Hindawi
Journal of Food Processing and Preservation
Volume 2023, Article ID 5777460, 9 pages
https://doi.org/10.1155/2023/5777460

Research Article

Antifungal Mechanism of Cinnamon Essential Oil against Chinese Yam-Derived *Aspergillus niger*

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Received 10 September 2022; Revised 8 December 2022; Accepted 27 December 2022; Published 4 April 2023

Academic Editor: Anand Babu Perumal

Chinese yam with damaged outer skin can be easily oxidized and infected by spoilage fungi. To find preservatives in the storage of the Chinese yam, *Aspergillus niger* 103 was isolated, identified, and determined as the dominant spoilage fungus in Chinese yam according to Koch's postulates. Then, the strain was used as a model to screen antifungal agents and study antifungal mechanisms in this study. We found that cinnamon essential oil was the best antifungal agent, and the minimum concentration against *Aspergillus niger* 103 was 25 μg/mL. The storage life of Chinese yam could significantly extend by 27.66 days by spraying with cinnamon essential oil (25 μg/mL). To further explore the antifungal mechanism of cinnamon essential oil against *Aspergillus niger* 103, alkaline phosphatase activity and electrolyte content in the fungal solution were measured. The alkaline phosphatase activity and electrolyte content of the fungal solution with cinnamon essential oil were significantly increased than those without cinnamon essential oil, which showed that the cinnamon essential oil could destroy the integrity of the cell wall and cell membrane of *Aspergillus niger* 103, and disrupted cellular homeostasis of *Aspergillus niger* 103.

1. Introduction

Chinese yam belonged to the family of Dioscoreaceae and is the fourth most important tuber crop in the world, after cassava, potato, and sweet potato, and contains dietary fiber and carbohydrates. Chinese yam as a nutritious, delicious food can be processed into flour, chips, decoction pieces, bread slices, wine, fermented milk, etc. As for medicinal properties, Chinese yam has glycemia and blood lipid-lowering properties; immunoregulatory and digestion-boosting functions; and antitumor, antioxidant, and antiaging effects [1]. However, Chinese yam needs to be handled carefully in the process of harvesting, transportation, and storage, because its skin is thin and brittle. Once the skin is abraded or broken, the tubers can be easily oxidized or be infected by the microorganism, resulting in considerable economic losses. Chinese yam becomes soft and sticky due to dampness, turning moldy within 2 weeks without an appropriate storage method. The annual loss of Chinese yam from 10% to 20% due to spoilage ranges even going as high as 50% in serious cases [2].

Chinese yam is easily infected by airborne microorganisms when exposed to the air. Microorganisms that caused the spoilage of Chinese yam during storage mainly include *Pseudomonas allii* [3], *Botryodiplodia theobromae* Pat, *Penicillium oxalicum* Currie and Thom, *P. sclerotigenum* Yamamoto, *Fusarium moniliforme* var. *subglutinans* Wollenw and Reinking, *Aspergillus niger* Van Tiegh, *A. tamarii* Kita, *Rhizoctonia* spp., *Serratia* spp. [4], *Serratia marcescens*, *Erwinia carotovora*, *Klebsiella oxytoca*, and *Pseudomonas aeruginosa* [5].

During the period of storage, antiseptic drugs including limestone, thiophanate-methyl, copper chloride oxide, chitosan, 1-methylcyclopropene, and thiabendazole are sprayed regularly to inhibit the propagation and growth of spoilage bacteria [2]. These antiseptics could achieve the antiseptic effect by killing spoilage bacteria, and they need to be soaked or sprayed resulting in the problems of high labor intensity and cumbersome operation when they are used. Furthermore, phosphine as a fumigant can prevent microbial growth, if it was used abundantly for the long term, which could cause environmental pollution, and reduce antibacterial susceptibility [6]. Therefore, it is urgent to find convenient and bacteriostatic preservatives to prevent the deterioration of Chinese yam during storage.

In recent years, plant-derived essential oils were paid more attention in food storage because of their high volatility, easy degradation, and nontoxic side effects. Plant essential oil derived from aromatic plants is a complex combination of volatile secondary metabolites and lipophilic compounds derived from aromatic plants with antibacterial, antioxidant, and insect repellent effects. In addition, plant essential oil is also friendly to the environment, safe for people and animals, and easy to decompose by microorganisms. Research showed that plant-derived essential oils could fight microbial spoilage during postharvest storage of food [7]. Furthermore, essential oils can also be used as food preservatives in combination with other substances or technologies. For example, Anand Babu et al. found that the combination of air conditioning and essential oil could effectively control postharvest decay and preserve the physicochemical quality of mango fruits, extending their shelf life, and the effect was better than that of only using air conditioning and essential oil alone [8]. Therefore, plant-derived essential oil is a potential natural preservative with great development value.

