensitivity of consumers to environmental pollution and the toxic effects of many synthetic fungicides, the importance of using natural alternatives is becoming necessary [11]. Nowadays, studies are turning to the search for biopesticides, which can be of plant, animal or microbial origin. Numerous studies are currently being developed to isolate or identify secondary metabolites extracted from plants that have insecticidal, insect repellent activity. As far as fungal contaminants are concerned, few studies have been carried out in search of a biopesticide. The reduction of their development relies solely on the respect of good post-harvest practices. However, [12] showed that *Pseudomonas fluorescens* CI exerted fungicidal activity on certain fungal species, notably *Fusarium* sp, *Rhizopus oryzae*, *Aspergillus aculeatus*, *Candida carpophila* and *Geotrichum candidum*, isolated from pineapple fruits. Also, [13] reported inhibition of post-harvest fungal pathogens by *Pseudomonas fluorescens* during commercial storage of apples. Other studies have shown that incorporating *Pseudomonas fluorescens* strains into seeds promotes crop development and resistance to pathogen attack [14]. This resistance to certain pathogens could be due to the production of antibiotic compounds and enzymes that induce systemic resistance [15]. In view of the above, and in order to obtain groundnut seeds of acceptable quality and safety during storage, the objective of this work is to evaluate the inhibitory activity of *Pseudomonas fluorescens* CI on fungal contaminants of groundnut seeds sold during storage in the markets of Abidjan.

2. Materials and Methods

2.1. Materials

2.1.1. Study Material



Figure 1. Groundnut seeds during storage

The study material consisted of groundnut seeds (Figure 1) collected from the storage warehouses of the markets of three Abidjan communes, namely Abobo, Adjamé and Yopougon.

2.1.2. Biological Material

The biological material used to control post-harvest fungal spoilage of groundnut seeds was *Pseudomonas fluorescens* CI from the Laboratory of Food Biotechnology and Microbiology, NANGUI ABROGUA University.

2.2. Methods

2.2.1. Presentation of the Study Area

The district of Abidjan, located in the south-east of Côte d'Ivoire, comprises 10 communes (Abobo, Adjamé, Attécoubé, Cocody, Koumassi, Marcory, Plateau, Port-Bouët, Treichville and Yopougon) and four departments or towns, including Anyama, Bingerville, Brofodoumé and Songon. The communes that were the subject of the study are Abobo, Adjamé and Yopougon. These three communes were chosen because of their demographic and economic importance. The economic activity of these three communes is reflected in the presence of a multitude of markets and commercial stores which are the place of supply and storage of foodstuffs from the interior of the country, and then for the supply of the other towns and communes of the district of Abidjan.

2.2.2. Sampling

Groundnut seeds were collected from the market storage stores of three randomly selected sellers in each of the three study communes. From each sellers, 3 samples of groundnut seeds were collected, or 9 samples per commune. In total, 27 samples of groundnut seeds were collected in all three communes. A sample consisted of 500 g of groundnut seeds. Once collected, the samples were individually packaged in stomachers plastic bags (Sacs Humeau, French), labelled, sealed and kept in a bag. The samples were then transported to the laboratory for analysis.

2.2.3. Fungal Strains Isolation by Direct Method

Direct method described by [16] has been used for the isolation of moulds. It is one of the appropriate methods to detect, assess the contamination rate of samples and isolate fungi from foodstuffs [17]. Per sample, 4 groundnut seeds collected. The resulting groundnut seeds (72 seeds) were surface disinfected with a chlorine solution (2%) for one minute at room temperature. The seeds were then placed on Sabouraud's Chloramphenicol agar which had been poured into Petri dishes. The plates were then incubated at 30°C for five days. To obtain a pure strain, each colony obtained was plated on Sabouraud's Chloramphenicol agar and then identified on the basis of macroscopic and microscopic characteristics using identification keys [18].

