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Review

Inhibitory effect of essential oil on aflatoxin activities

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Aflatoxins, which are well-known to be mutagenic, carcinogenic, teratogenic, hepatotoxic and immunosuppressive, also inhibit several metabolic systems. Aflatoxins are biologically active secondary metabolites produced by certain strains of *Aspergillus parasiticus, Aspergillus nominus* and *Aspergillus flavus*. Many different substances, such as essantial oils, flavanoids, could inhibit the aflatoxin production and growth of Aspergillus. In this study, aflatoxins biosyntesis, aflatoxins damaged and aflatoxins with essential oils interaction are evaluated.

Key words: Aflatoxins, essential oils, antioxidant, oxidative stress.

INTRODUCTION

Aflatoxins (*Aspergillus flavus* toxins) are biologically active secondary metabolites produced by certain strains of *Aspergillus parasiticus, Aspergillus nominus* and *Aspergillus flavus* (Cotty et al., 1994). The aflatoxin producing fungi are widely distributed in nature and can grow over a wide range of environmental conditions (Holmquist et al., 1983). Aflatoxins have been detected in cereal grains, oil seeds, fermented beverages made from grains, milk, cheese, meat, nut products, fruit juice and numerous other agricultural commodities (Bullerman, 1986).

Aflatoxins have been shown to be hepatotoxic, carcinogenic, mutagenic and teratogenic to different species of animals (Wogan et al., 1974; Eaton and Gallagher, 1994; Abdel-Wahhab et al., 1999). Aflatoxin B_1 (AFB_1) is the most prevalent and carcinogenic of the aflatoxins and the International Agency for Research on Cancer (IARC) classify AFB_1 as a group I carcinogen (that is, an agent that is carcinogenic to humans). Epidemiological studies also indicate that areas in the world with high levels of aflatoxin are correlated with high incidence of liver cancer (IARC, 1985).

AFB_1 caused damage by two different way in the cells. Firstly, AFB_1 ($C_{17}H_{12}O_6$) is activated to AFB1-8,9-oxide and forms adduct primarily at N7 position of guanine and is responsible for its mutagenic and carcinogenic effects (Wang and Groopman, 1999; Denissenko et al., 1999). Secondly, aflatoxins especially AFB_1, produce reactive oxygen species (ROS) such as superoxide radical anion, hydrogen peroxide and lipid hydroperoxides; though these do not appear to interact with DNA, but they are precursors to the hydroxyl radical. The hydroxil radicals interact with DNA and produces mutations (Halliwell and Gutteridge, 1999).

Numerous diverse compounds and extracts containing activity inhibitory to aflatoxin biosynthesis have been reported. The most of these inhibitors are plant-derived such as phenylpropanoids, terpenoids and alkaloids (Holmes et al., 2008). A group of plant-derived inhibitors is essantial oils (EO) that possess antimicrobial activities against *A. parasiticus* and/or *A. flavus* (Rasoli and Owlia, 2005; Kumar et al., 2007; Rasoli et al., 2008; Bluma and Etcheverry, 2008).

Up to date, no review directly has been carried out to evaluate the protective effects of essential oils against the aflatoxins. The objective of this study is to explain the protective effects of essential oil against the growth of *A. parasiticus* and *A.flavus*, synthesis of aflatoxins as well as the damage of aflatoxins.

Abbreviations: **AFB_1**, Aflatoxin B_1, **ROS**, reactive oxygen species; **EO**, essantial oils; **8-OHdG**, 8-hydroxy-2'-deoxyguanosine; **G.C**, guanine-cytosine; **T.A**, thymine-adenine; **SOD**, superoxide dismutase; **GPx**, glutathione peroxidase; **CAT**, catalase.

BIOSYNTHESIS OF AFLATOXINS

Aflatoxins belong to the polyketide class of secondary metabolites and are synthesized by enzymes encoded