The objectives of this study were to isolate dominant spoilage fungi from Chinese yam with black mycelia or spots in a cellar in Jiaozuo, then to screen the best antifungal agent from several natural preservatives to inhibit the growth of spoilage fungi, and investigate the antifungal mechanism of the selected preservative and its application in Chinese yam, to develop a natural and high efficient biopreservative to extend the shelf life of foods.

2. Materials and Methods

2.1. Experimental Materials

2.1.1. Chinese Yam. The Chinese yam used in the present work derived from a storage cellar in Jiaozuo City, Henan Province, China. The sample was rotten and had black mycelia or spots. Its cut surface was black and with festering and abnormally rancid odor.

2.1.2. Six Preservatives. Rose essential oil, chamomile essential oil, cinnamon essential oil, garlic essential oil, and rosemary essential oil were obtained from Henan Feinarui Aromatic Biotechnology Co., Ltd. (Biyang, Henan, China). Protamine was obtained from Hebei Wangyou Biotechnology Co., Ltd. (Langfang, Hebei). The six preservatives were stored at 4°C until further use.

2.2. Experimental Methods

2.2.1. Isolation and Identification of Spoilage Fungi

(1) Isolation of Strains. 10 g of the naturally rotten parts of Chinese yam was put into 100 mL of sterile normal saline and incubated with incubated at 37°C, shaking at 150 rpm for 24 h. The spoilage strains that caused black plaques on Chinese yam were isolated, purified, propagated, and infiltrated according to Koch's four postulates [3].

(2) Observation of Colony Morphology and Cell Morphology. The morphology of cells was observed under a microscope (Nikon 80i, Nikon Optical Instruments (China) Co., Ltd., Wuxi, Jiangsu) with lactophenol cotton blue staining.

(3) Molecular Biological Identification. DNA was extracted by the CTAB method for PCR amplification and was sent to GenScript Biotechnology Co., Ltd. (Nanjing, China) for molecular biological identification to determine the genus and species of the strain [9]. The bacterial strain genotype was identified by 16S rRNA gene sequence analysis universal ITS1 and ITS4 primers (ITS1: TCCGTAGGTGAACCTG CGG and ITS4: TCCTCCGCTTATTGATATGC). The similarity search of sequences was performed by conducting a comparison with the NCBI (http://www.ncbi.nlm.nlh.gov) database. The phylogenetic analysis was carried out by MEGA 5.0.

2.2.2. Screening of Antifungal Agents

(1) Preparation of the Fungal Suspension. The strain of *Aspergillus niger* from -80°C freezer stock was inoculated in the Czapek solid medium (3 g sodium nitrate, 1 g dipotassium hydrogen phosphate, 0.5 g magnesium sulfate, 0.5 g potassium chloride, 0.01 g ferrous sulfate, 30 g sucrose, 20 g agar, and 1000 mL distilled water) for culture. After 24 h of activation and culture with the three-phase streaking pattern, single colonies were distinguished on the Czapek solid medium, and a single colony was picked and diluted with sterile water to obtain the fungal suspension with a McFarland unit of 1.5 for later use [4].

(2) Dilution of Antifungal Agents. Natural preservatives, including protamine and essential oils derived from rose, chamomile, rosemary, garlic, and cinnamon, were selected for evaluation of the antifungal activities. The concentrations, solvents, and symbols of preservatives are listed in Table 1.

(3) Screening of Antifungal Agents. The sensitivity of *Aspergillus niger* 103 to six antifungal agents was detected by the agar diffusion method [10]. The dilutions of *Aspergillus niger* 103 cultures were spotted on the Czapek plates. Then, holes were punched out using a 6 mm cork borer in the plates, 100 μL of different concentrations of each antifungal agent was added into the holes, and the plates were incubated at

Table 1: Concentration, solvent, and symbol of six preservatives.

Preservatives	Concentration (mg/mL)	Solvent	Symbol
Protamine	10	Sterile water	F
Chamomile essential oils	2.5	Tween-80	I
Rosemary essential oils	2.5	Tween-80	J
Cinnamon essential oils	2.5	Tween-80	K
Garlic essential oils	2.5	Tween-80	L
Rose essential oils	2.5	Tween-80	M

37°C for 48 h. The growth of *Aspergillus niger* 103 was observed, and the diameter of the inhibition zone was measured with a vernier caliper to screen the best antifungal agent.

(4) Measurement of the Minimum Inhibitory Concentration (MIC) of Cinnamon Essential Oil against Aspergillus niger. The MIC of cinnamon essential oil against the *Aspergillus niger* 103 was determined by the broth dilution method cinnamon essential oil (25 mg/mL), and the cinnamon essential oil was dissolved in the Czapek solid medium that was sterilized and cooled to 50°C ± 2°C [11]. A stock solution of cinnamon essential oil with a concentration of 2500.00 μg/mL was prepared, and the stock solution was diluted by 10-fold serial dilution to concentrations of 250.00, 25.00, 2.50, 0.25, and 0.025 μg/mL with the Czapek solid medium. The medium was poured into the plates, and after the medium was solidified, 200 μL of the test fungal suspension was spread onto the plates. Sterile water was the blank control and inoculated, and triplicate biological replicates were set up for each concentration. The plates were inverted and incubated at 37°C for 24 h. The MIC of cinnamon essential oil was defined as the lowest concentration in which there was no visible growth of *Aspergillus niger* 103.

