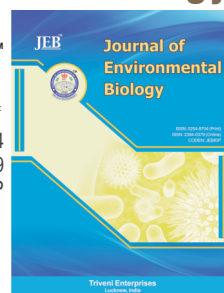
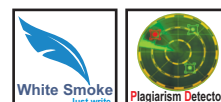




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Antimicrobial activity of *Cymbopogon citratus* essential oil against the mycoflora of stored dried fruits of *Zanthoxylum armatum*



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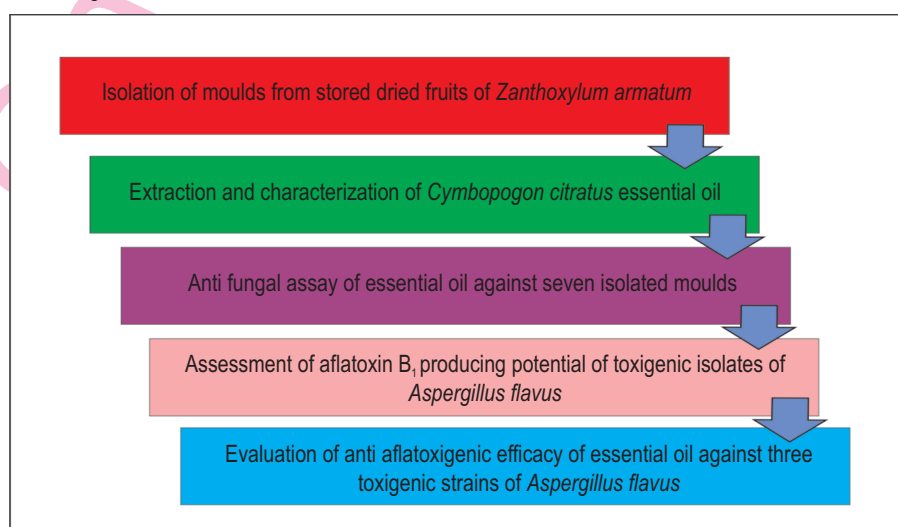
Abstract

Aim : The study aimed to investigate the fungal contamination in dried fruits of *Zanthoxylum armatum* and the effect of essential oil of *Cymbopogon citratus* against the deteriorating fungi and aflatoxin production by *Aspergillus flavus*.

Methodology : Mycoflora analysis of dried fruits of *Z. armatum* was done by dilution plate technique, while the antifungal assay of essential oil of *C. citratus* against seven isolated moulds was carried out by poisoned food technique. Aflatoxigenic potential of *Aspergillus flavus* and anti-aflatoxigenic activity of essential oil of *C. citratus* was done by spectrophotometric method.

Results : A total of 17 fungal species were isolated with *Aspergillus* as the predominant genus. The characterization of *C. citratus* essential oil revealed α -citrinal and β -citrinal as major components. Essential oil significantly exhibited antifungal activity against the growth of tested fungal species. The minimal inhibitory concentration of essential oil was found to be $1.5 \mu\text{l ml}^{-1}$ for *Fusarium graminearum*, $2.5 \mu\text{l ml}^{-1}$ for *Alternaria alternata*, *Aspergillus flavus*, *A. ochraceus* and *Penicillium expansum* and $3.0 \mu\text{l ml}^{-1}$ for *A. parasiticus* and *P. citrinum*, respectively. The essential oil completely checked the production of aflatoxin B₁ by the toxigenic strains of *A. flavus*.

Interpretation : Both mycelial growth and aflatoxin B₁ production followed a declining trend with an increase in essential oil concentration, demonstrating its practical efficacy as a plant based antimicrobial for enhancing the shelf-life of *Z. armatum*.