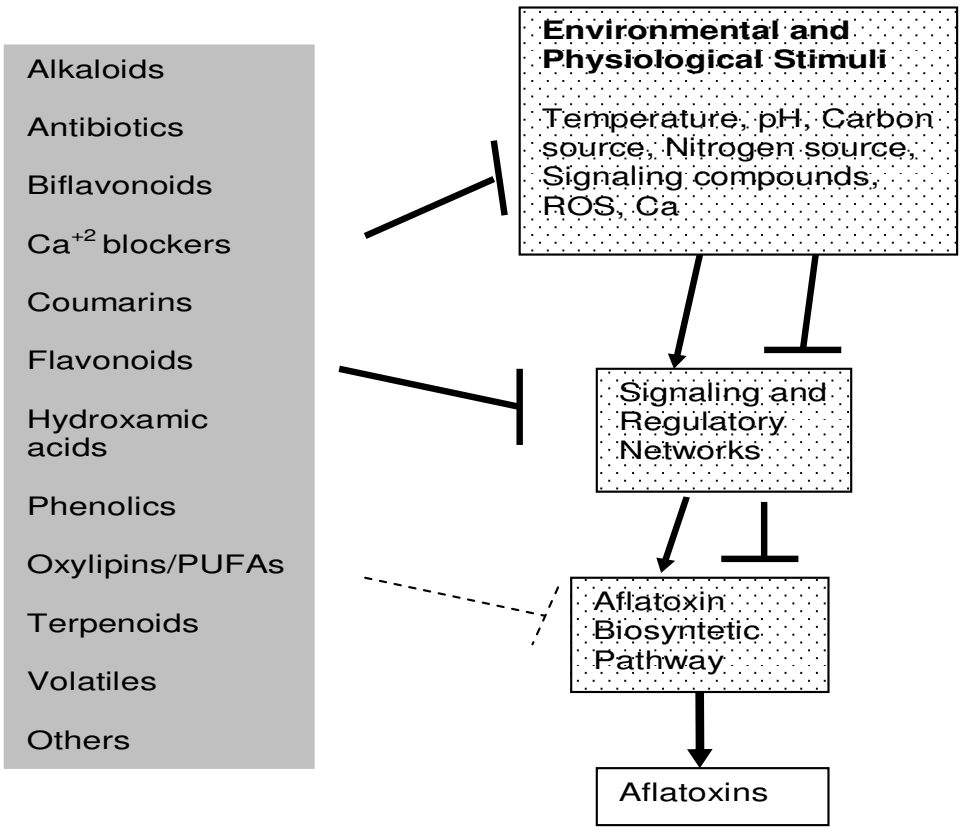

Figure 1. Inhibition of aflatoxin synthesis.

within a large gene cluster (Yabe and Nakajima 2004; Yu et al., 2004). The initial step in the generation of the polyketide backbone of aflatoxins is proposed to involve polymerization of acetate and nine malonate units (with a loss of CO_2) by a polyketide synthetase in a manner analogous to fatty acid biosynthesis (Dutton, 1988; Bhatnagar et al., 1992).

Syntesis of aflatoxins is control by specific enzymes which are expressed by DNA through many steps. Each step in gene expression, transcription, RNA transport and processing, translation, protein processing and localization can in theory be inhibited by natural plant products or other agents (Trail et al., 1995).

Many inhibitors of aflatoxin biosynthesis may act at three levels: (1) Modulate environmental and physiological factors affecting aflatoxin biosynthesis, (2) inhibit signaling circuits upstream of the biosynthetic pathway, or (3) directly inhibit gene expression or enzyme activity in the pathway (Figure 1). While the mode of action of most inhibitory compounds is unknown, there is a little evidence for the described compounds having an effect on gene transcription or enzyme activity of individual steps in the biosynthetic pathway. More likely, the known inhibitory compounds either alter known environmental and physiological modulators of aflatoxin biosynthesis or they alter signaling transduction pathways in the upstream regulatory network (Figure 1) (Holmes et al., 2008).

DAMAGES OF AFLATOXINS IN CELLS

Aflatoxins, which are well-known to be potentially mutagenic, carcinogenic, teratogenic, hepatotoxic and immunosuppressive, also inhibit several metabolic systems (Minto and Townsend, 1997; Wogan, 1999). The carcinogenic mechanism of aflatoxin B_1 (AFB_1) has been extensively studied. It has been shown that AFB_1 is activated by hepatic cytochrome P450 enzyme system to produce a highly reactive intermediate, AFB_1-8,9-epoxide, which subsequently binds to nucleophilic sites in DNA and the major adduct 8,9-dihydro-8-(N7 guanyl)- 9-hydroxy AFB_1 (AFB_1 N7-Gua) is formed (Sharma and Farmer, 2004; Klein, et al., 2002; Bedard and Massey, 2006). The formation of AFB_1-DNA adducts is regarded as a critical step in the initiation of AFB_1-induced hepatocarcinogenesis (Preston and Williams, 2005).