(5) Sensory Evaluation. Sensory evaluation was analyzed based on a previous method with some minor modifications [8]. The undamaged yams were stored for 2 weeks at 25°C and put into boxes (42 cm × 20 cm × 23.5 cm) made of corrugated paper, and 50 mL of 0MIC, 2MIC, and 4MIC cinnamon essential oil was sprayed inside the boxes. The order of the sample presentation was randomized, and the evaluations were carried out under ambient conditions (25°C). Thirty panelists were requested to examine the quality of yam for flavor and appearance of raw yam and the taste after steaming. After opening the boxes, the sensory analysis was performed within 2 h. Sensory profiles were evaluated based on 9-point hedonic scale (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely).

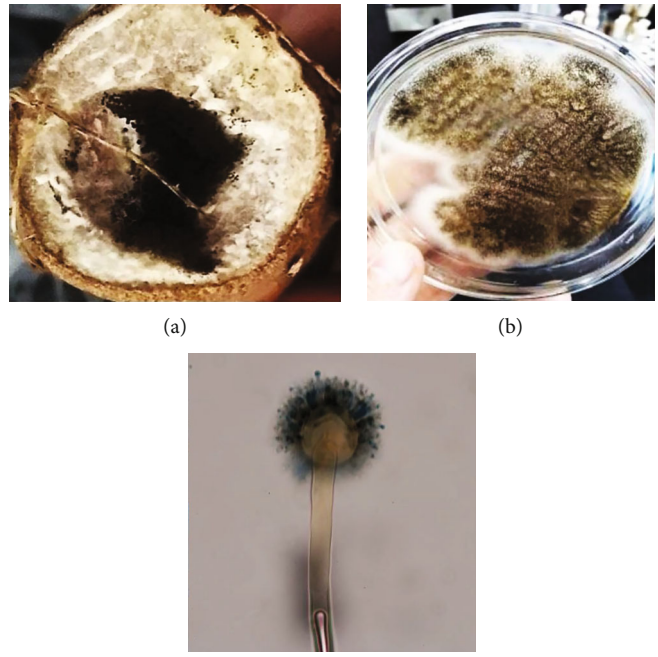
2.2.3. Growth Curve. The cinnamon is essential to the liquid mediums at a final concentration of 0MIC, 1/2MIC, 1MIC, 2MIC, and 3MIC, respectively. One percent *Aspergillus niger* 103 fungal solution (approximately 1×10^5 CFU/mL) was inoculated into a liquid medium and incubated at 37°C for 24 h with shaking. Sampling was conducted at a time interval of 2 h. The optical density (OD) of each sample was determined by a spectrophotometer (Model-722, Qingdao Juchuang Environmental Protection Group Co., Ltd., Qingdao, Shandong, China) at a wavelength of 600 nm. The OD600 was then plotted against inoculation time to obtain the OD-time relationship curve.

2.2.4. Cell Integrity. The seed cultures of *Aspergillus niger* 103 were inoculated into the Czapek liquid medium and incubated at 37°C, shaking at 150 rpm for 12 h. To determine the mechanisms of action of cinnamon essential oil against *Aspergillus niger* 103, we designed five treatments in this study: control and 1/2MIC, 1MIC, 2MIC, and 3MIC groups, with cinnamon essential oil concentrations of 0MIC, 1/2MIC, 1MIC, 2MIC, and 3MIC, respectively. The cultures were incubated at 37°C, 150 rpm for 8 h, and the fermentation cultures were collected every hour [12]. The ALP activity of the fermentation cultures of each group was determined by the ALP assay kit with a microplate reader, and the potassium ion (K^+) content was determined by the potassium assay kit with a microplate reader according to the instructions of the kit manufacturer (Nanjing Jiancheng Bioengineering Inc. Nanjing, China).

The electrical conductivity (RC) was measured as follows. The fungal solution from each group was cultured in a shaker at 37°C and 150 rpm for 6 h. The Thunder Magnetic Conductivity Meter (DDS-307A; Shanghai Yidian Scientific Instrument Co., Ltd. Shanghai, China) was used to measure the conductivity of the fungal solution every hour.

2.2.5. The Application of Cinnamon Essential Oil in Chinese Yam. The Chinese yam sample was cut into short rods with a length of 40 cm, and the cut surface of Chinese yam was infected by spraying with 100 μL of the fungal solution containing *Aspergillus niger* 103 in the stationary phase. Yam pieces were put into boxes (42 cm × 20 cm × 23.5 cm) made of corrugated paper, and 50 mL of 0MIC, 1/2MIC, 1MIC, 2MIC, or 3MIC cinnamon essential oil was sprayed inside the boxes. The cut surface of the Chinese yam pieces in the control group was not infected with the fungal solution and was directly put into a corrugated paper box [13]. Six test groups were set up for the shelf life test of Chinese yam, and 3 repeats were set up in each group. Finally, the cartons were placed from light at 10–25°C. Spoilage of the yam pieces was observed daily until the appearance of black plaques on the cut surface.