Introduction

Dried fruits are an important group of agricultural and confectionary commodities being used since the dawn of human civilization all over the world. Owing to their flavour, taste and indispensable nutrients, an array of health protective bioactive ingredients ideally increase the diet quality and help to decrease the risk of unrelieved diseases (Chang *et al.*, 2016). Moisture content of dried fruits varies from 2 to 22 % and further reduction in the water content of these commodities by drying inhibits microbial growth and slows down enzymatic reactions (Vinson *et al.*, 2005). In general, most of the dried commodities have adequately low water activity to slow down bacterial growth. However, filamentous moulds, especially the xerophilic moulds are the most important micro-organisms in dried fruits in terms of biodeterioration, if their drying and storage is inadequate. Some of the deteriorating moulds are also potential producers of various mycotoxins. Among these, aflatoxins produced by the *Aspergillus flavus* and other related species are the most important mycotoxins occurring in food and feed (Udomkun *et al.*, 2017). Use of these contaminated commodities causes aflatoxicosis, a disease having symptoms of abnormal liver functioning, depressed immune response, carcinogenesis etc. (Shukla *et al.*, 2009). To prolong the shelf-life of dried fruits and prevent the growth of filamentous fungi and production of aflatoxins, it is imperative to establish an ideal preservative.

Currently, to manage storage moulds in dried commodities, most of the synthetic chemicals used during post-harvest treatment are man-made xenobiotics whose unabated applications have led to the development of fungal resistance as well as residual toxicity (Brent and Hollomon, 1998). They are also responsible for the stimulation of aflatoxin biosynthesis (Jayashree and Subramanyam, 2000). The present discussion on the negative effects of synthetic preservatives has also renewed interest of researchers towards natural food additives to improve the shelf-life of food commodities and to protect them from infesting microbes. One of such alternatives is the application of eco-friendly, cost-effective botanicals to minimize fungal deterioration of agricultural commodities and to improve their quality (Burt, 2004).

Since, the essential oils of higher plants and their components are highly volatile and biodegradable, they are easily accepted by consumers. Consequently, there is an increasing attention worldwide by various researchers to study the antimicrobial activities of various plant extracts to control moulds in stored food commodities that pose less risk to human health and environment (Weckesser *et al.*, 2007; Gandomi *et al.*, 2009; El-Nagerabi *et al.*, 2013). *Cymbopogon citratus* (DC.) Stapf (Lemon grass) is known to possess various antimicrobial, anti-diarrheal and antioxidant attributes owing to the presence of terpenoids, phenolic compounds and essential oils (Tzortzakakis and Economakis, 2007; Manvitha and Bidya, 2014; Mosquera *et al.*, 2016; Kausar *et al.*, 2017; Oliveira *et al.*, 2018). Therefore, the present study was undertaken to screen the fungi responsible for

deteriorating stored dried fruits of *Zanthoxylum armatum* (locally known as timbru) and detection of toxigenic strains of *Aspergillus flavus* among these spoilage moulds. Also, the essential oil of *C. citratus* was evaluated for its antifungal and anti-aflatoxigenic activity in order to assess its efficacy as a prospective food additive.

Materials and Methods

Procurement of dried fruits : A total of 64 samples (200 g each) of dried fruits of *Zanthoxylum armatum* were purchased from households, wholesalers, markets and retail shops in different localities of Jammu province (Jammu, Reasi, Kathua, Rajouri, Poonch, Samba and Udhampur). The samples were collected in sterilized polythene bags, sealed over flame to prevent further contamination and stored at low temperature (5°C) for further mycoflora and mycotoxin analysis.

Mycoflora analysis : The filamentous fungi of dried fruits of *Z. armatum* were isolated by dilution plate technique following the method of Singh *et al.* (1991). 10 gm each of powdered samples was homogenized in 90 ml sterile distilled water in Erlenmeyer flask (250 ml). Dilutions of residue were made with sterilized distilled water and one ml of aliquot of each sample was then poured in Petri plate containing 10 ml freshly prepared Czapek's-dox agar (CDA) medium. Three replicates of each sample were prepared and incubated (27±2°C) for seven days. Different fungal colonies were counted and fungal species were identified on the basis of their cultural and micro-morphological characters using relevant literature and recommended keys (Raper and Fennell, 1965; Booth, 1971; Ellis, 1971; Pitt, 1979). The cultures of fungal isolates were maintained on PDA slants at 4°C. The occurrence frequency of isolated fungi was determined following Mandeel's (2005) formula.