AFB_1 also has been shown to induce 8-hydroxy-2'-deoxyguanosine (8-OHdG) formation in rat (Shen et al., 1995; Yarborough et al., 1996) and duck (Barraud et al., 2001) liver in *in vivo* treatment. The mutagenic specificity of 8OHGua provides a potential tag for assessing the role of ROS mutagenesis in human cancer. It is of interest that the spectrum of p53 tumor suppressor gene mutations includes G.C+T.A transversions in about half of non-small cell carcinomas of the lung and nearly three-quarters of primary liver carcinomas (Hollstein et al.,

1991).

Although the mechanism underlying the hepatotoxicity of aflatoxins is not fully understood, several reports suggest that toxicity may ensue through the generation of intracellular ROS during the metabolic processing of AFB_1 by cytochrome P450 in the liver (Towner et al., 2003; Sohn et al., 2003). Free radicals provoked by various environmental chemicals as well as endogenous metabolism are involved in a number of diseases like tumors, inflammation, shock, atherosclerosis, diabetes, infertility, gastric mucosal injury and ischemia due to the oxidative damage to DNA, lipids and proteins and which can result in failure of cellular functions (Kasai, 2002). Free radicals also contribute to G. C + T. A transversions by the production of 8OHGua in liver DNA, therapies designed to reduce damage by oxygen free radicals (Ames, 1983) during chronic hepatitis would be predicted to delay the onset of primary liver cancer (Cheng et. al., 1992).

To control the level of ROS and to protect cells under stress conditions, living tissues contain several enzymes (SOD, GPx, and CAT) and many antioxidant substances. The effect of ROS is balanced by the antioxidant action of non-enzymatic antioxidants, as well as by antioxidant enzymes. Such antioxidant defenses are extremely important as they represent the direct removal of free radicals (prooxidants), thus, providing maximal protection for biological sites (Valko et al., 2006).

A lot of antioxidant compounds such as EO, phenolics compounds and secondary metabolites, which are synthesized by plants, serve in defense against ROS. The antioxidant properties of essential oil of plant origin have been studied in recent years. A strong correlation has been found between the essential oil level and the antioxidant activity potential.

Some EOs and other extracts (vitamins, riboflavin, carotenoids, beta-carotene, alfa-carotene, lycopene, ascorbic acid, curcumin, several flavonoids, phenolic compouds and synthetic phenolic compounds) of plants could potentially provide protection against aflatoxins especially AFB_1 (Nyandieka et al., 1990; Webster et al., 1996; Rasoli and Owlia, 2005; Agar et al., 2005; Kumar et al., 2007; Rasoli et al., 2008; Bluma and Etcheverry, 2008; Alpsoy et al., 2009). In addition, many essential oils could reduce toxic and mutagenic effect of aflatoxins. Most studies indicated that antiaflatoxigenic properties may be due to inhibition of penetration of *A. flavus* and *A. parasiticus* (Rasoli et al., 2008; Bluma and Etcheverry, 2008).

IMPACT OF ESSENTIAL OIL ON GROWTH OF *ASPERGILLUS*

Essential oils are volatile, natural and complex compounds characterized by a strong odour and are produced from aromatic plants as secondary metabolites. They are usually obtained by steaming or hydro-distillation which was first developed in the Middle Ages by the Arabs. Having been known for their antiseptic and medical properties such as bactericidal, virucidal and fungicidal and fragrance, they were used in embalmment, preservation of foods and for the treatment of antimicrobial, analgesic, sedative, anti-inflammatory, spasmolytic and locally anesthesic diseases. Essential oils can contain about 20-60 components in quite different concentrations. They are characterized by two or three major components at fairly high concentrations (20-70%) compared to others present in trace amounts (Bakkali et al., 2008).

Until now, many studies have revealed that *Aspergillus* growth was completely inhibited by many plants EOs. The effects of essential oils of 58 plant species (18 Family) were examined on the development of *A. flavus* and/or *A. parasiticus* (Table 1). EOs were extracted from leaf, stem and flower and they were also purchased from local market. Used different consentration of EOs was found to inhibit the development of *Aspergillus* species.

There are complex interactions of environmental factors, like water availability, which influence the efficacy of essential oils. It is possible to use a combination of them to reduce growth and aflatoxin production of *A. flavus* and *A. parasiticus*. The antifungal efficacy of plant essential oils may be attributable to the oil compositions. This result may be explained by the high content of some of these substances in the plants essential oils. Many researches indicate that the components of essential oil reduce the growth rate of *A. flavus* and *A. parasiticus*. Major components can constitute up to 85% of the EO, whereas other components are present only as a trace.

