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In vitro assessment of *Eucalyptus citriodora* essential oil as phytopreservative against fungal contamination of Wheat grains during storage

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Abstract
Postharvest losses of wheat (*Triticum aestivum*) grains due to fungal infestation pose a serious challenge to food security and grain quality during storage. Wheat grains are highly susceptible to deterioration under higher temperature and moisture content along with suitable pH that favour microbial contamination. During study, collected stored wheat samples showed pH 6.58 and moisture content 13.86% that significantly correlating with increased fungal incidence. Dominant fungal contaminants isolated from wheat grains belonged to *Aspergillus*, *Cladosporium*, *Penicillium*, and *Fusarium* species. A total of 231 fungal isolates were recovered in which *Aspergillus flavus* (25.11%) exhibited highest relative density followed by *Cladosporium* sp. (18.61) and *Aspergillus niger* (13.85%), while, lowest relative density was found in *Aspergillus sydowii* (1.73%) followed by *Fusarium* sp. (3.03%). The minimum inhibitory concentration (MIC) of *Eucalyptus citriodora* essential oil against *Aspergillus flavus* was recorded at 9.0 µL/mL and also exhibited broad fungitoxic spectrum. The findings suggest that ECEO is an effective, eco-friendly botanical fungicide for the management of fungal infestation in stored wheat grains.

Keywords: *Eucalyptus citriodora*, essential oil, wheat grains, *Aspergillus flavus*, antifungal

Introduction
Wheat (*Triticum aestivum* L.) is one of the most important staple cereal crops worldwide and a key pillar of food security in developing countries, including India. It contributes substantially to global cereal production and serves as a major source of calories, proteins, and essential nutrients. [1] In India, wheat is extensively cultivated in the Indo-Gangetic plains and plays a vital role in national food reserves, farmer's livelihoods, and agro-based industries. Despite its importance, considerable quantities of wheat are lost annually during storage due to fungal and insect infestations, resulting in quality deterioration, economic losses, and food safety concerns. [2,3]
Fungal deterioration of wheat grains is one of the major reasons of post-harvest losses are mainly caused by storage fungi such as *Aspergillus*, *Penicillium*, and *Fusarium* species. [4] These agents cause both quantitative and qualitative damage to stored grains. Fungal infestation often leads to mycotoxin production, particularly aflatoxins, which are carcinogenic and immunosuppressive, posing serious health risks. [5]
Traditionally, storage pests have been managed using synthetic pesticides and fumigants such as phosphine and organophosphates. [6] Although effective, their indiscriminate use has led to pest resistance, environmental contamination, toxic residues in food, and human health hazards. [7] Increasing regulatory restrictions and the phase-out of hazardous chemicals have further emphasized the need for safer alternatives.
Botanical pesticides have emerged as eco-friendly options due to their biodegradability, low mammalian toxicity, and complex bioactive constituents. [8] Among these, *Eucalyptus citriodora* Hook. essential oil, rich in citronellal and other terpenoids, has shown strong antifungal efficacy against storage moulds. [9] This study evaluates the efficacy of *E. citriodora* essential oil as a botanical fungicide for managing fungal infestation in stored wheat grains, aiming to support sustainable and safe post-harvest pest management strategies.

Materials and Methods
1. Collection and preparation of samples:
Stored wheat grain samples (500 g) were collected from local retailer of Gorakhpur, Uttar Pradesh, India, during October 2025, using sterile, labeled polyethylene bags. The samples were transported to the laboratory and stored under suitable conditions until further physicochemical and mycological analyses. [10]

2. Determination of pH
The pH of collected wheat grain samples was determined using a digital pH meter. Ten grams of collected wheat grains was finely ground and mixed with 100 mL of distilled water. The suspension was stirred thoroughly, allowed to settle, and its pH was measured using a calibrated pH meter. [11]

3. Determination of moisture content (%)
The moisture content of collected wheat grain samples was determined using the oven-drying method. Approximately 5 g of grains was weighed in a pre-weighed moisture dish and dried in a hot-air oven at 100°C until a constant weight was obtained. Moisture content (%) was calculated from the weight loss. [12]

4. Mycoflora analysis of wheat grain samples:
Mycoflora analysis of collected wheat grain samples was performed using the standard dilution plate method.