Extraction of essential oil : For extraction of essential oil, fresh leaves (500 gm) of *Cymbopogon citratus* were collected from the Botanical Garden, University of Jammu, Jammu. After washing twice with distilled water, leaves were subjected to Clevenger's hydro distillation apparatus (3 hrs). The essential oil was separated and water traces were removed by anhydrous sodium sulphate and stored at 4°C in dark for further experiments.

Characterization of *C. citratus* essential oil : The essential oil of *C. citratus* was analyzed through GC equipped with a flame ionization detector. The GC conditions were capillary column CP-Sil-8 (30m x 0.32mm x 0.25µm thick film); helium was the carrier gas; injection temperature 280°C, split ratio 1:150, column oven temperature 50°C for 5 min, then 250°C held for 7 min. The identification of various compounds was based on their retention times relative to those of standards and matching spectral peaks available.

Antifungal assay : The antifungal activity of essential oil was performed by using poisoned food technique using CDA medium (Perrucci *et al.*, 1994) against seven spoilage moulds (*Alternaria alternata*, *Aspergillus flavus*, *A. ochraceus*, *A. parasiticus*, *F.*

graminearum, *Penicillium citrinum* and *P. expansum*) isolated from dried fruits of *Z. armatum*. Different concentrations of essential oil (0.5 – 3.0 $\mu\text{l ml}^{-1}$) were poured in Petri dishes containing 0.5 ml acetone and 9.5 ml molten CDA. Likewise, CDA plates without essential oil served as control. The plates were then inoculated with discs of test fungi and incubated at $27\pm 2^\circ\text{C}$ for 7 days. Antifungal index was calculated as follows-

$$\text{Antifungal index (\%)} = (1 - \text{Dt}/\text{Dc}) \times 100$$

Where, Dt : diameter of growth zone in the test plate;
Dc : diameter of growth zone in the control plate.

Determination of MIC and MFC : The minimal inhibitory concentration (MIC) of essential oil of *C. citratus* was recorded against the fungal species by poisoned food technique following Perrucci *et al.* (1994) at different concentrations of *C. citratus* oil viz., 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 $\mu\text{l ml}^{-1}$. The lowest concentration that did not permit any visible growth was taken as MIC. The inhibited discs of the fungi were sub-cultured on treatment-free PDA plates to find out if the inhibition was reversible. If the mycelial growth was inhibited, the plant extract was fungicidal at this concentration and allowed the determination of minimal fungicidal concentration (MFC).

Detection of aflatoxigenic isolates : Fifty nine isolates identified as *A. flavus* from contaminated dried fruit samples of *Z. armatum* were examined for their aflatoxin B₁ (AFB₁) producing potential by thin layer chromatography (TLC) (Nabney and Nesbitt, 1965). Each isolate was added to 250 ml Erlenmeyer flask containing 25 ml SMKY medium (Diener and Davis, 1966) and incubated at $27\pm 2^\circ\text{C}$ for 10 days. The content of each flask was then filtered and extracted with 20 ml chloroform. The extract was evaporated to dryness on water bath and redissolved in one ml chloroform. Then 50 μl of chloroform extracts were applied on the activated TLC plates. The aflatoxin standard (aflatoxin B₁) was also spotted on TLC plates as reference spots and then developed with solvent system (toluene:isoamyl alcohol:methanol; 90:32:2 v/v). After developing, the plates were air dried and was observed in UV-transilluminator (360 nm) and their presence were chemically confirmed by spraying 25% H₂SO₄. The intensity of the blue fluorescent spot in the UV transilluminator varies among different aflatoxigenic strains (light blue to deep blue). The toxigenic isolates of *A. flavus* (A-16, A-19 and A-21) produced maximum blue fluorescence under UV light and were, therefore, selected for further investigations. The blue spots were scratched from TLC plates and then dissolved in 5 ml methanol and centrifuged at 3000 rpm for 5 min. Absorbance of the supernatant was recorded at 360 nm and aflatoxin B₁ was calculated by the following formula :

$$\text{Aflatoxin B}_1 \text{ content } (\mu\text{g l}^{-1}) = \frac{D \times M}{E \times L} \times 1000$$

D = absorbance, M = molecular weight (312), E = molar extinction coefficient aflatoxin B₁ (21800), L = path length (1 cm)