2.2.6. Data and Statistical Analysis. All experiments were performed in triplicate. The data were analyzed for statistical significance using SPSS 19.0 software. The data were expressed as the mean ± SD. One-way analysis of variance (ANOVA) was used to express the significance of differences ($P \leq 0.05$) between means. Figures were drawn using the SigmaPlot 14.0 software.



(a) (b) (c)

Figure 1: Manifestations of putrid Chinese yam (a), colony morphology (b), and cell characteristics (c) of dominant spoilage microorganism.

3. Results

3.1. Identification of Spoilage Fungi

3.1.1. Colony Morphology and Cell Morphology. Figure 1(a) shows the spoilage of yam with black plaques. The colonies of the dominant spoilage fungi were larger, loose in texture, round, dry, and opaque, with black mycelia in the middle and white mycelia at the edges, manifesting a loose shape (Figure 1(b)). And tight adhesion between the colonies and the medium was observed, so the colonies were difficult to pick. The different areas of the colonies exhibited different colors. The cell morphological characteristics (Figure 1(c)) were as follows: the conidia were spherical, dark brown, and rough; well-developed and branched mycelia were formed by septate, coenocytic, and multicellular hyphae (fungi); conidiophores arose vertically from swollen hyphal cells.

3.1.2. Molecular Biological Identification. The ITS fragment was amplified from the genomic DNA of the isolated fungus by PCR, producing an amplified product with a clear band of about 600 bp. To elucidate the phylogenetic relationship between the isolate and other species of the genus Aspergillus, an NJ phylogenetic tree was conducted (Figure 2). The 103 strain was most closely related to members of the genus; the sequence similarity values between *Aspergillus niger* ZZ6-10-1 and the 103 strain were 100% (accession number EHA21132.1). Combined with the results from colony morphology and cell morphology, strain 103 was within the genus Aspergillus.

3.2. Screening Results of Aspergillus niger 103 Inhibitors

3.2.1. Screening Results of Preservatives. As can be observed from Figure 3, rose essential oil (M), chamomile essential oil (I), or protamine (F) had no inhibitory effect on *Aspergillus niger* 103, while cinnamon essential oil (K), garlic essential oil (L), and rosemary essential oil (J) all had inhibitory effects on *Aspergillus niger* 103. The diameter of the inhibition zone of cinnamon essential oil (K) (2.46 ± 0.03 cm) was significantly larger than those of garlic essential oil (L) (1.86 ± 0.42 cm) and rosemary essential oil (J) (1.42 ± 0.06 cm).

3.2.2. Determination of MIC. The MIC of cinnamon essential oil for against of *Aspergillus niger* 103 was 25.00 μg/mL, as revealed by the broth dilution method.

3.2.3. The Effect of Cinnamon Essential Oil on Sensory Attributes of Chinese Yam. The sensory attributes of Chinese yam treated with cinnamon essential oil were evaluated at the end of the storage period, and the results are shown in Figure 4. Compared to the group with 0MIC cinnamon essential oil treatment, there was no major change in the overall acceptability scores of Chinese yams. After treated with 2MIC and 4MIC cinnamon essential oil, there was a slight drop in flavor ratings, but the results were not significant during the storage period. For the appearance of raw yam and the taste after steaming, there were no changes in the acceptability scores after the essential oil treatment.

3.3. The Effect of Cinnamon Essential Oil on the Growth of Aspergillus niger 103.

As shown in Figure 5, the growth of *Aspergillus niger* 103 followed a typical growth curve: 0-4 h was the lag phase; 4-12 h was the exponential growth phase; 12-18 h was the stationary phase. Subsequently, the strain entered the decay phase. The addition of 1/2MIC cinnamon essential oil in the fungal solution inhibited the growth of *Aspergillus niger* 103, and the absorbance value of the fungal