Some researchers reported that there is a relationship between the chemical structures of the most abundant compounds in the essential oils and the antimicrobial activity. Compositional analysis of EOs showed that compounds such as carvacrol, r-cimene, a-terpinolene, anethol and eugenol were the main components present in the different EO studied. According to Baydar et al. (2004) phenolic components, such as eugenol, anethole, carvacrol, its precursors r-cimene and g-terpinolene and its isomers thymol, are chiefly responsible for the antimicrobial properties of essential oils. Also, the physical nature of essential oils, that is, low molecular weight combined with pronounced lipophilic tendencies allow them to penetrate cell membrane more quickly than other substances (Pawar and Thaker, 2007).

However, there is evidence that minor components have a critical part to play in antimicrobial activity, possibly by producing a synergic effect between other components (Burt, 2004). The antimicrobial activity of essential oils or their constituents such as thymol, carvacrol and vanillin could be in different ways; (1) The result could be in the form of damage to the enzymatic cell system, including those associated with energy production and synthesis of structural compounds (Conner and Beuchat, 1984 a,b), (2) denaturation of the enzymes responsible for spore germination or interference

Table 1. Examples of plants that has antifungal activitiy.

Species	Family	Part of plant	Aspergillus	References
Rosmarinus officinalis	Lamiaceae	Leaf	*A. parasiticus*	Rasoli et al., 2008
Ocimum basilicum	Lamiaceae	Leaf	*A. flavus, A. paraiticus*	Montes-Belmont and Carvajal, 1998; Soliman and Badeaa, 2002; Atanda et al., 2007
Thymus eriocalyx	Lamiaceae	Leaf	*A. parasiticus*	Rasoli and Abyaneh, 2004
Thymus x-porlock	Lamiaceae	Leaf	*A. parasiticus*	Rasoli and Abyaneh, 2004
Satureja hortensis	Lamiaceae	Leaf	*A. parasiticus*	Razzaghi-Abyaneh et al., 2008
Ocimum gratissimum	Lamiaceae	Leaf	*A. flavus*	Neguefact et al., 2004
Thymus vulgaris	Lamiaceae	All of plant, Leaf	*A.flavus, A. paraiticus*	Montes-Belmont and Carvajal, 1998; Soliman and Badeaa, 2002; Neguefact et al., 2004; Kumar et al., 2007
Mentha viridis	Lamiaceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002
Mentha piperita	Lamiaceae	Leaf, Leaf and stem	*A.flavus, A. paraiticus*	Montes-Belmont and Carvajal, 1998; Bluma et al., 2007
Origanum vulgare	Lamiaceae	Leaf, Leaf and stem	*A.flavus, A. paraiticus*	Montes-Belmont and Carvajal, 1998; Bluma et al., 2007
Minthostachys verticillata	Lamiaceae	Leaf and Stem	*A.flavus, A. paraiticus*	Bluma et al., 2007
Lavandula officinalis	Lamiaceae	Leaf	*A. flavus*	Kumar et al., 2007
Mentha arvensis	Lamiaceae	Leaf	*A. flavus*	Kumar et al., 2007
Ocimum canum	Lamiaceae	Leaf	*A. flavus*	Kumar et al., 2007
Pogostemon cablin	Lamiaceae	Leaf	*A. flavus*	Kumar et al., 2007
Matricaria chamomilla	Asteraceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002
Calendula officinalis	Asteraceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002
Achillea millefolium	Asteraceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002
Achillea fragrantissima	Asteraceae	Leaf	*A. flavus, A. paraiticus*	Soliman and Badeaa, 2002
Artemisia nilagirica	Asteraceae	Leaf	*A. flavus*	Kumar et al., 2007
Eupatorium cannabinum	Asteraceae	Leaf	*A. flavus*	Kumar et al., 2007
Chrysactinia mexicana	Asteraceae	Flower	*A. flavus*	Alvarez-Castellanos et al., 2001
Trachyspermum copticum	Apiaceae	Seed	*A. parasiticus*	Rasoli et al., 2008
Coriandrum sativum	Apiaceae	Leaf	*A. parasiticus*	Atanda et al., 2007
Pimpinella anisum	Apiaceae	Leaf, Seed	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002; Bluma et al., 2007; Bluma et al., 2008
Carum carvi	Apiaceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002; Kumar et al., 2007
Foeniculum vulgare	Apiaceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002
Entandrophragma utile	Meliaceae	Leaf	*A. parasiticus*	Anthony, 2006
Khaya grandifoliola	Meliaceae	Leaf	*A. parasiticus*	Anthony, 2006
Lovoa trichilioides	Meliaceae	Leaf	*A. parasiticus*	Anthony, 2006
Pseudocedrela kotschyi	Meliaceae	Leaf	*A. parasiticus*	Anthony, 2006
Trichilia heudilotii	Meliaceae	Leaf	*A. parasiticus*	Anthony, 2006