The macroscopic examination takes into account the surface and the back of the Petri.dishes On the surface, the characteristics were observed the appearance of the colonies (powdery, fluffy, etc.), the shape (dome, starry, etc.), the colour (white, green, etc.) and the size (small, extensive,

invasive, etc.). On the reverse side, the ability of the mycelium to penetrate the agar, the colour of the reverse, the presence or absence of pigment was observed.

For microscopic analysis, a portion of the colony to be identified was removed with forceps and placed in a drop of methylene blue on a slide. The preparation thus obtained was covered with a slide and then observed under a light microscope at the x 40 objective. The characteristics were observed the aspect of the mycelium (partitioned or not), the shape of the conidia or spores, the conidial heads and the conidiophores, the presence of metules, the arrangement and the shape of the phialides.

2.2.4. Pathogenicity Test of Isolated Fungal Strains

The microbial suspensions used in the biological control experiments were prepared from 2 to 5 day cultures of fungal strains isolated according to the method of [19]. Thus, the stock solution was obtained by scraping 10 mL of sterile distilled water spread on PDA agar (Merck, Darmstadt, Germany) previously poured into a Petri dish. Successive decimal dilutions were made up to 10^{-7} so as to obtain a microbial load of 10^5 CFU/mL. The tubes were stored at 4°C in the refrigerator (Trino Triton Ceti, Belgium). The microbial load was enumerated according to formula 1 [20].

$$N(\text{UFC/g}) = \frac{\sum C}{V \times (n_1 + 0.1 \times n_2) \times d} \quad (1)$$

n_1 is the number of plates of the very first dilution at which the colonies could be counted. n_2 is the number of plates of the dilution which precedes the very first dilution at which the colonies could be counted. d is the dilution rate of the first dilution at which the colonies could be counted. V is the volume of inoculum applied to each dish. N is the average count of microorganisms in CFU/mL. $\sum C$ is the sum of colonies in all retained boxes.

The pathogenicity activity of fungal strains on groundnut seeds was carried out according to the method of [21] with some modifications. Healthy shelled groundnut seeds were disinfected on the surface with a chlorine solution (2%) for one minute at room temperature. Stock suspensions of isolated molds were prepared from 9 mL of buffered peptone water (EPT) and 1 mL of the previously prepared inoculum. 50 µL of each stock solution was individually applied to 10 previously disinfected healthy peanut seeds in previously sterilized jars. Control groundnut seeds were disinfected and treated with sterile distilled water. The groundnut seeds were stored at room temperature for 14 days and an observation was made on the presence or absence and type of symptoms.

2.2.5. In Vitro Antagonism Test

The antifungal activity of *Pseudomonas fluorescens* CI was carried out according to the method described by [22] with some modifications. The test was carried out on Sabouraud Chloramphenicol agar to verify the existence of a possible *Pseudomonas fluorescens* CI inhibitory action against strains isolated from groundnut seeds.

Using a sterile platinum loop, *Pseudomonas fluorescens* CI is inoculated in the form of a straight streak which divides the Petri dish into two equal parts. Two discs, each having the diameter of the tip of a Pasteur pipette, obtained with a punch from a culture of fungal strains are placed on either side of the streak 1 cm from the edge of the dish at the different following times:

-T=0, the altering agent and the antagonist agent were inoculated at the same time

-T=24h, the altering agent was inoculated 24h after the antagonist agent

-T=48h, the alteration agent was inoculated 48h after the antagonist agent

-T=72h, the altering agent was inoculated 72h after the antagonist agent

Control dishes were inoculated only with the spoilage agent placed in the center of the dish and used to assess the antifungal activity of *Pseudomonas fluorescens* CI. The plates were incubated at 30°C for 4 days. The inhibition rate of *Pseudomonas fluorescens* CI was estimated by calculating the percentage inhibition of mycelial growth using the following formula [23]:

$$\% \text{ Inhibition} = \left(\frac{R - r}{R} \right) \times 100 \quad (2)$$

R is the radial growth of the microorganism without antagonist confrontation

r is the radial growth of the microorganism with antagonist

2.2.6. Statistical Analysis

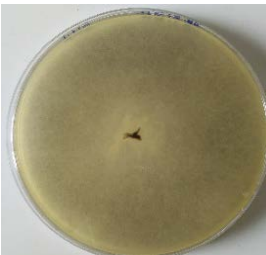
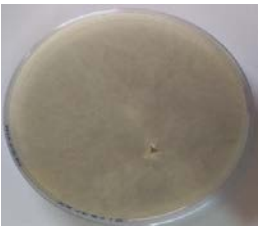
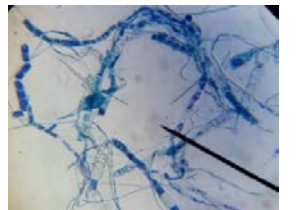
The statistical analysis of the results was carried out using STATISTICA software version 7.1 (StatSoft). It was used to calculate the means and standard deviations of the data obtained. The various parameters analysed were then subjected to an analysis of variance (ANOVA). For this purpose, a repeated measures ANOVA and Duncan's multi-range tests were used. In case of a significant difference between the studied parameters, the ranking of the means was done according to the Duncan test. The significance level is $\alpha = 0.05$. Statistical differences with a probability value less than 0.05 ($p < 0.05$) are considered significant. When the probability is higher than 0.05 ($p > 0.05$), the statistical differences are not significant.

3. Results

3.1. Macroscopic and Microscopic Characteristics of Fungal Contaminants Isolated from Groundnut Seeds Samples

On the basis of identification keys taking into account macroscopic and microscopic characters, five fungal genera have been identified. These are *Absidia*, *Mucor*, *Rhizopus*, *Aspergillus* and *Trichophyton* (Table 1).

Table 1. Macroscopic and microscopic characteristics of fungal genera isolated of groundnut seeds during storage

Macroscopic aspect		Microscopic aspect	Fungal genus
Obverse	Backhand		
			<i>Absidia</i> sp.
			<i>Mucor</i> sp.
			<i>Rhizopus</i> sp.
			<i>Aspergillus</i> sp.
			<i>Trichophyton</i> sp.

3.2. Frequency of Isolation of Fungal Contaminants Involved In Spoilage of Groundnut Seeds During Sale

Table 2. Frequency of isolation of the main fungal strains involved in the spoilage of groundnut during sale

Communes investigated	Isolated germs	Frequency isolation (%)
Abobo	<i>Aspergillus</i>	40
	<i>Absidia</i>	10
	<i>Trichophyton</i>	30
	<i>Rhizopus</i>	10
	<i>Mucor</i>	10
Adjamé	<i>Aspergillus</i>	71
	<i>Trichophyton</i>	29
Yopougon	<i>Aspergillus</i>	50
	<i>Trichophyton</i>	38
	<i>Rhizopus</i>	12

Based on the identification keys, five fungal genera were isolated from groundnut seeds sold during storage in the shops. These were *Absidia*, *Mucor*, *Rhizopus*, *Aspergillus* and *Trichophyton*. The genus *Aspergillus* recorded the highest frequency in Adjamé (71%), Yopougon (50%) and Abobo (40%) respectively, followed by *Trichophyton*, 38% in Yopougon, 30% in Abobo and 30% in Adjamé. The least isolated fungal genus were *Absidia* (10%) and *Mucor* (10%) in Abobo, and *Rhizopus* (10%) in Abobo and Yopougon (12%) (Table 2).

3.3. Pathogenicity of Fungal Strains in Groundnut Seeds Spoilage

Groundnut seeds inoculated with *Absidia* sp showed rot symptoms characterised by tegument discoloration

and soft rot (Figure 2a). *Mucor* spoilage is only a slight discoloration of the seed coat (Figure 2b). Healthy groundnut seeds inoculated with *Rhizopus* sp. showed rot symptoms manifested as black spots, discoloration of the seed coat and soft rot (Figure 2c). The *Aspergillus* sp

spoilage resulted in discoloration and drying of the groundnut seeds (Figure 2d). The *Mucor* sp spoilage is only a slight discoloration of the seeds coat. The genus *Trichophyton* caused only a slight discolouration and drying of the seeds (Figure 2e).