Efficacy of *C. citratus* essential oil for analyzing aflatoxin B₁ production by *A. flavus* : Required amounts of *C. citratus* essential oil were dissolved in 0.5 ml acetone and added to 24.5 ml SMKY to achieve the various concentrations from 0.5 to 3.0 $\mu\text{l ml}^{-1}$. The medium inoculated separately with one ml spore suspension (10^6 spores ml^{-1}) of toxigenic isolates of *A. flavus* (A-16, A-19 and A-21) was incubated for ten days at $27\pm 2^\circ\text{C}$. Likewise, control sets were prepared using same amount of distilled water without essential oil. The medium was filtered and mycelium was dried at 80°C for 12 hrs. Aflatoxin B₁ was detected by thin layer chromatography following the method of Nabney and Nesbitt (1965).

Statistical analysis : The statistical significance of the results was analyzed by one way analysis of variance (ANOVA) using SPSS software. Data analyzed were expressed as mean \pm SE. Means were separated by the Tukey's multiple range tests when ANOVA was significant ($P \leq 0.05$).

Results and Discussion

The result of the mycoflora analysis revealed that 64 samples of dried fruit of *Z. armatum* were contaminated with different fungal species (Table 1). A total of 279 isolates belonging to 17 species were recovered from these dried samples. They were represented by 7 genera viz., *Acremonium* (1sp.), *Alternaria* (1sp.), *Aspergillus* (6 spp.), *Cladosporium* (2 spp.), *Mucor* (1 sp.), *Fusarium* (3 spp.) and *Penicillium* (3 spp.). These species contributed as major fungal components of dried fruits and represented a group of taxa of ubiquitous nature that could exploit almost any substrate and accumulate toxic secondary metabolites.

Analysis of mycoflora indicated genus *Aspergillus* as the most frequent colonizer that comprised of six species and thus,

Table 1 : Mycoflora analysis of dried fruits of *Z. armatum*

Fungal species	Occurrence frequency (%)
<i>Acremonium roseolum</i> (G. Smith) W. Gams	1.07
<i>Alternaria alternata</i> (Fr.) Keissl.	4.30
<i>Aspergillus conjunctus</i> (Kwon and Fennell)	2.86
<i>A. flavus</i> Link	21.14
<i>A. niger</i> Van Tieghem	11.47
<i>A. ochraceus</i> Wilhelm	7.53
<i>A. oryzae</i> (Ahlburg) Cohn	3.94
<i>A. parasiticus</i> Speare	10.39
<i>Cladosporium cladosporioides</i> (Fresen.) de Vries	4.66
<i>C. resinae</i> (Lindau) de Vries	0.72
<i>Mucor mucedo</i> Fresen.	0.36
<i>Fusarium camptoceras</i> Wollenweber and Reinking	3.22
<i>F. graminearum</i> Schwabe	6.81
<i>F. oxysporum</i> Schlechtendahl	4.66
<i>Penicillium capsulatum</i> Raper and Fennell	1.07
<i>P. citrinum</i> Thom	6.81
<i>P. expansum</i> Link ex Gray	8.96

Table 2 : Level of aflatoxin B₁ production by *Aspergillus flavus* isolates in SMKY medium

<i>A. flavus</i> isolates	Concentration (μl^{-1})
AF-3	567.89 \pm 3.21*
AF-9	322.0 \pm 2.98
AF-16	1510.65 \pm 15.87
AF-17	687.07 \pm 3.75
AF-19	1120.87 \pm 5.67
AF-21	1211.0 \pm 2.78
AF-29	299.08 \pm 1.09
AF-35	789.43 \pm 1.21
AF-41	534.89 \pm 2.32
AF-47	245.89 \pm 12.39
AF-49	767.74 \pm 9.89
AF-56	654.01 \pm 2.33