Approximately 10 g of wheat grains was homogenized in 90 mL of sterile distilled water and serially diluted. An aliquot of each dilution was inoculated onto potato dextrose agar (PDA) supplemented with an appropriate antibiotic to suppress bacterial growth. The plates were incubated at 27 ± 2°C for 7 days. [10] Emerging fungal colonies were counted, isolated, and identified based on their morphological and microscopic characteristics. [13,14]

$$\text{Relative Density of fungus (\%)} = \frac{\text{No. of isolates of a fungus}}{\text{Total no. of isolates of all fungi}} \times 100$$

5. Test fungi

Aspergillus flavus was selected as main test fungus due to its higher relative density and well known aflatoxigenic potency. Other seven (07) fungal taxa *viz. Alternaria* sp., *Aspergillus fumigatus*, *Aspergillus niger, Aspergillus terreus*, *Cladosporium* sp., *Fusarium* sp. and *Penicillium* sp. isolated during mycological analysis were selected to determine fungitoxic spectrum of essential oil.

6. Extraction of *Eucalyptus citriodora* essential oil

The leaves (500 g) of *Eucalyptus citriodora* were washed and hydro-distilled using a Clevenger apparatus for 3 hrs. The essential oil was separated from the aqueous phase, collected, and dried over anhydrous sodium sulphate. The extracted oil was stored in airtight amber glass vials at 4±2 °C until further analysis. [15]

7. Antifungal activity of *Eucalyptus citriodora* essential oil

The antifungal activity of *Eucalyptus citriodora* essential oil against *Aspergillus flavus* was evaluated using the poisoned food technique. [16] Different concentrations of essential oil were incorporated into molten potato dextrose agar (PDA), mixed thoroughly, and poured into sterile Petri plates. Each plate was inoculated with a fungal mycelial disc (5 mm) and incubated at 27 ± 2°C. Radial growth was measured and compared with the untreated control to calculate percentage inhibition. [16]

8. Fungitoxic spectrum of *Eucalyptus citriodora* essential oil

The fungitoxic spectrum of *Eucalyptus citriodora* essential oil was evaluated against seven fungal isolates *viz. Alternaria* sp., *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus terreus*, *Cladosporium* sp., *Fusarium* sp. and *Penicillium* sp. isolated during mycological analysis of collected wheat grain samples at 9.0 µL/mL i.e. minimum inhibitory concentration (MIC) against *Aspergillus flavus* using the poisoned food technique. [16] The poured Petri plates were inoculated separately with mycelial discs (5 mm) of each fungal isolate. The inoculated plates were incubated at 27 ± 2°C for 7 days. Radial growth of control and treatment sets was measured and percentage inhibition was determined. [15]

9. *In situ* fumigant activity of *Eucalyptus citriodora* essential oil against *Aspergillus flavus*

To determine the fumigant antifungal efficacy of *Eucalyptus citriodora* essential oil during storage, 100 g of fresh wheat grains were kept separately (three sets) in different plastic containers having aerial volume 250 mL. Each container was inoculated with 1 mL spore suspension (≈10^6 spores/mL) of *Aspergillus flavus*. Two sets of containers were fumigated separately with *Eucalyptus citriodora* essential oil having concentrations 9.0 µL/mL and 18.0 µL/mL (v/v) i.e. MIC and 2×MIC against *Aspergillus flavus*, while one set of container run parallel as control without essential oil treatment. All the containers were sealed and stored for six months at room temperature. [17] After storage, mycological analysis of fumigated wheat grains for only *Aspergillus flavus* extent was performed. [10]

Result and Discussion

The collected stored wheat grains studied in the present study had a pH of 6.58 and relatively high moisture content (13.86%) suggesting favourable conditions for the development of storage fungi and rapid biodeterioration during storage (Table 1). One of the most significant factors influencing the growth of storage fungi in wheat grains is moisture content; high moisture content encourages seed respiration, enzymatic activity, lipid degradation, and microbial colonization. [18,19] The high moisture contents in wheat grains make them more vulnerable to fungal invasion and aflatoxin contamination during storage. [20,21,22] The slightly acidic pH of the seeds may have encouraged the growth of storage fungi, particularly *Aspergillus* and *Penicillium* species, thrive in mildly acidic environments. [23]

