Efficacy of three botanicals on postharvest fungal contaminants of melon (Citrullus colocynthis) kernels

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INTRODUCTION
Melon (Citrullus colocynthis L.) commonly known as Egusi is an important crop used mainly for soups in Nigeria. Egusi: as it is commonly called in Nigeria is contaminated by many fungal pathogens which reduce quality of seeds during storage. Use of botanicals can be a safe method to manage fungal contamination instead of chemicals which pose threat to human health. Therefore, efficacy of Piper guineense, Xylopia aethiopica and Ocimum gratissimum on fungi in shelled Egusi seed kernels (EK) were evaluated. One market in each of six South-western Nigerian states where Egusi is sold was purposively selected in 2012 and 2013. Egusi kernels (%/kg, n = 162) were purchased from selected traders for fungi isolation, identification and incidence (%) determination. Clean EK treated with botanical powder (10, 20 and 40 g kg⁻¹) were inoculated with Aspergillus flavus, A. niger, A. tamaris, Rhizopus sp., Penicillium aurantiogriseum, P. citrinum and Fusarium solani bi-weekly for 14-week storage period to evaluate growth reduction (%). Control was inoculated with sterile distilled water. Aspergillus flavus, A. niger, A. tamaris, Penicillium citrinum, P. aurantiogriseum, Fusarium solani and Rhizopus sp. were frequently encountered in EK. Aspergillus (32.4±1.6%) was the most predominant fungus followed by Rhizopus (21.5±2.0%) in all States. Piper guineense (40 g kg⁻¹) powders significantly reduced aflatoxin contamination by 42.5%, 56.5% and 45.0%, respectively; fungi growths were progressively reduced by P. guineense (5.5-90.0%), X. aethiopica (6.7-100.0%) and O. gratissimum (40.0%) reduced fungi growth on Egusi considerably and therefore could be used as a safe management option to mitigate storage fungi contamination in Egusi kernels.

Melon (Citrullus colocynthis L.) commonly known as Egusi is an important soup spice produced in Western Nigerian states. Many groups of fungi are known to contaminate Egusi seeds during storage. They reduce seed storability, quality, export and marketability potentials; and above all deposit a large number of metabolites in the seeds; some of which are toxic to humans (Chiejina, 2006; Atehnkeng et al., 2008). Fungi species belonging to the genera Rhizopus, Penicillium amongst others have been reported as seed pathogens of Nigerian stored Egusi seed. Many storage fungi that have been variously implicated in the spoilage of fruits and vegetables have been isolated from Egusi seeds by various authors (Chiejina, 2006; Aboloma et al., 2009; Aboloma et al., 2012). Fungal deterioration of seeds occurs in form of rot, sclerotization of seed, and seed discolourization (Shetty 1992). Prior to harvest of Egusi seeds, fungal infection may not be up to the level that can lead to economic damage. Small quantities of spores of storage fungi may be present on grain meant for storage or may be present on spilled grains present in storage equipment or structures. This small amount of inoculum can multiply rapidly leading to significant grain infection under poor storage conditions. Bankole (1993) reported as many as 13 storage fungal species in stored Egusi seeds. Also, Chiejina (2006) isolated thirteen different fungal species and
two unidentified species from Egusi seed kernel. These fungi are widely distributed and almost always present on the seeds during storage. However, the development of these fungi are influenced by the moisture content, the temperature, the condition of the Egusi seed going into storage, the length of time the seed is stored and the amount of insect and mite activity in the stored seed.

Interestingly, nature supplies a reasonable number of plant products that have useful properties for crop protection, which are often neglected in favour of commercial products. These natural substances cause little disturbance to the natural balance between living organisms. They are cheap and can be produced by farmers from local sources. They are often harmless to humans and animals and are rarely toxic to plants when compared with artificial (Dusanee, 2011).

The use of benzoic acid, gamma-irradiation and fumigants to prevent postharvest fungal contamination have been emphasized and in use but they are not safe for crops meant for human consumption. Treatment with natural products from plants or herbs (botanicals) which are edible prior to storage is a safe option for grains meant for humans. The botanicals are mostly available locally and are not potential environmental and biological hazards. The possibilities of using botanical pesticides seem almost endless and their potentials can be fully exploited (Yallappa et al., 2012). The prevention of postharvest fungal contamination in Egusi is one of the best and most effective strategies to reduce yield loss and maximize income from harvested seeds; hence the need to assess the potentials of some medicinal plants for the control of storage fungi in stored Egusi seed kernels. The objective of this study therefore was to determine the effects of selected botanicals on fungal growth in treated Egusi seed kernels.