* mean \pm SE

formed the largest diversity among all the recovered genera. The highest frequency of occurrence was recorded for *Aspergillus flavus* (21.14%) followed by *A. niger* (11.47%) and *A. parasiticus* (10.39%). Owing to their strong competitive ability to produce hydrolytic enzymes and abundant sporulation, the incidence of *Aspergillus* species usually remains to be high (Bala et al., 2014, 2016; Gupta et al., 2017). In view of the known aflatoxin producing potential of *A. flavus*, 59 isolates of *A. flavus* were evaluated for their aflatoxigenic potency. Out of these, 12 isolates were found toxigenic in nature producing blue fluorescence under UV light. However, three of these toxic isolates namely AF-16, AF-19 and AF-21 produced maximum blue fluorescence under UV light and further subjected to antiaflatoxigenic bioassay. The quantitative analysis revealed that these 12 isolates elaborated aflatoxin B₁ in the range of 245.89 – 1510.65 $\mu\text{g l}^{-1}$ (Table 2).

Prior to evaluation of antifungal activity, the *Cymbopogon citratus* oil was characterized by GC-MS analysis. The essential oil was light yellow in colour and showed the presence of 18 different components. Their retention time and percentage are tabulated in Table 3 and Fig. 1. Monoterpene aldehydes viz., α

Table 3 : Chemical composition of *C. citratus* essential oil

Components	Percentage (%)	Retention time (Minutes)
Methyl heptenone	1.33	16.774
β pinene	1.99	16.998
Limonene	0.42	19.257
Cis Ocimene	1.54	19.509
Linalool	2.42	22.900
(+)- Limonene oxide	1.77	26.062
Cis Verbenol	3.29	27.009
β Citral	26.16	29.908
Geraniol	0.33	30.426
α Citral	49.45	31.295
Methyl acetate	1.01	36.168
Methyl eugenol	3.24	37.263
β Caryophyllene	1.24	38.372
Germacrene D	0.46	40.944
Cadinene	0.11	42.370
Caryophyllene oxide	1.12	45.122
α Selinene	1.93	48.330
α Bisabolol	2.12	48.823

citral (49.45 per cent) and β citral (26.16 per cent) were the major components of *C. citratus* essential oil accounting for 75.61 per cent of the total oil composition. Percentage of each of the remaining constituents of essential oil was less than 4 percent. Citral has also been found in other medicinal plants like *Lippia alba* and *Cymbopogon khasans* (Mishra et al., 2012). The chemical profile of essential oil of a particular plant species is influenced by seasonal, climatic and geographical conditions, plant parts used, time of harvesting and method of isolation, and these chemotypic variations significantly affect the biological efficacy of oil (Shukla et al., 2009; Prakash et al., 2011). Since chemical characterization of essential oil of *C. citratus* in the present study showed citral as its major component, it might have proved effective in retarding the growth of filamentous fungi by inhibiting the mycelial growth through a mechanism of cell membrane damage, compromising its integrity and permeability and inhibition of inter- and extracellular enzymes (De Souza et al., 2005). These measures can occur alone or in blend and

Table 4 : Antifungal index of *C. citratus* essential oil against different fungal species isolated from dried fruits of *Z. armatum*

Fungal species	Antifungal index (% mycelial growth inhibition)					
	Essential oil concentration ($\mu\text{l ml}^{-1}$)					
	0.5	1.0	1.5	2.0	2.5	3.0
<i>Alternaria alternata</i>	45.54 \pm 5.67 ^b	58.32 \pm 1.47 ^c	71.34 \pm 0.85 ^c	85.28 \pm 0.88 ^{bcd}	100 ^a	100 ^a
<i>Aspergillus flavus</i>	46.01 \pm 0.93 ^b	50.02 \pm 0.56 ^d	68.45 \pm 1.32 ^{cd}	81.91 \pm 2.12 ^d	100 ^a	100 ^a
<i>A. ochraceus</i>	47.72 \pm 0.75 ^b	61.63 \pm 2.34 ^{bc}	71.69 \pm 0.86 ^c	88.91 \pm 1.73 ^b	100 ^a	100 ^a
<i>A. parasiticus</i>	39.15 \pm 1.65 ^c	46.02 \pm 4.56 ^{de}	68.05 \pm 3.45 ^{cd}	75.19 \pm 0.65 ^e	89.04 \pm 1.37 ^b	100 ^a
<i>Fusarium graminearum</i>	65.41 \pm 2.45 ^a	81.03 \pm 0.67 ^a	100 ^a	100 ^a	100 ^a	100 ^a
<i>Penicillium citrinum</i>	32.91 \pm 1.53 ^d	42.81 \pm 0.98 ^e	54.09 \pm 1.23 ^e	71.34 \pm 0.43 ^{ef}	89.31 \pm 2.18 ^b	100 ^a
<i>P. expansum</i>	48.01 \pm 2.34 ^b	66.03 \pm 2.12 ^b	75.01 \pm 3.54 ^b	89.07 \pm 0.78 ^b	100 ^a	100 ^a