Table 1: pH and moisture content (%) of collected wheat grains

Parameter	Groundnut seed sample
pH	6.58±0.17
Moisture content (%)	13.86%

Mycological study of collected wheat grains indicated the presence of 231 fungal isolates belonging to five different genera with some unidentified forms indicating substantial fungal contamination of the stored grains. The dominant fungal flora consisted of *Aspergillus* species like *Aspergillus flavus*, *Aspergillus fumigatus*, *Aspergillus niger*, *Aspergillus sydowii* and *Aspergillus terreus*. Similar predominance of *Aspergillus* spp. in stored wheat grains was found in earlier reports. [24,25,26] Aspergilli are considered typical storage fungi because they can grow in the high temperatures and low water activity that are often found during storage. *Aspergillus flavus* had the highest relative density among the isolated fungi (25.11%), followed by *Cladosporium* sp. (18.61%) and *Aspergillus niger* (13.85%) (Table 2; Figure 1). The dominance of *Aspergillus flavus* is very important since this fungus is known to produce aflatoxins, especially aflatoxin B1, one of the most hazardous natural carcinogens. [5,27] The frequent prevalence of *Aspergillus flavus* in stored wheat grains and its relationship with aflatoxin contamination have also been reported in earlier reports. [28]

Table 2: Mycoflora analysis of collected stored wheat grain sample

Isolated fungi	No. of fungal isolates	Relative density %
Alternaria sp.	12	5.19
Aspergillus flavus	58	25.11
Aspergillus fumigatus	20	8.66
Aspergillus niger	32	13.85
Aspergillus sydowii	04	1.73
Aspergillus terreus	14	6.06
Cladosporium sp.	43	18.61
Fusarium sp.	07	3.03
Penicillium sp.	18	7.79
Unidentified	23	9.96
Mucorales *	4 Genera	-
Total isolates	231	

*Members of order Mucorales are not included

The second most frequent group of fungi isolated from the wheat grains was *Cladosporium* sp. *Cladosporium* spp. are important storage fungi that can cause seed discolouration and loss in germination potential. [29] The high incidence of *Cladosporium* sp. in the present investigation signifies inadequate storage hygiene and excess moisture situations. Another prominent spoilage fungus related with deterioration of stored food commodities was *Aspergillus niger*, recorded with 13.85% relative density. *Aspergillus sydowii* recorded the lowest relative density (1.73%) followed by *Fusarium* sp. (3.03%) and *Alternaria* sp. (5.19%) (Table 2). The low incidence of *Fusarium* sp. and *Alternaria* sp. could be related to poor adaption to xerophilic storage conditions than *Aspergillus* spp. [10,30,31]

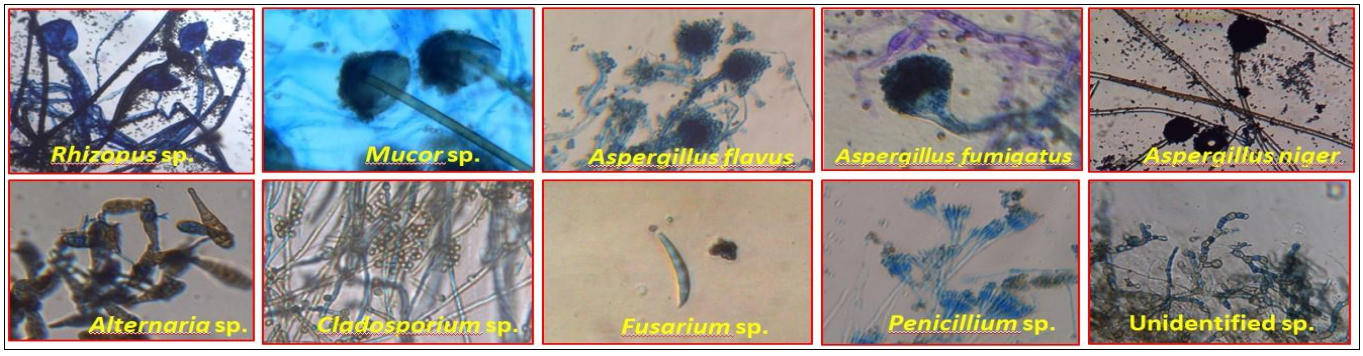


Fig 1: Some storage fungi (microscopic) isolated from stored wheat grains

The antifungal activity of *Eucalyptus citriodora* essential oil against *Aspergillus flavus* was evaluated using the poisoned food technique. The essential oil exhibited a concentration-dependent inhibitory effect on fungal growth. The untreated control showed maximum colony development (4.90 ± 0.75 cm), whereas treatment with 1.0 µL/mL reduced colony diameter to 3.27 ± 0.60 cm, corresponding to 33.26% inhibition. A substantial increase in antifungal activity was observed at 3.0 µL/mL (78.16%), followed by 90.41 and 95.31% inhibition at 5.0 and 7.0 µL/mL, respectively. Complete inhibition of visible mycelial growth (100%) was achieved at 9.0 µL/mL (Table 3). These findings are supported by Khan *et al*. [32], who demonstrated antifungal and antimycotoxigenic potential of *Eucalyptus citriodora* essential oil and its major constituents, citronellal and β-citronellol, against mycotoxigenic fungi. Similarly, Cai *et al*. [33] reported strong antifungal activity associated with citronellal-rich essential oil. Overall, the results demonstrate the potential of *Eucalyptus citriodora* essential oil as a botanical fungitoxicant for managing fungal deterioration of stored wheat grains.