MATERIALS AND METHODS

Sample Collection
A total of 162 melon vendors were randomly selected in each of the six South-western Nigerian States (Sabo in Ondo, Sabo in Ekiti, Oto in Lagos, Sabo in Ogun, Oja Oba in Osun, Bodija in Oyo) in 2012 and 2013. Shelled melon seeds (kernel) were purchased directly from a major market where melon from the producing areas is unloaded in each of the six south-western states of Nigeria. For each market visited Simple random sampling was adopted for sample collection. From each trader, 0.5-1 kg of melon seed was purchased and taken to the laboratory for studies. Various melon seeds were purchased from three traders at different points within the same market, packed into different polythene bags and these served as the replicates. For each bag, sampled melon kernels were collected at different points in the bag to form a composite sample.

Preparation of Botanical Powder
The botanicals were purchased from the Ojo market. The botanicals were thoroughly washed, air-dried under shade until they were properly dried; ground to fine powder using the Warring laboratory blender (Warring Commercial, Springfield, MO) and stored at 4°C until when needed.

Application of Plant Powders to Egusi Kernels and Fungal Contamination Test
The botanical powders were prepared as already described above; the botanical powders were used to dust 1 kg of clean (uninfected) Egusi kernels in plastic woven bags, mixed properly and placed on the shelf for a period of three and half months. Prior to treatment and storage, shelled melon kernels were dried to moisture content of 10% (determined with Pfeuffer helite moisture meter). The controls were not dusted with any botanical powder (Bankole and Joda, 2004). Subsamples of 50 g were collected from each 1 kg sample at 2nd, 4th, 6th, 8th 10th 12th and 14th week for fungal contamination test with A. flavus and other identified predominant fungal species (A. niger, A. tamaril, Rhizopus sp., P. aurantiogriseum, P. citrinum and F. solani). Inocula suspensions were prepared from fresh, mature (5-day-old) fungi cultures. Fungal colonies were covered with 5 ml of distilled sterile water containing 1% Tween 20 per 100 ml to enhance uniform spore dispersal for hydrophobic genus such as Apergillus. The final inoculum size was adjusted to a concentration of 1.0 × 10^6 spore/ml by microscopic enumeration with a cell-counting haemocytometer (Aberkane et al., 2002). The Egusi kernels treated with botanicals were washed in three changes of sterile distilled water and then twenty kernels were inoculated with 100 μL of spore suspension of each test fungi. Five kernels were plated on petri dishes containing solidified Potato Dextrose Agar (PDA) and incubated at room temperature for five days. The controls were plated on PDA without inoculation with any fungal species. Percentage kernel colonization was recorded after incubation.

Isolation and Identification of Fungi from Market Melon Samples
Egusi seed kernels from traders’ shop were processed and fungi isolated done following the methods described by (Atehnkeng et al., 2014) using PDA in which 0.05 ml of lactic acid had been added to suppress bacterial growth (Atehnkeng et al., 2008). After incubation for 5 days at room temperature, the colony forming units (cfu ml^-1) of each fungal species identified was determined by counting the number of colonies formed. Axenic culture of each isolate was obtained by sub culturing on fresh PDA plates. Identification of the isolated fungi was done based on colony morphology and microscopic examination which
were compared with the literature. Slides were prepared from fungal colonies produced on the medium for identification of the organisms using mycological reference books and research articles (Barnett and Hunter, 1999; Alexopoulos et al., 2002; Samson et al., 2004) and the descriptions of Barnett and Hunter (1999). The experiments were carried out with treatment in triplicates laid out in completely randomized design.

Determination of Percentage Occurrence of the Fungal Isolates
This was done to determine the incidence of occurrence of the different fungal isolates. The total number of each isolate in all samples was obtained against the total number of all the isolates in all the samples screened. Frequency of occurrence was determined using the method described by Giridhér and Ready (1997):

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\text{Percentage of frequency} = \frac{\text{No. of observations in which a species appeared} \times 100}{\text{Total no. of observations}}
\]

Data Analysis
Data on fungal incidence in melon grains were analyzed using SAS (version 9.2, SAS Institute Inc., Cary, NC). The means were separated using Fisher’s protected least significant difference (LSD) test to determine significant differences among the means obtained from the different states or treatments.