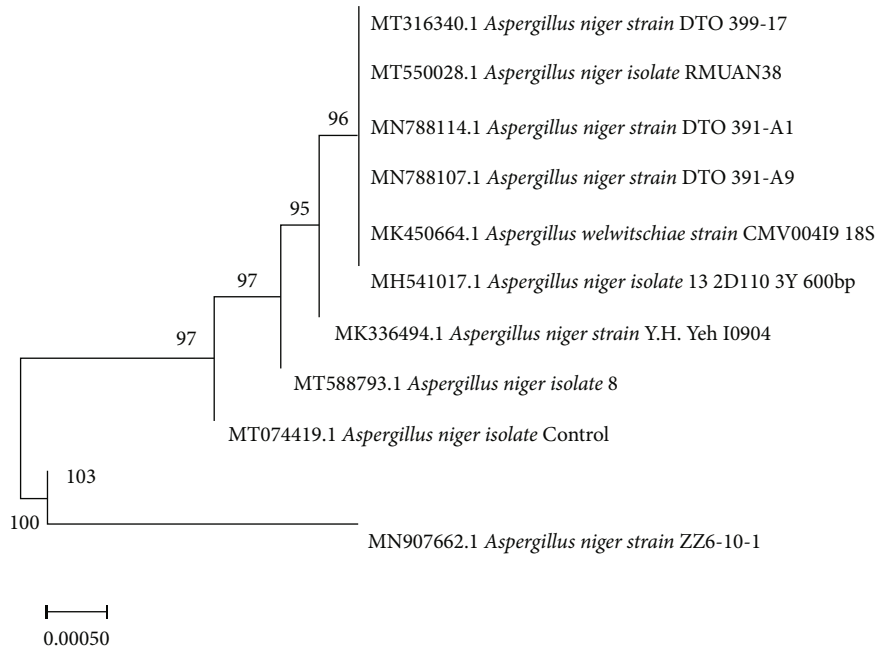


Figure 2: Phylogenetic tree of *Aspergillus niger* 103.

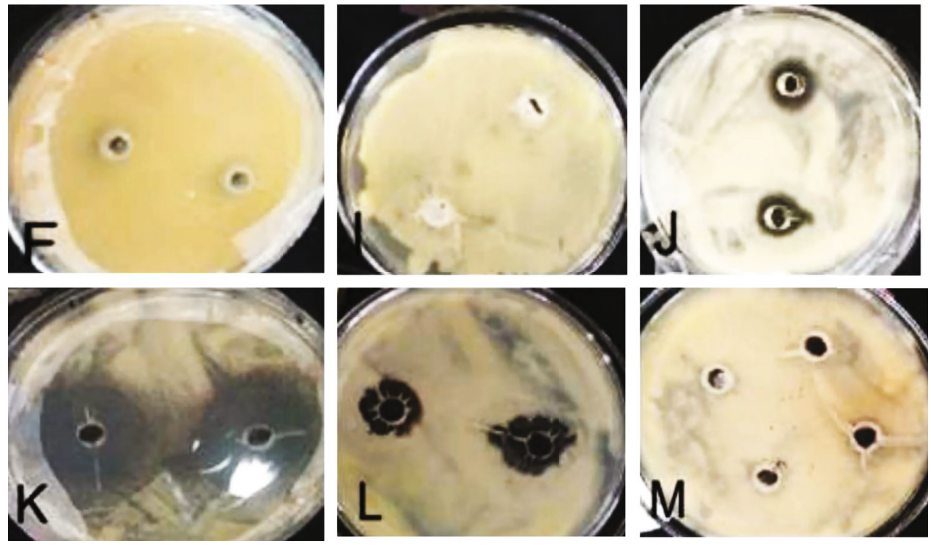


Figure 3: Bacteriostatic effect of six preservatives.

solution decreased significantly ($P \leq 0.05$). The antifungal effect was concentration-dependent. When 1MIC, 2MIC, and 3MIC of cinnamon essential oil were added to the fungal solution, the growth of *Aspergillus niger* 103 was almost completely inhibited.

3.4. Effects of Cinnamon Essential Oil on the Cell Wall and Cell Membrane Permeability of Aspergillus niger 103. The measurement results of ALP activity, RC, and K^+ content in *Aspergillus niger* 103 fungal solution after the addition of cinnamon essential oil are shown in Figure 6.

The ALP activity, K^+ content, and RC in the fungal solution all increased significantly after adding cinnamon essential oil. These results indicated that cinnamon essential oil can increase the permeability of the cell wall and cell membrane of *Aspergillus niger* 103, the extravasation of ALP in the cell wall, and the extravasation of electrolytes such as K^+ in the cell membrane, destroying the integrity of the cell wall and cell membrane. Therefore, the antifungal function disrupted the original cellular homeostasis.

3.5. Application Effect of Cinnamon Essential Oil on Chinese Yam. As can be observed from Figure 7, the storage life of the untreated group after smearing *Aspergillus niger* 103 solution was significantly shorter than that of the control group ($P \leq 0.05$). After spraying with cinnamon essential