Table 3: Antifungal activity of *Eucalyptus citriodora* essential oil against *A. flavus* using poisoned food technique

Concentration (µl/ml)	Colony diameter (cm)	Percent inhibition
Control	4.90±0.75^{c}	0.00
1.0	3.27±0.60^{b}	33.26
3.0	1.07±0.21^{a}	78.16
5.0	0.47±0.06^{a}	90.41
7.0	0.23±0.06^{a}	95.31
9.0	0.00±0.00^{a}	100.00

Values are mean (n = 3) ± SD; P < 0.05; Means followed by same letter in the same column are not significantly different according to ANOVA and Tukey's multiple comparison tests

The fungitoxic spectrum of *Eucalyptus citriodora* essential oil was evaluated against seven storage associated fungal species at MIC (9.0 µL/mL) and 2×MIC (18.0 µL/mL). At MIC, complete inhibition (100%) was observed against all the tested fungal taxa except *Alternaria* sp. and *Cladosporium* sp. exhibited inhibition of 93.38% and 86.17%, respectively (Table 4). Interestingly, increasing the concentration to 2×MIC resulted in complete inhibition

(100%) of all tested fungal species, indicating a broad-spectrum antifungal potential of the essential oil (Table 4). The pronounced activity against *Aspergillus* and *Penicillium* species is particularly important because these genera are frequently associated with deterioration of stored agricultural commodities. [34,35] Similar findings were reported by Khan *et al*. [32], who demonstrated antifungal activity of *Eucalyptus citriodora* essential oil and its major constituents against mycotoxigenic fungi. Furthermore, a recent study, innovative antifungal and food preservation potential of *Eucalyptus citriodora* essential oil in combination with modified potato peel starch, reported complete inhibition of *Aspergillus niger* and *Penicillium griseofulvum*, supporting its potential in food preservation. [32]

Table 4: Fungitoxic spectrum of *Eucalyptus citriodora* essential oil against some storage fungi

Fungi	Percent inhibition (%)	
	MIC (9.0 µL/mL)	2×MIC (18.0 µL/mL)
Alternaria sp.	93.38	100
Aspergillus fumigatus	100	100
Aspergillus niger	100	100
Aspergillus terreus	100	100
Cladosporium sp.	86.17	100
Fusarium sp.	100	100
Penicillium sp.	100	100

The six-month fumigation trial demonstrated a reduction in recoverable *Aspergillus flavus* isolates in *Eucalyptus citriodora* essential oil treated wheat samples. At MIC (9.0 µL/mL), the number of isolates decreased from 674 in the control to 334, representing 50.45% inhibition. Fumigation at 2×MIC (18.0 µL/mL) further reduced the count to 283 isolates (58.01% inhibition) (Table 5). Although the higher concentration improved suppression, the response was not proportional to the dose increase, suggesting that prolonged fumigation may provide sustained but incomplete control of *Aspergillus flavus*. Recent studies similarly support the use of essential oil vapours for managing storage fungi and mycotoxigenic *Aspergillus* species. [12,15,16] These findings suggest that *Eucalyptus citriodora* oil has potential as a botanical fumigant for reducing *Aspergillus flavus* contamination during prolonged wheat storage.

Table 5: Percent inhibition in *Aspergillus flavus* isolates after six months fumigation of *Eucalyptus citriodora* essential oil

Samples	No. of *A. flavus* isolates	Per cent inhibition
Control	674	-
Fumigation at MIC (9.0 µL/mL)	334	50.45
Fumigation at 2×MIC (18.0 µL/mL)	283	58.01

Conclusion

The present study revealed that the stored wheat grains are highly susceptible to fungal infestation mainly by *Aspergillus flavus* along with several other species of storage fungi under high moisture conditions. *Eucalyptus citriodora* essential oil showed high potency along with broad range antifungal activity with good suppression of storage fungi. Therefore, *Eucalyptus citriodora* essential oil can be an effective eco-friendly and natural phytopreservative for improving storage quality and safety of wheat grains.