Figure 2a. Inoculation of groundnut seeds 14 days after inoculation with *Absidia* sp



Figure 2b. Appearance of groundnut seeds 14 days after inoculation with *Mucor* sp



Figure 2c. Appearance of groundnut seeds 14 days after inoculation with *Rhizopus* sp



Figure 2d. Appearance of groundnut seeds 14 days after inoculation with *Aspergillus* sp



Figure 2e. Appearance of groundnut seeds 14 days after inoculation with *Trichophyton* sp

Figure 2. Pathogenicity tests of different fungal genus on groundnut seeds after 14 days

3.4. Antifungal Activity of *Pseudomonas fluorescens* CI on Fungal Strains Weathering Groundnut Seeds

Table 3 shows the appearance of the Petri dishes after confrontation of the isolated moulds with the antagonist agent. At T=0, apart from *Aspergillus* and *Trichophyton* strains, the antifungal activity of *Pseudomonas fluorescens* CI on the genus *Absidia*, *Mucor* and *Rhizopus* remains weak. This is evidenced by a weak zone of demarcation between these strains and *Pseudomonas fluorescens* CI. However, the inhibition rates become increasingly important when *Pseudomonas fluorescens* CI

is grown 72h before seeding the fungal strains.

The inhibition rates of *Pseudomonas fluorescens* CI on groundnut seeds spoilage fungal genus obtained in this study ranged from 19.74 ± 1.86 to 80.42 ± 0.42 %. The antifungal activity of *Pseudomonas fluorescens* CI was significant on half of the strains tested from 24 hours endorsed by *Aspergillus*. Inhibition of *Pseudomonas fluorescens* CI against isolated fungal strains was high across all isolated fungal genera. The most sensitive fungal genus to *Pseudomonas fluorescens* inhibition was *Trichophyton* with 80.42 ± 0.4 % while *Aspergillus* was the least sensitive with 52.63 ± 3.73 % at 72 hours of confrontation (Table 4).

Table 3. *In vitro* antagonism of *Pseudomonas fluorescens* CI on groundnut seeds spoilage fungal genera

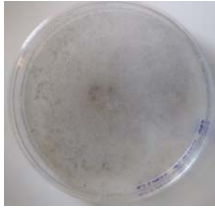
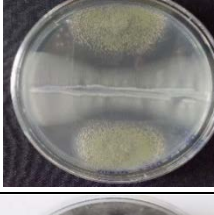
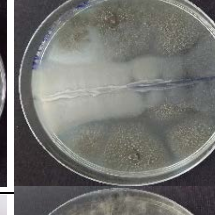
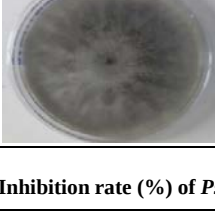
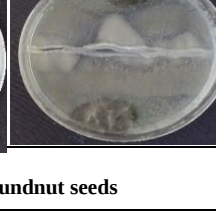
Fungal genus	Control	Shelf life			
		T=0h	T=24h	T=48h	T=72h
<i>Absidia</i> sp.					
<i>Mucor</i> sp.					
<i>Rhizopus</i> sp.					
<i>Aspergillus</i> sp.					
<i>Trichophyton</i> sp.					