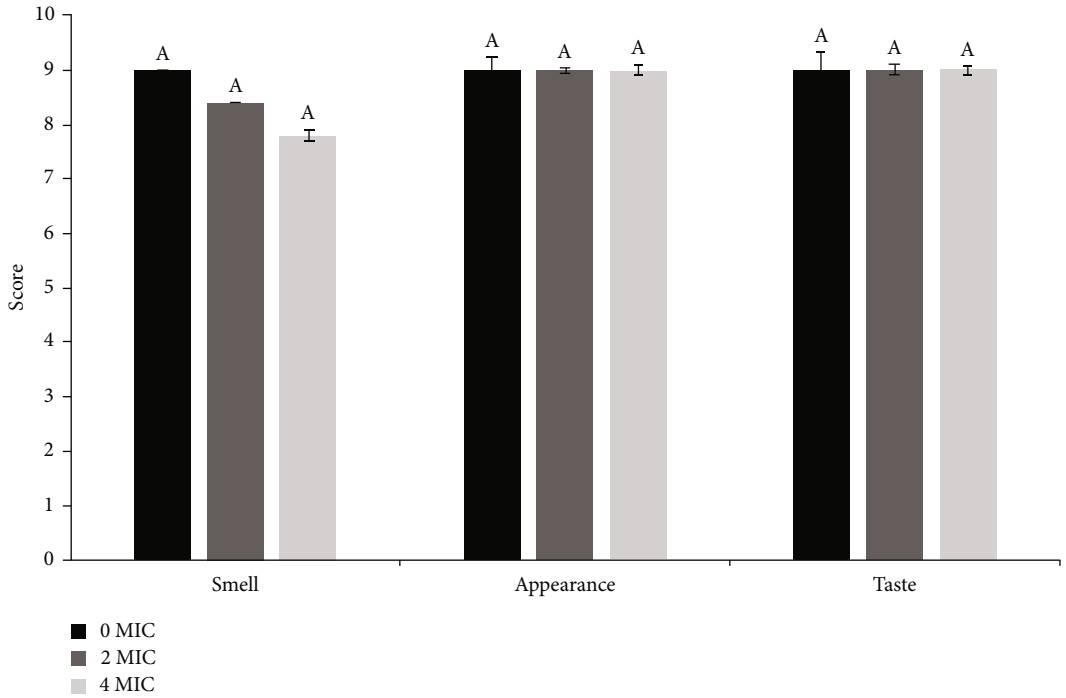


Figure 4: The effect of cinnamon essential oil on sensory attributes of Chinese yam.

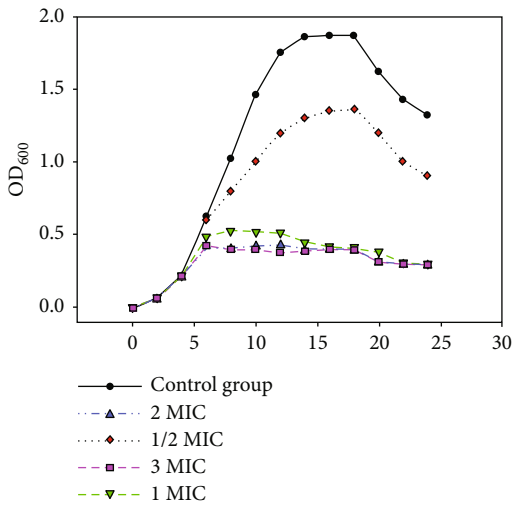


Figure 5: Effect of cinnamon essential oil on the growth of *Aspergillus niger* 103.

oil, the storage life was extended by 27.66 days. These results indicated that cinnamon essential oil played a key role in the preservation of Chinese yam ($P \leq 0.05$). Furthermore, the storage life was more greatly extended after 2MIC and 3MIC cinnamon essential oil spraying.

4. Discussion

4.1. Isolation and Identification of Spoilage Fungi on Black Plaques of Chinese Yam. It is difficult for spoilage fungi to infect yam when the surface of the yam tuber is intact. However, the skin of the yam was bruised and damaged in the process of harvesting, sorting, and transportation, and in this situation, it would be infected with spoilage fungi, resulting in rotting [14]. In this study, Chinese yam (Jiaozuo City, Henan Province) existed black mycelia or spots over the storage period that was used to isolate spoilage fungi, and the predominant fungus of yam was determined according to Koch's four postulates. Then, the spoilage fungus belonged to the genus of *Aspergillus* based on the ITS gene sequence analysis together with morphological characteristics. It has been demonstrated that *Aspergillus niger* is isolated from *Dioscorea rotundata* and rice [5, 15]. In this study, we isolated one strain of *Aspergillus niger* from yam with black plaques. However, Shiriki et al. isolated nine species of spoilage microorganisms from rotten yam over the storage period [5]. There might be some limitations when we focused on only one fungus.

4.2. Screening and Application of Antifungal Agents against Aspergillus niger 103 Derived from Chinese Yam during Storage. Six natural preservatives were selected and investigated for their inhibitory activity against *Aspergillus niger* 103. The results demonstrated that cinnamon essential oil was the best antifungal agent among the six preservatives, which could inhibit the growth of *Aspergillus niger* 103. In this study, a plate counting method was used to determine the antibacterial activity of essential oil. Some researchers also used the disc volatilization method to determine the antibacterial activity of essential oils [16–18]. These methods can be used to measure the experimental results effectively. When the damaged yam was sprayed with 1MIC of cinnamon essential oil, the storage life of the damaged yam was significantly extended by 27.66 days ($P \leq 0.05$).