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References

1. Sharma K, Sharma P. Wheat as a nutritional powerhouse: Shaping global food security. in *Triticum* - The pillar of global food security, (eds) Meena VS, Jaiswal JP, Jinger D, Paramesh V. IntechOpen, 2025. https://doi.org/10.5772/intechopen.1009499.
2. Kumar D, Kalita P. Reducing postharvest losses during storage of grain crops to strengthen food security in developing countries. Foods,2017:6(1):8.
3. Singh G, Joshi NK. Insect pests of wheat in north India: A comprehensive review of their bio-ecology and integrated management strategies. Agriculture,2025:15(19):2067.
4. He X, Zhao JQ, Wu B, Fan YY, Zhang M, Wu Q, *et al*. Effects of dominant fungi on wheat quality during storage. Foods,2026:15(9):1595. DOI:10.3390/foods15091595.
5. Koshiol J, Yadav A, Groopman JD, Dutta U. Aflatoxins and human health: Global exposure, disease burden, and one health strategies. Toxins (Basel),2026:18(2):90. DOI:10.3390/toxins18020090.
6. Rajendran S. Insect pest management in stored products. Outlooks Pest Management,2020:31:24–35.
7. Islam T, Danishuddin, Tamanna NT, Matin MN, Barai HR, Haque MA. Resistance mechanisms of plant pathogenic fungi to fungicide, environmental impacts of fungicides, and sustainable solutions. Plants,2024:13(19):2737.
8. Ashokkumar K, Murugan M, Prasath GA, Dhanya MK. Botanical sources, mechanisms and efficacy of biopesticides derived from plant essential oils. Discover Plants,2026:3:180. https://doi.org/10.1007/s44372-026-00662-5
9. El Youssfi C, Charki A, Afassi F, El Hassania L, Ahari M, Amhamdi H, *et al*. Extraction methods, chemical composition and biological activities of essential oils. Food Chemistry Advances,2026:13:101405. https://doi.org/10.1016/j.focha.2026.101405
10. Kumar A, Dubey NK, Srivastava S. Antifungal evaluation of *Ocimum sanctum* essential oil against