Table 1. Contd

Cymbopogon citratus	Poaceae	Leaf, Commerical	*A. flavus*	Paranagama et al., 2003; Neguefact et al., 2004; Souza et al., 2005; Helal et al., 2007
Syzygium aromaticum	Myrtaceae	Leaf, Airal part,Flower bud	*A. flavus*	Montes-Belmont and Carvajal, 1998; Bluma et al., 2007; Bluma et al., 2008
Cymbopogon flexuosus	Poaceae	Leaf	*A. flavus*	Kumar et al., 2007
Cymbopogon martinii	Poaceae	Leaf	*A. flavus*	Kumar et al., 2007
Melaleuca leucadendron	Myrtaceae	Leaf	*A. flavus*	Kumar et al., 2007
Vetiveria zizanoides	Poaceae	Leaf	*A. flavus*	Kumar et al., 2007
Eucalyptus globulus	Myrtaceae	Commerical, Airal part	*A. flavus*	Souza et al., 2005; Bluma et al., 2007
Eugenia uniflora	Myrtaceae	Commerical	*A. flavus*	Souza et al., 2005
Cinnamomum cassia	Lauraceae	Leaf	*A. flavus*	Atanda et al., 2007
Laurus nobilis	Lauraceae	Leaf	*A. flavus*	Atanda et al., 2007
Cinnamomum zeylanicum	Lauraceae	Commerical; Leaf	*A.flavus, A. paraiticus*	Montes-Belmont and Carvajal, 1998; Soliman and Badeaa, 2002; Carmo et al., 2008
Lippia alba	Verbenaceae	Commerical, Leaf	*A. flavus*	Souza et al., 2005; Kumar et al., 2007
Lippia turbinate	Verbenaceae	Airal part	*A. flavus*	Bluma et al., 2007; Bluma et al., 2008
Lippia microphylla	Verbenaceae	Commerical	*A. flavus*	Souza et al., 2005
Teloxys ambrosioides	Amaranthaceae	Leaf	*A. flavus*	Montes-Belmont and Carvajal, 1998
Aegle marmelos	Rutaceae	Leaf	*A. flavus*	Kumar et al., 2007
Chenopodium ambrosioides	Amaranthaceae	Leaf	*A. flavus*	Kumar et al., 2007
Citrus limon	Rutaceae	Commerical	*A. flavus*	Souza et al., 2005
Monodora myristica	Annonaceae	Seed	*A. flavus*	Neguefact et al., 2004
Zingiber officinale	Zingiberaceae	All of plant, Leaf	*A. flavus*	Neguefact et al., 2004; Kumar et al., 2007
Agrimonia eupatoria	Rosaceae	Leaf	*A.flavus, A. paraiticus*	Soliman and Badeaa, 2002
Peumus boldus	Monimiaceae	Leaf, Commerical	*A.flavus, A. paraiticus*	Souza et al., 2005; Bluma et al., 2007; Bluma et al., 2008
Pelargonium graveolens	Geraniaceae	Leaf	*A. flavus*	Kumar et al., 2007
Santalum album	Santalaceae	Wood	*A. flavus*	Kumar et al., 2007
Hedeoma multiflora	Malpighiaceae	Airal part, Leaf	*A. flavus*	Bluma et al., 2007, Bluma et al., 2008
Sardinia juniperus	Cupressaceae	Leaf	*A. flavus*	Cosentino et al, 2003

with the aminoacid involved in germination (Nychas, 1995) and (3) irreversible damage in cell wall, cell membrane and cellular organelles when *A. parasiticus* and *A. flavus* were exposed to different essential oils (Rasoli and Owlia, 2005; Helal et al., 2007).

Table 2. Examples of plants that has antiaflatoxigenic activitiy.