Table 4. Inhibition rate (%) of *Pseudomonas fluorescens* CI on fungal genus responsible for spoilage of groundnut seeds

Incubation time (hours)	Inhibition rate (%) of <i>Pseudomonas</i> CI on fungal genera				
	<i>Absidia</i>	<i>Rhizopus</i>	<i>Mucor</i>	<i>Aspergillus</i>	<i>Trichophyton</i>
T = 0	51.18 ± 0.83^b	56.47 ± 1.67^b	55.30 ± 1.65^b	19.74 ± 1.86^c	57.84 ± 1.70^a
T = 24	55.30 ± 1.66^a	55.30 ± 1.66^a	57.06 ± 2.50^b	29.61 ± 0.93^c	60.85 ± 0.86^b
T = 48	69.15 ± 1.05^a	59.30 ± 1.45^a	62.36 ± 0.51^b	39.15 ± 1.70^c	60.57 ± 0.66^b
T = 72	75.30 ± 1.66^a	75.30 ± 1.66^a	75.59 ± 1.24^a	52.63 ± 3.73^c	80.42 ± 0.42^b

On the same line, the mean values followed by different alphabetical letters are statistically different ($P \leq 0.05$) (DUNCAN multiple t-test)

4. Discussion

The results of this study showed that groundnut seeds traded in stores in Abidjan markets during storage are contaminated with five main fungal genera, namely *Absidia*, *Rhizopus*, *Mucor*, *Aspergillus* and *Trichophyton*. The presence of fungal genus isolated in this study could be explained by environmental factors of storage facilities including rats and insects as reported by [24] in similar studies. This is because damage from rats and insects predisposes groundnut seeds to heavy mold contamination. The openings left by the larvae of *Caryedon serratus*, for example, facilitate the attack of other insects which favor the development of molds [25]. This contamination could also be explained by the use of polyethylene bags for the storage of post-harvest groundnut seeds in stores from producers to traders [4-26]. Indeed, the use of polyethylene bags of a poorly ventilated nature promotes the development of molds [27]. Lack of ventilation during storage of groundnut seeds could cause a variation in temperature which can cause an increase in seed moisture; this risks the development of mould. The presence of certain fungal genera including *Aspergillus*, *Mucor* and *Rhizopus* in the contamination of groundnut seeds during storage has been reported by several authors [4] in Côte d'Ivoire, [28] in Korea and [29] in Ghana. Among the different fungal genera, *Aspergillus* was the most isolated fungal contaminant. Our results corroborate those of several authors [30-31-32] who reported the presence of fungal species of the genus *Aspergillus* as the predominant contaminant of groundnut seeds during storage. In addition, [33] also reported the predominance of this fungal genus on zucchini during marketing. These results could be explained by the fact that *Aspergillus* are certainly the most halting fungal contaminants to metabolise more nutritive substrates including carbohydrates, proteins, fibres, fats and minerals that constitute their vital nutritive source. The results could also be explained by the fact that groundnut seeds offer a favourable environment for the growth of fungal contaminants given their biochemical composition. Indeed, according to [34] and [26], groundnut and its various derived products are very sensitive to contamination by pathogenic fungal of the genus *Aspergillus*. The results of this study confirm those of [35] and [36] who reported the predominance of contamination of agricultural products by fungi of the genus *Aspergillus* during post-harvest storage. Indeed, according to [37], groundnut and its various by-products are very susceptible to contamination by pathogenic fungal. On the other hand, [7] reported that groundnut and its derived products, especially groundnut paste, contain proteins, oils, fatty acids, carbohydrates and minerals that provide a nutrient-rich environment for the growth of moulds.

Pathogenicity tests showed that all the fungal genera isolated promoted total or partial spoilage of groundnut seeds marked by discoloration. Groundnut seeds inoculated with *Rhizopus* and *Absidia* showed the greatest spoilage characterised by discoloration of the seed coat and soft rot. The presence of the genus *Rhizopus* in the spoilage of groundnut seeds confirms the work of [38]

who reported that fungi of the genus *Rhizopus* are the second most common cause of contamination of groundnut seeds sold in markets in the Kenyan provinces. Furthermore, [39] also reported the incidence of *Rhizopus* on groundnut seeds in similar studies. In addition, *Aspergillus* caused discoloration and drying of the seed coat. The involvement of *Aspergillus* in groundnut seed spoilage demonstrates that this mould has been identified as one of the major causes of groundnut seed spoilage during storage [30-32]. Inoculation of seeds with *Trichophyton* resulted in partial spoilage of the seeds resulting in drying and partial discoloration of the seed coat. This would be related to the fact that *Trichophyton* is not potentially pathogenic to groundnut seeds. Its presence is thought to be due to poor hygienic conditions when handling the seeds. *Trichophyton* is a mould that is found both as a contaminant and as an opportunistic pathogen. Indeed, this mould is considered in humans and animals as a commensal of the skin. This could explain its presence on seeds during storage.