RESULTS
Nine different fungal genera apart from Aspergillus were identified in the melon samples collected in 2012. They are Fusarium, Penicillium, Rhizopus, Botryodiplodia, Trichoderma, Alternaria, Sclerotium, Cladosporium, and Macrophomina. Across the six states, Aspergillus species were the most predominant fungal species identified, followed by species belonging to the genera Rhizopus, Fusarium, Penicillium, Alternaria, Sclerotium, while Cladosporium, Botryodiplodia, and Macrophomina species were the least predominant. Aspergillus species had the highest fungal colonies per gram (cfu g\(^{-1}\)) and was significantly (\(p = 0.05\)) higher than all other fungal genera identified. The highest fungal colonies per gram (cfu g\(^{-1}\)) of Aspergillus species was recorded in samples from Osun State (11,920 cfu g\(^{-1}\)) while the least cfu g\(^{-1}\) was recorded in Lagos State and they were significantly different across the states. The highest cfu g\(^{-1}\) of Fusarium, Botryodiplodia, Alternaria, Sclerotium and Cladosporium were isolated from samples from Lagos State. The highest cfu g\(^{-1}\) of Penicillium and Rhizopus were found in Ondo (2193.3 cfu g\(^{-1}\)) and Ogun (766.7 cfu g\(^{-1}\)), respectively (Table 1).

Aspergillus, Fusarium, Penicillium, Rhizopus, Botryodiplodia, Paecilomyces, Alternaria, Sclerotium and Macrophomina were identified in the melon samples collected during 2013 sampling (Table 1). Aspergillus species were the most predominant fungal species identified across the six states, followed by species belonging to the genera Rhizopus, Penicillium, Fusarium, Alternaria, Sclerotium, while Cladosporium, Botryodiplodia, and Macrophomina species were the least predominant. Aspergillus species had the highest fungal colonies per gram (cfu g\(^{-1}\)) and was significantly (\(p = 0.05\)) higher than all other fungal genera identified except in Ondo where the highest Rhizopus colonies was recorded (11990.7 cfu g\(^{-1}\)), and also in Ogun State (2466.7 cfu g\(^{-1}\)). The highest fungal colonies per gram (cfu g\(^{-1}\)) of Aspergillus species was recorded in samples from Oyo State (3250 cfu g\(^{-1}\)) while the least cfu g\(^{-1}\) was recorded in Ekiti State and they were significantly different across the states. The highest cfu g\(^{-1}\) of Penicillium, Fusarium, Botryodiplodia, Alternaria, and Paecilomyces were isolated from samples collected from Ogun State. The highest cfu g\(^{-1}\) of Sclerotium was recorded in Osun while the highest cfu g\(^{-1}\) of Cladosporium occurred in Lagos (22.2 cfu g\(^{-1}\)) and Ogun (22.2 cfu g\(^{-1}\)) States (Table 1).

### Table 1: Mould content of Egusi kernels collected from the six states of South-western Nigeria in 2012 and 2013

| Year | State  | Asp  | Rhz  | Pen  | Bot  | Fus  | Cld  | Alt  | Scl  | Pec  | Tri  |
|------|--------|------|------|------|------|------|------|------|------|------|------|
|      | 2012   |      |      |      |      |      |      |      |      |      |      |
|      | Ekiti  | 2406.7 | 444.4 | 155.6 | 22.2 | 22.2 | 22.2 | 22.2 | 22.2 | 0.0  | 0.0  |
|      | Lagos  | 2366.7 | 188.9 | 355.6 | 500.0 | 500.0 | 500.0 | 500.0 | 500.0 | 0.0  | 100.0 |
|      | Ogun   | 3128.3 | 766.7 | 513.3 | 0.0  | 20.0 | 0.0  | 0.0  | 0.0  | 0.0  | 100.0 |
|      | Ondo   | 4600.0 | 122.2 | 2193.3 | 120.0a | 120.0 | 120.0 | 120.0 | 120.0 | 0.0  | 0.0  |
|      | Ogun   | 11920.0 | 322.2 | 1753.3 | 158.0a | 126.7a | 126.7 | 126.7 | 126.7 | 0.0  | 100.0 |
|      | Oyo    | 5794.7 | 133.3 | 1005.6a | 94.4a | 188.9b | 88.9 | 89.0 | 89.0 | 0.0  | 0.0  |
| 2013 | Ekiti  | 1511.1 | 383.3 | 372.2b | 0.0  | 5.6b | 0.0  | 55.6b | 0.0  | 0.0  | 0.0  |
|      | Lagos  | 2116.7 | 225.0 | 8.3  | 0.0  | 5.6 | 22.2 | 25.0 | 0.0  | 0.0  | 0.0  |
|      | Ogun   | 2230.3 | 2466.7 | 2076.3 | 100.0 | 1868.7 | 6.7 | 880.0 | 126.7 | 266.7 | 0.0  |
|      | Ondo   | 2736.7 | 11990.7 | 1923.6 | 100.0 | 873.6 | 22.2 | 116.7 | 50.0 | 6.7  | 0.0  |
|      | Ogun   | 2380.0 | 1055.6 | 350.0 | 0.0  | 50.0 | 8.3 | 0.0  | 166.7 | 0.0  | 0.0  |
|      | Oyo    | 3250.0 | 2622.2 | 566.7 | 0.0  | 50.0 | 0.0  | 0.0  | 150.0 | 111.1 | 0.0  |