Values represent mean of three replicates \pm SE. The mean followed by same letters in the same column are not significantly different according to ANOVA and Tukeys multiple comparison tests

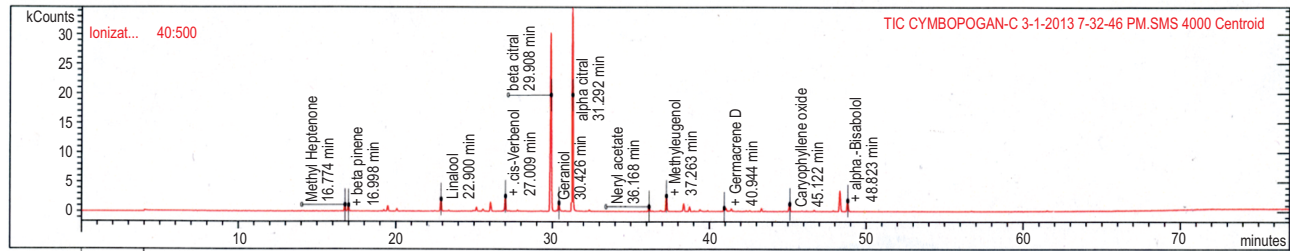


Fig. 1 : GC-MS chromatogram of essential oil of *Cymbopogon citratus*.

culminate inhibition of mycelium growth (Cowan, 1999). The antifungal activity of citral against moulds and yeasts has already been detected (Bellelli *et al.*, 2008; Droby *et al.*, 2008; Adukwu *et al.*, 2016). Palhano *et al.* (2004) reported that monoterpene (citral) proved effective in controlling mycelial growth and conidial germination of *C. gloeosporioides*. In the present study, besides citral, other constituent compounds like linalool, limonene and geraniol also might have augmented the antifungal potentiality of essential oil of *C. citratus* as confirmed earlier (Hyldgaard *et al.*, 2012). While linalool has been identified to inhibit spore germination by respiratory suppression of aerial mycelia (Matasyoh *et al.*, 2011), geraniol enhances the rate of potassium leakage out of the cells (Bard *et al.*, 1988).

The essential oil of *C. citratus* exhibited pronounced antifungal activity against all the tested fungal species isolated

Table 5 : Minimum inhibitory concentration (MIC) and minimum fungicidal concentration (MFC) of *C. citratus* essential oil against fungal species

Fungal species	MIC ($\mu\text{l ml}^{-1}$)	MFC ($\mu\text{l ml}^{-1}$)
<i>Alternaria alternata</i>	2.5	3.0
<i>Aspergillus flavus</i>	2.5	3.0
<i>A. ochraceus</i>	2.5	3.0
<i>A. parasiticus</i>	3.0	>3.0
<i>Fusarium graminearum</i>	1.5	2.5
<i>Penicillium citrinum</i>	3.0	>3.0
<i>P. expansum</i>	2.5	3.0