The use of bacterial biopesticide (*Pseudomonas fluorescens* CI) in this study demonstrated the ability of this agent, to inhibit the main fungal strains responsible for spoilage of groundnut seeds, notably *Absidia*, *Rhizopus*, *Aspergillus*, *Mucor* and *Trichophyton*. For the majority of these fungal contaminants, this inhibition is greater when *Pseudomonas fluorescens* CI is seeded 72h before the fungal strains. The inhibition rates ranged from 52.63 to 80.42%. This reduction in the incidence of fungal contaminants in groundnut seed spoilage could be explained by the rapid and extensive colonisation of the sites by the inhibiting agent. The presence of this biological agent would prevent the establishment of pathogenic fungal strains on the interstitial pores of groundnut seeds by reducing space and access to available nutrients. Indeed, according to [40], the application of biopesticides to wound sites prior to pathogen infection is necessary to ensure better colonisation and maximum inhibition rate. This result could also be due to the fact that *Pseudomonas* would constitute a natural protective flora of food [41] [27]. Our results corroborate those of [33] who reported a significant inhibition of fungal contaminants responsible for spoilage of courgettes by *Pseudomonas fluorescens* F19 during marketing in Abidjan markets. The inhibition of fungal strains of groundnut seed spoilage by *Pseudomonas fluorescens* CI could also be explained by its ability to produce enzymatic substances that have antifungal activity. Indeed, according to [42], the cell wall of phytopathogenic fungi consists of chitin, a linear polymer of β -(1-4)-N acetylglucosamine (GlcNAc) and the production of chitinases by *Pseudomonas fluorescens* disintegrates this polymer. Furthermore, [43] and [44] also reported the inhibition of pathogenic fungal and other pests by the production of chitinases excreted by *Pseudomonas fluorescens*. This result could also be explained by the extraction of several antimicrobial metabolites with antifungal activity by *Pseudomonas fluorescens* CI. Indeed, [45], *Pseudomonas fluorescens* produces several stationary phase antifungal metabolites such as phenazines, pyrrolnitrin, pyoluteorin and DAPG (2,4-diacetylphloroglucinol) which are iron chelating agents preventing its use by pathogens.

5. Conclusion

The assessment of fungal contaminants in groundnut seeds sold during storage in the stores revealed the presence of several fungal genera including *Absidia*, *Rhizopus*, *Mucor*, *Aspergillus* and *Trichophyton*. Thus, in view of their seed spoilage action, *Absidia*, *Rhizopus* and *Aspergillus* were considered as potential pathogens of groundnut seeds. The *in vitro* antagonism test of *Pseudomonas fluorescens* CI showed its ability to inhibit the fungal growth of pathogens isolated from groundnut seeds. This strain probably has properties that can be used for the preservation of groundnut seeds.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

Authors' Contributions

This work was carried out with the collaboration of all the following authors. Author WAMA-B designed the study. Authors ZBIAB, WHC, RB; KMJ-PB and WAMA-B carried out the literature searches, statistical analyses, drafted the experimental protocol and participated in writing the manuscript. All authors read and approved the final manuscript.

ACKNOWLEDGMENTS

Our thanks go to the groundnut seeds sellers in the storage warehouses of the three communes of Abidjan who facilitated the collection of samples, without forgetting those responsible for the Laboratory of Biotechnology and Microbiology of the University Nangui Abrogoua.

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