fungal deterioration of raw materials of *Rauvolfia serpentina* during storage. Industrial Crops and Products,2013:45:30-35.
11. Kedia A, Prakash B, Mishra PK, Dwivedi AK, Dubey NK. *Trachyspermum ammi* L. Essential oil as plant based preservative in food system. Industrial Crops and Products,2015:69:104-109.
12. Kumar A, Kumari S, Dubey NK. Assessment of *Ocimum canum* Sims. essential oil as phyto-preservative against fungal deterioration of vasicine of stored herbal raw materials of *Justicia adhatoda* L. Journal of Postharvest Technology,2023:11(1):77-94.
13. Gilman JC. A manual of soil fungi. Biotech Books, New Delhi, 1998.
14. Mukerji KG, Manoharachary C. Taxonomy and ecology of Indian fungi. IK International Pvt. Ltd., 2010.
15. Rao R, Kumari S, Kumar A. Evaluation of chemically characterized *Ocimum tenuiflorum* L. essential oil as phytopreservative against fungal deterioration of *Justicia adhatoda* L. raw materials during storage. International Journal of Current Microbiology and Applied Sciences,2024:13(8):132-145.
16. Kumar A, Shukla R, Prakash B, Kumari S, Dubey NK. Chemically characterized *Apluda mutica* L. (*Poaceae*) essential oil: a novel antifungal, aflatoxin suppressor and antioxidant. Vegetos, 2026. https://doi.org/10.1007/s42535-026-01862-w
17. Maddheshiya K, Arif N, Fatma S, Rao R, Pawar A, Kumari S, *et al*. *In vitro* assessment of *Ocimum basilicum* essential oil as phytopreservative against fungal contamination of groundnut seeds during storage. International Journal of Agriculture and Plant Science,2026:8(2):163-167.
18. Li Y, Huang Z, Petropoulos E, Ma Y, Shen Y. Humidity governs the wall-inhabiting fungal community composition in a 1600-year tomb of Emperor Yang. Scientific Reports,2020:10(1):8421.
19. Pan Z, Li X, Zhao R, Nie J, Fang Y, Zhang X, *et al*. Advances in postharvest storage of edible fungi: mechanisms, technologies, and future perspectives. Agricultural Products Processing and Storage,2026:2:9.
20. Mutegi CK, Wagacha JM, Christie ME, Kimani J, Karanja L. Effect of storage conditions on quality and aflatoxin contamination of peanuts (*Arachis hypogaea* L.). International Journal of AgriScience,2013:3(10):746-758.
21. Yeboah A, Ahiakpa JK, Adjei-Nsiah S. Aflatoxin levels in seeds of commonly grown groundnut varieties (*Arachis hypogaea* L.) in Ghana as influenced by storage method. African Journal of Food, Agriculture, Nutrition and Development,2020:20(1):15402-15414.
22. Aminou MM, Falalou H, Abdou H, Mendu V. Aflatoxin B1 Contamination Association with the Seed Coat Biochemical Marker Polyphenol in Peanuts Under Intermittent Drought. Journal of Fungi,2024:10(12):850.
23. Divya V, Malarkodi K, Mathiyazhagan S, Manonmani V, Anand T, Velayutham A. Effect of pH on the mycelial growth of *Aspergillus niger* and *Aspergillus flavus*. International Journal of Environment and Climate Change,2023:13(10):1104-9.
24. Kumari R, Jayachandran LE, Ghosh AK. Investigation of diversity and dominance of fungal biota in stored wheat grains from governmental warehouses in West Bengal, India. Journal of the Science of Food and Agriculture,2019:99:3490–3500.
25. Mahata PK, Dass RS, Gunti L, Thorat PA. Studies on seed-borne fungi, *Aspergillus* diversity, and their detection using beta-tubulin gene sequences in *Foeniculum vulgare* seeds in India. Frontiers in Microbiology,2026:17:1782984. DOI:10.3389/fmicb.2026.1782984
26. Rafique A, Sharmin S, Raj A, Mohiuddin AL, Mahmud MIA, Bin Md Omer H. Comparative overview of *Aspergillus fumigatus*, *A. flavus*, and *A. niger*: Pathogenicity, resistance, and public health significance. Journal of Infection and Public Health,2026:19:103070.
27. Ahmad T, Wang S, Liu Y. *Aspergillus flavus* and Aflatoxins (3rd Edition). Toxins (Basel),2025:17(7):326.
28. Dadzie MA, Oppong A, Ofori K, Eleblu JS, Ifie EB, Blay E, *et al*. Distribution of *Aspergillus flavus* and aflatoxin accumulation in stored maize grains across three agro-ecologies in Ghana. Food Control,2019:104:91-98. https://doi.org/10.1016/j.foodcont.2019.04.035
29. Olszak-Przybyś H, Korbecka-Glinka G. The diversity of seed-borne fungi associated with soybean grown in Southern Poland. Pathogens,2024:13(9):769. DOI:10.3390/pathogens13090769
30. Aiswarya N, Bhattiprolu SL, Reddy Bayyapu K, Rao Rama G. Effect of *Aspergillus* spp. on seed quality characters of groundnut. Indian Journal of Agricultural Research,2024:58(2):306-312.
31. Guo Z, Zhang J, Wang H, Li S, Shao X, Xia L, *et al*. Advancing detection of fungal and mycotoxins contamination in grains and oilseeds: Hyperspectral imaging for enhanced food safety. Food Chemistry,2025:470:142689.
32. Khan N, Fatima S, Sadiq MB. Innovative antifungal and food preservation potential of *Eucalyptus citriodora* essential oil in combination with modified potato peel starch. Foods,2025:14(4):602. https://doi.org/10.3390/foods14040602
33. Cai H, Xie P, Zhang X, Lin Z, Xu Z, Chen S, *et al*. Biotoxicity of essential oil of *Eucalyptus citriodora* Hook (*Myrtaceae*) to dust mites. Frontiers in Plant Science,2025:16:1708798. DOI:10.3389/fpls.2025.1708798
34. Quaglia M, Tini F, Bajrami E, Quadrini E, Fedeli M, Sulyok M, *et al*. Occurrence of *Aspergillus* and *Penicillium* species, accumulation of fungal secondary metabolites, and qPCR detection of potential aflatoxigenic *Aspergillus* species in chickpea (*Cicer arietinum* L.) seeds from different farming systems. Foods,2025:14(15):2610. DOI:10.3390/foods14152610
35. Zakaria L. An overview of major *Penicillium* species associated with plant diseases. Journal of Fungi,2026:12(4):286. https://doi.org/10.3390/jof12040286