**Note:** Asp – Aspergillus; Pen – Penicillium; Fus – Fusarium; Rhz – Rhizopus; Bot – Botryodiplodia; Tri – Trichoderma; Cld – Cladosporium; Alt – Alternaria; Scl – Sclerotium; Pec – Paecilomyces. For each column, means with same letters are not significantly different.
Incidence of Fungal Species in Egusi Kernels

Aspergillus species had the highest percentage incidence across all the states, followed by Penicillium and Fusarium species while Macrophomina was the least in 2012 (Figure 1). In Ekiti and Ogun States, significant differences were not observed in the incidence of Fusarium and Alternaria species. The same trend was observed in Fusarium and Penicillium species in Lagos and Osun States. In 2013, Aspergillus species also had the highest percentage incidence across all the states, followed by Rhizopus and Penicillium species while Paecilomyces was the least. The incidence of Aspergillus species was significantly \( (p = 0.05) \) higher than all other fungal genera identified except in Osun State where Aspergillus and Rhizopus species were significantly \( (p = 0.05) \) higher than all other fungal genera identified in both 2012 and 2013 (Figures 1 and 2).

Effect of Selected Botanicals on Growth of Fungal Contaminants in Treated Egusi Kernels

Storing Egusi kernels together with botanical powders significantly reduced fungal growth in the stored Egusi kernels. All the botanicals tested differed from each other in their ability to reduce fungal growth on the seeds. The result presented in Table 2 shows the percentage reduction of fungal growth in Egusi seeds treated with different concentrations of \( P. \) guineense. Forty-gram (40 g kg\(^{-1}\)) treatment generally had the highest growth reduction for the various fungal isolates except for \( F. \) solani where 10 and 20 g kg\(^{-1}\) treatment gave the highest growth reduction of 60.0% while 40 g kg\(^{-1}\) had the least growth reduction (10.0%). Percentage growth reduction declined gradually as the storage period increased. One month after treatment, the botanicals were not effective in inhibiting the growth of \( R. \) oryzae \( sp. \) Figure 1: The growth of \( P. \) aurantiogriseum was inhibited effectively up to 8th week, 10th week and 12th week after storage at 10, 20 and 40 g kg\(^{-1}\) treatment, respectively. \( P. \) citrinum growth was effectively reduced by more than 20.0% by the various levels of the botanical treatments throughout the 14 weeks of Egusi storage. The second experiment gave similar results. Treatment at 40 g kg\(^{-1}\) generally had the highest growth reduction for the various fungal isolates except for \( F. \) solani where 10 and 20 g kg\(^{-1}\) treatment gave the higher growth reductions of 55.0% and 65.0%, respectively than 40 g kg\(^{-1}\) which had the least growth reduction of 15.0%. \( P. \) citrinum growth was still effectively reduced by more than 20.0% by the various levels of the botanical treatments throughout the period of 14 weeks of Egusi storage (Table 2).