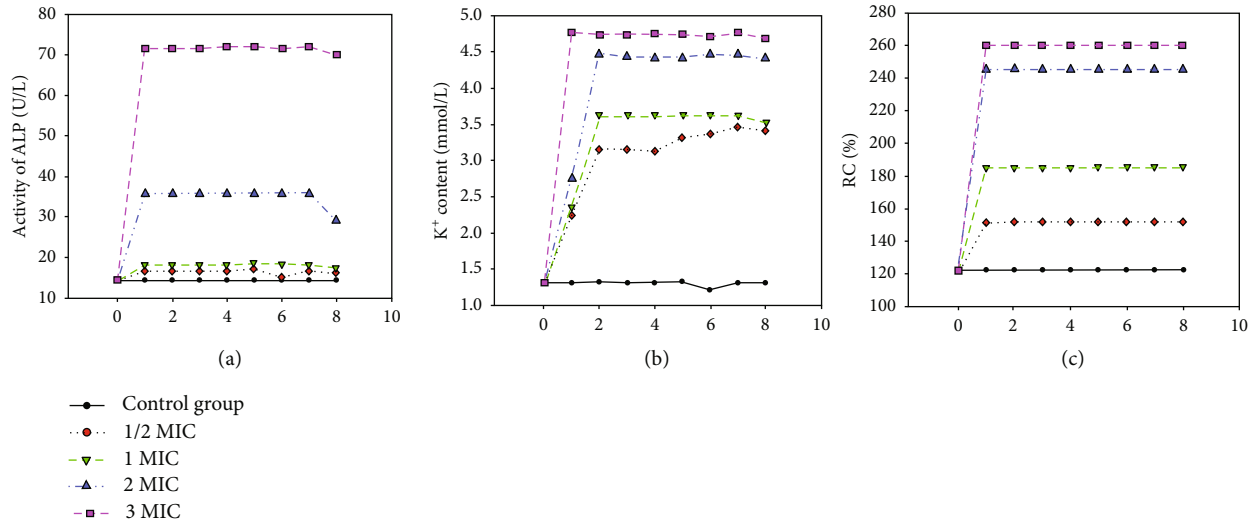


Figure 6: Effect of cinnamon essential oil on ALP activity (a), K^+ (b), and RC content (c) in *Aspergillus niger* 103 fungal solution.

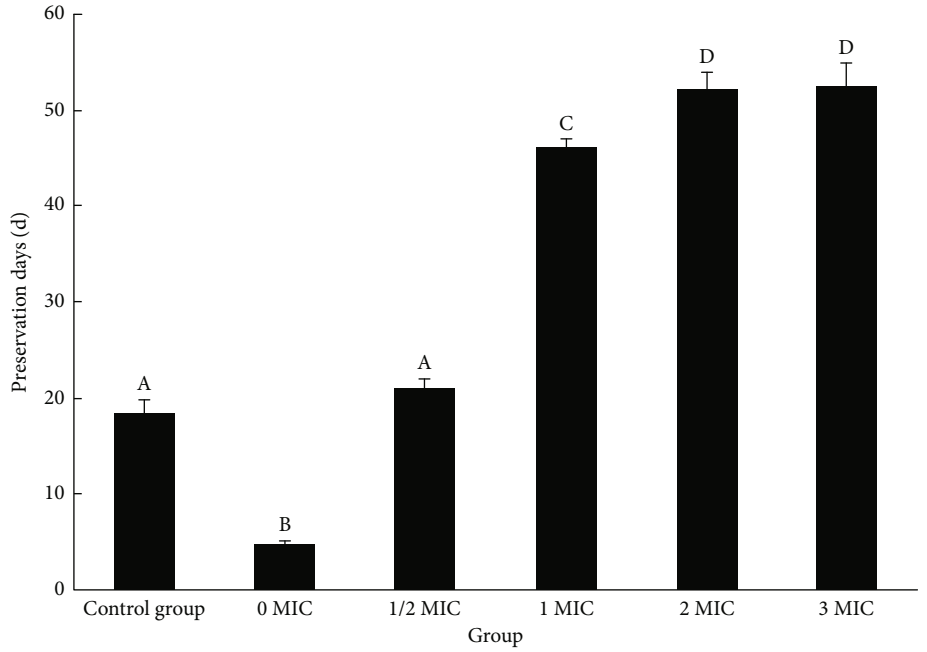


Figure 7: The storage life of Chinese yam with different concentrations of cinnamon essential oil. Different letters represent statistically significant differences between the means ($P \leq 0.05$).

The main components of cinnamon essential oil are trans-cinnamaldehyde and α-phellandrene [19]. Considerable advancements have been made in research on the effects of cinnamon essential oil on the postharvest preservation of vegetables and fruits owing to its anti-inflammatory, anticancer, antioxidant, insecticidal, and antifungal functions [8, 20]. Chitosan-coated cinnamon essential oil can preserve the physiological and quality characteristics of fresh dates when they are stored at 4°C for 60 days [21]. *Psidium guajava* L. fruit do not show significant changes in firmness, chlorophyll content, carotenoid content, pH, soluble solid content, or flavor index after storage at 10°C for 28 days with cinnamon essential oil treatment [22]. Cinnamon essential oil helps retain the edible and commercial value of mango stored at 25°C for 14 days and of apple stored at 5°C for 60 days [23, 24].