from dried fruits of *Zanthoxylum*. The MIC of essential oil was $2.5 \mu\text{l ml}^{-1}$ for *Alternaria alternata*, *Aspergillus flavus*, *A. ochraceus* and *Penicillium expansum*. *F. graminearum* was most sensitive to essential oil as it was controlled even at $1.5 \mu\text{l ml}^{-1}$, whereas mycelial growth of *A. parasiticus* was inhibited at $3.0 \mu\text{l ml}^{-1}$ (Table 4). The MIC of *C. citratus* essential oil against test fungi was found to be different than some earlier reported essential oils viz., *Adenocalymma alliaceum* (Shukla *et al.*, 2008) and *Anethum graveolens* (Prakash *et al.*, 2012). The MFC of essential oil for *Alternaria alternata*, *Aspergillus flavus*, *A. ochraceus* and *P. expansum* was recorded at $3.0 \mu\text{l ml}^{-1}$ while it was $2.5 \mu\text{l ml}^{-1}$ for *F. graminearum*. However, *A. parasiticus* and *P. citrinum* showed MFC $>3.0 \mu\text{l ml}^{-1}$, as the revival growth of inhibited mould disc was observed when they were sub-cultured in fresh culture medium suggesting fungistatic nature of test samples (Table 5). These results corroborate earlier reports on the efficacy of essential oil of *C. citratus* and *C. martini* signifying strong inhibition of mycelial growth of yeast and other filamentous fungi (Helal *et al.*, 2006; Tzortzakis and Economakis, 2007; Sonker *et al.*, 2014; Kausar *et al.*, 2017). In support of antifungal activity, Singatwadia and Katewa (2001) demonstrated the ability of *C. citratus* essential oil to inhibit the growth of moulds such as *Cladosporium* sp., *Aspergillus niger* and *Mucor* at lower concentrations. Recently, Youssef *et al.* (2016) reported that *C. citratus* essential oils exhibited broad fungitoxic activity against *Aspergillus parasiticus*. The inhibition of fungal mycelial may be due to the occurrence of phenolic compounds in the essential oils. Besides, the lipophilic nature of essential oil allows it to cross

Table 6 : Effect of *C. citratus* essential oil on aflatoxin B₁ production by *A. flavus* in SMKY medium ($\mu\text{g l}^{-1}$)

Concentration ($\mu\text{l ml}^{-1}$)	Aflatoxin B ₁ ($\mu\text{g l}^{-1}$)		
	AF-16	AF-19	AF-21
CN	1510.65 \pm 15.87 ^a	1120.87 \pm 5.67 ^a	1211.0 \pm 2.78 ^a
0.5	876.0 \pm 3.67 ^b	793.65 \pm 14.43 ^b	919.42 \pm 8.54 ^b
1.0	523.34 \pm 7.89 ^c	124.67 \pm 9.89 ^c	325.31 \pm 4.78 ^c
1.5	0 ^d	0 ^d	156.46 \pm 4.79 ^d
2.0	0 ^d	0 ^d	0 ^e
2.5	0 ^d	0 ^d	0 ^e
3.0	0 ^d	0 ^d	0 ^e

Values represent mean (n=3) \pm SE. The mean followed by same letters in the same column are not significantly different according to ANOVA and Tukeys multiple comparison tests; CN- control

the fungal cell membrane and interaction with the membrane enzymes and proteins thereby, creating a flux of protons towards the cell's exterior that alters the cell's and eventually causes death (Bakkali *et al.*, 2008).

The antifungal efficacy of *C. citratus* oil against three toxigenic strains of *A. flavus* (AF-16, AF-19 and AF-21) is summarized in Table 6. The essential oil inhibited aflatoxin B₁ production by AF-16, AF-19 and AF-21 at 1.5 µl ml⁻¹, 1.5 µl ml⁻¹ and 2.0 µl ml⁻¹, respectively. The essential oil showed inhibition of aflatoxin B₁ production at a concentration lower than their MIC for growth of *A. flavus* supporting the findings of earlier workers (Prakash *et al.*, 2012; Mishra *et al.*, 2015). Therefore, the essential oil would be acting by two diverse mode of action (i) inhibitor of fungal growth, and (ii) aflatoxin suppression (Rasooli and Abyaneh, 2004). The chemical constituents of the essential oils are responsible for the enzymatic modulation and could form a source for their potential antiaflatoxicogenic roles (Hajare *et al.*, 2005). Citral, the major component of *C. citratus* essential oil, is widely used natural ingredient and is added to foods, soft drinks and cosmetics as flavouring and fragrance agent. Thus, there would be no chance of off-flavour and harmful effects on sensory quality if the *C. citratus* essential oil is recommended as plant based food additive for complete prevention against quantitative losses from food-borne fungi, qualitative losses due to aflatoxins and as an alternative to synthetic preservative to improve the storage life of dried commodities.

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