![Figure 1: Percentage incidence of fungal species isolated from Egusi kernels collected from six states in South-western Nigeria in 2012. Asp – Aspergillus; Pen – Penicillium; Fus – Fusarium; Rhiz – Rhizopus; Botryo – Botryodiplodia; Tri – Trichoderma; Clad – Cladosporium; Alt – Alternaria; Scl – Sclerotium. For each bar, the vertical line represents the standard error of the means.](image1)

![Figure 2: Percentage incidence of fungal species isolated from Egusi kernels collected from six states in South-western Nigeria in 2013. Asp – Aspergillus; Pen – Penicillium; Fus – Fusarium; Rhiz – Rhizopus; Botryo – Botryodiplodia; Tri – Trichoderma; Clad – Cladosporium; Alt – Alternaria; Scl – Sclerotium; Pec – Paecilomyces. For each bar, the vertical line represents the standard error of the means.](image2)
Table 3 shows the percentage reduction of fungal growth in Egusi kernels treated with different concentrations of X. aethiopica, A. tamarii and A. niger. A. tamarii and A. niger had maximum growth reduction at 40 g kg$^{-1}$ treatment while A. flavus recorded the highest growth reduction of 50% at 20 and 40 g kg$^{-1}$ treatment. For F. solani, 20 g kg$^{-1}$ treatment gave the highest growth reduction of 75.0%, followed by 10 g kg$^{-1}$ treatment (70% reduction) while 40 g kg$^{-1}$ had the least growth reduction (30%) after 2 weeks of treatment. Percentage growth reduction gradually declined as the storage period increased. X. aethiopica at various concentrations only had effect on Rhizopus sp. growth after 2 weeks of treatment. The growth of P. aurantiogriseum was effectively inhibited up to 14th week after storage at all treatment levels because up to 20% growth reduction was recorded at 10 g kg$^{-1}$ treatment even at the 14th week. P. citrinum growth was also effectively reduced by more than 20% by the various levels of the botanical treatments throughout the 14 weeks of Egusi storage (Table 3). The second experiment gave similar results. A. tamarii had maximum growth reduction at 40 g kg$^{-1}$ treatment while A. flavus growth reduction of 66.7% was recorded at 20 g kg$^{-1}$; although not significantly different from 40 g kg$^{-1}$ treatment which had 55.6% growth reduction at two weeks after storage. However, at 4th week after storage 40 g kg$^{-1}$ treatment recorded a growth reduction of 61.1% while 20 g kg$^{-1}$ had 66.7% growth reduction. Percentage growth reduction declined gradually as the storage period increased. After one month of treatment O. gratissimum was not effective in inhibiting the growth of Rhizopus sp. The growth of P. aurantiogriseum was effectively inhibited up to 8th week, 10th week and 12th week after storage at 10, 20 and 40 g kg$^{-1}$ treatment, respectively. Growth of P. citrinum was effectively reduced by up to 20% by the various levels of the botanical treatments throughout the 14 weeks of Egusi storage. The second experiment gave similar results. Forty (40) g kg$^{-1}$ treatment generally had the highest growth reduction for the various fungal isolates except for A. flavus, where 20 g kg$^{-1}$ treatment gave the highest growth reduction of 80%. This was followed by 40 g kg$^{-1}$ treatment which had 65.0% growth reduction P. citrinum growth was still effectively reduced by up to 20.0% and above by the various levels of the botanical treatments throughout the 14 weeks of Egusi storage except at 2.0% treatment in the 14th week after storage where only 10.0% reduction was recorded (Table 4).
**DISCUSSION**

Fungal species belonging to nine genera were isolated and identified in Egusi kernels from the six states in South-western region of Nigeria and *Aspergillus* species were the most predominant. High levels of *Aspergillus* species population have previously been reported in Nigeria in post-harvest maize (Atehnkeng et al., 2008). The *Aspergillus* species recorded in the present study had previously been reported in high frequencies in Egusi (Bankole, 1993) and groundnut, another Nigerian oil seed (Ogunjoku, 1980).