The MIC of cinnamon essential oil was 0.200 μL/mL for *Colletotrichum acutatum* [25], 0.05–0.10 mg/mL for *Aspergillus flavus* [26], and 0.250 μL/mL for *Aspergillus oryzae* [27]. In this study, the MIC of cinnamon essential oil against *Aspergillus niger* 103 was determined to be 25.00 μg/mL. The fluctuation of MIC may be due to the difference in extraction sites, harvest times, and geographical environments of cinnamon cultivation [25].

4.3. Antifungal Mechanism of Cinnamon Essential Oil against Aspergillus niger 103. Previous research showed that EO can cause bacterial death by causing cell wall disruption

and leakage of intracellular substances or inhibiting the proton motive force, mitochondrial respiratory and electron transport chain, and loss of metabolites and interrupts functional component (DNA, RNA, protein, lipid, and polysaccharides) synthesis [28]. In this study, under normal circumstances, ALP is present between the cell wall and cell membrane of *Aspergillus niger*, and K^+ and RC exist in the cytoplasm, with considerably low activity or content in the extracellular fungal solution [29]. When the permeability of the cell wall and cell membrane is enhanced, ALP can pass via the cell wall, and K^+ and RC be extruded into the extracellular fungal solution via the cell membrane and cell wall. Therefore, the degree of destruction of the cell wall and cell membrane can be indirectly reflected by the measurement of ALP, K^+, and RC.

After the addition of 1MIC of cinnamon essential oil into *Aspergillus niger* 103 solution, the ALP activity was significantly increased by 23.77% ($P \leq 0.05$). This indicated that the integrity of the cell wall of *Aspergillus niger* 103 was damaged, and the permeability was improved, and ALP was secreted into the extracellular fungal solution. Furthermore, the ALP activity in the fungal solution was increased with increasing concentrations of cinnamon essential oil. These results were consistent with the previous reports [30], and cinnamon essential oil could improve the permeability of the cell walls of *Staphylococcus aureus*, *Escherichia coli*, and *Streptococcus enteritidis* and significantly enhanced the ALP activity in the fungal solution.

When 1/2MIC of cinnamon essential oil was added into *Aspergillus niger* 103 fungal solution, the K^+ content and RC percentage significantly increased by 126.92% and 21.08% ($P \leq 0.05$), respectively. These results indicated that the barrier function of the cell membrane and cell wall was damaged, and ion homeostasis was disturbed by the addition of cinnamon essential oil, resulting in the loss of cellular functions. Researchers have also observed irreversible damage to the cell wall and cell membrane of molds such as *Aspergillus flavus* by cinnamon essential oil via transmission electron microscopy [31, 32].

The addition of cinnamon essential oil disrupted the permeability of cell membranes and cell walls of *Aspergillus niger* 103, ALP, and electrolytes (such as K^+) penetrated into the solution, which interfered with cellar functions, ultimately leading to cell death [33].

5. Conclusion

Cinnamon essential oil showed a significant inhibitory effect against the fungus *Aspergillus niger* 103, derived from the black plaques of rotten Chinese yam over the storage period. The storage life of Chinese yam was extended by 27.66 days by spraying with 1MIC (25.00 μg/mL) of cinnamon essential oil. Cinnamon essential oil exerted antifungal activity against *Aspergillus niger* 103 by destroying the integrity of the cell wall and cell membrane and inhibiting normal growth. Moreover, the antifungal ability of cinnamon essential oil against *Aspergillus niger* 103 was proportional to its concentration. Our findings demonstrated that cinnamon essential oil has great potential to be developed as a natural and efficient storage preservative for Chinese yam. However, the anti-*Aspergillus niger* mechanism of cinnamon essential oil requires further study, and more fungal strains and species should be tested.

Data Availability

The [DATA TYPE] data used to support the findings of this study are included within the article.

Additional Points

Practical Applications. Chinese yam, an important root crop, is prone to spoilage by airborne bacteria and fungi during prolonged storage. *Aspergillus niger* 103 was isolated from a rotten sample and screened the most effective antifungal agent from a panel of natural agents. The results demonstrated that spraying cinnamon essential oil was a natural and effective approach to extend the storage life of Chinese yam by almost a month.

Conflicts of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Authors' Contributions

WMC, WGL, LDH, and LEZ designed the study. WMC, LHY, DYY, LCD, XJ, and LEZ performed the experiments. WMC drafted the work. WMC, WGL, QZ, and LDH wrote and revised the manuscript. WMC, WGL, LEZ, and QZ revised the final version to be published.

Acknowledgments

This work was supported by the Science and Technology Development Plan Project of Henan Province of China (222102110243), the Key Scientific Research Project of Colleges and Universities in Henan Province (23A550018), and the Industrial Innovation and Development Research Project of Zhumadian City (20200102).

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