| Weeks | Conc. (g kg⁻¹) | Percentage growth reduction | 
|-------|----------------|-----------------------------|
|       |                | First experiment (2012)      | Second experiment (2013) |
|       | FLV            | NIG            | RHIZ         | SOL         | TAM      | YEL     | FLV      | NIG     | RHIZ    | SOL    | TAM  | YEL  |
| 2     | 16.7b          | 35.0b          | 70.0a        | 5.0b        | 15.0b    | 100.0a | 5.0b     | 25.0b   | 100.0a  | 5.0b    | 25.0b | 100.0a |
| 4     | 22.2b          | 25.0b          | 85.0a        | 0.0b        | 30.0b    | 15.0b  | 90.0b    | 22.2b   | 25.0b   | 95.0b   | 5.0b  | 35.0b |
| 6     | 5.6a           | 20.0b          | 43.0b        | 0.0b        | 20.0ab   | 15.0a  | 80.0a    | 5.6a    | 25.0a   | 65.0b   | 0.0a  | 20.0a |
| 8     | 5.6a           | 35.0b          | 60.0b        | 0.0a        | 15.0b    | 10.0a  | 90.0b    | 5.6a    | 30.0b   | 60.0b   | 0.0a  | 20.0a |
| 10    | 5.6a           | 66.7a          | 100.0a       | 0.0a        | 30.0a    | 20.0a  | 92.5a    | 5.6a    | 44.4a   | 100.0a  | 0.0a  | 20.0a |

Conc. = concentration; FLV = *Aspergillus flavus*; NIG = *Aspergillus niger*; PUR = *Penicillium aurantiogriseum*; RHIZ = *Rhizopus* sp.; SOL = * Fusarium solani*; TAM = *Aspergillus tamarii*; YEL = *Penicillium citrinum*. For each week, means with same letter in each column are not significantly different.
Besides Aspergillus, species of Penicillium, Fusarium, Trichoderma, Paecilomyces, Aternaria, Cladosporium, Sclerotium and Botryodiaploida were associated with melon seeds in Nigeria (Bankole and Joda, 2004; Chiejina, 2006; Aboloma and Ogumbusola, 2012). The bio deteriorating and aflatoxigenic fungal species spores that colonized melon must have been present in the atmosphere during sun drying and storage of the seeds. The fungi could have been introduced during exposure and direct contact of the seeds in the market (Okiqbo, 2003; Gbolagade et al., 2011).

This study reveals that, all the concentrations used showed antifungal activity. Thus, they can be useful in the control of the fungi associated with stored Egusi. This agrees with the findings of Kuri et al. (2011). Ogbebor and Adekunle (2005) and Ogbebor et al. (2007) reported that extracts of A. sativum and O. basilicum demonstrated good inhibitory effect on the pathogens tested. Many workers have reported antifungal activities of different plant species and stressed the importance of plants as possible sources of natural fungicides (Ogbebor and Adekunle, 2005; Ogbebor et al., 2005; Ogbebor et al., 2007; Ogbebor and Adekunle, 2008; Shovan et al., 2008; Oyewole and Abalaka, 2012).

Many reports exist on the use of botanicals against the plant pathogenic fungi. For example, O. basilicum and A. sativum on Colletotrichum gloeosporioides (Penz.). Allium cepa L., against Alternaria tenuis and Curvularia lunata Wakker, X. against Proteus mirabilis Hauser, Candida albicans Berkh and Staphylococcus aureus (Misra and Dixit, 1976; Okiqbo et al., 2005; Ogbebor et al., 2007). This shows that these botanicals contain bioactive ingredients that are inhibitory to the growth of these pathogens. The antifungal activities of botanicals were supported by many other investigators; neem oil, betel (Piper betel L.) leaf extract, Psidium guajava L. (Hema et al., 2009), Thymus vulgaris (LINN.), Zingiber officinale, Cymbopogon citratus Stapf (lemon grass) (Zeringue et al., 2001; Chalfoun et al., 2004; Neguefact et al., 2004; Faria et al., 2006; Kumar et al., 2007; Srichana et al., 2009; Bahraminejad, 2012). The presence of antifungal activity in X. aethiopica and O. gratissimum may be due to the presence of antifungal factors in them.

CONCLUSION

It is clear from the above observations that all the botanicals (O. gratissimum, P. guineense and X. aethiopica) investigated proved to be useful in the management of postharvest/storage fungi. Results obtained with the botanicals in this study confirmed the importance of these plant species as exhibiting antifungal properties both in the in vitro and in vivo experiments. The present investigation is an important step in preventing contamination of seeds with botanicals, which are eco-friendly for the management of the important seed borne fungi. Therefore, exploitation of naturally available chemicals from plant protection will play a prominent role in development of future commercial pesticides for crop protection strategies, with special reference to the management of plant diseases. This can also be usefully exploited in the protection of foods from mycotoxin contamination.

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