Species	Family	Part of plant	Aflatoxins	References
R. officinalis	Lamiaceae	Leaf	Aflatoxin	Rasoli et al., 2008
O.basilicum	Lamiaceae	Leaf	Aflatoxin, AFB1 and AFG1	Montes-Belmont and Carvajal, 1998; Soliman and Badeaa, 2002; Atanda et al., 2007
T. eriocalyx	Lamiaceae	Leaf	Aflatoxin	Rasoli and Abyaneh, 2004
T.x-porlock	Lamiaceae	Leaf	Aflatoxin	Rasoli and Abyaneh, 2004
S. hortensis	Lamiaceae	Leaf	AFB1 and AFG1	Razzaghi-Abyaneh et al., 2008
T. vulgaris	Lamiaceae	All of plant, Leaf	Aflatoxin	Montes-Belmont and Carvajal, 1998; Soliman and Badeaa, 2002; Neguefact et al., 2004; Kumar et al., 2007
M. viridis	Lamiaceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
M. chamomilla	Asteraceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
C. officinalis	Asteraceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
A. millefolium	Asteraceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
A. fragrantissima	Asteraceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
T. copticum	Apiaceae	Seed	Aflatoxin	Rasoli et al., 2008
C. sativum	Apiaceae	Leaf	AFB1 and AFG1	Atanda et al., 2007
P. anisum	Apiaceae	Leaf, Seed	Aflatoxin	Soliman and Badeaa, 2002; Bluma et al., 2007; Bluma et al., 2008
C.carvi	Apiaceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002; Kumar et al., 2007
F. vulgare	Apiaceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
E. utile	Meliaceae	Leaf	Aflatoxin	Anthony, 2006
K. grandifoliola	Meliaceae	Leaf	Aflatoxin	Anthony, 2006
L. trichilioides	Meliaceae	Leaf	Aflatoxin	Anthony, 2006
P.kotschyi	Meliaceae	Leaf	Aflatoxin	Anthony, 2006
T. heudilotii	Meliaceae	Leaf	Aflatoxin	Anthony, 2006
C. citratus	Poaceae	Leaf, Commerical	AFB1	Paranagama et al., 2003; Neguefact et al., 2004; Souza et al., 2005; Helal et al., 2007
S. aromaticum	Myrtaceae	Leaf, Airal part,Flower bud	Aflatoxin, AFB1	Montes-Belmont and Carvajal, 1998; Bluma et al., 2007; Bluma et al., 2008
E. globulus	Myrtaceae	Commerical, Airal part	AFB1	Souza et al., 2005; Bluma et al., 2007
C. cassia	Lauraceae	Leaf	AFB1 and AFG1	Atanda et al., 2007
L. nobilis	Lauraceae	Leaf	AFB1 and AFG1	Atanda et al., 2007
C. zeylanicum	Lauraceae	Commerical; Leaf	Aflatoxin	Montes-Belmont and Carvajal, 1998; Soliman and Badeaa, 2002; Carmo et al., 2008
L. turbinate	Verbenaceae	Airal part	Aflatoxin, AFB1	Bluma et al., 2007; Bluma et al., 2008
C. ambrosioides	Amaranthaceae	Leaf	AFB1	Kumar et al., 2007
A. eupatoria	Rosaceae	Leaf	Aflatoxin	Soliman and Badeaa, 2002
P. boldus	Monimiaceae	Leaf, Commerical	Aflatoxin	Souza et al., 2005; Bluma et al., 2007; Bluma et al., 2008
H. multiflora	Malpighiaceae	Airal part, Leaf	Aflatoxin, AFB1	Bluma et al., 2007, Bluma et al., 2008

INHIBITION OF AFLATOXIN PRODUCTION BY ESSENTIAL OILS

The effects of EO and its principal components showed inhibitory activity on aflatoxin biosynthesis by *A. flavus*. Many researcher reported that EOs of plants was able to inhibit both growth and/or mycotoxin production. The antiaflatoxigenic activity of EOs of different 32 plants are indicated by many researcher (Table 2). For instance, the EOs of *Pimpinella anisum*, *Peumus boldus*, *Hoya multiflora, Syzygium aromaticum* and *Lippia turbinate* inhibited aflatoxin production.

Essential oils, such as anisum and boldus, could be safely used as a preservative material on some foods because they stopped fungal growth and AFB_1 accumulation. They could also be added to grain in storage to protect it from fungal infection. These oils could be used as a substitute for chemical fungicides.

They may also prove valuable as 'lead structure' for the development of synthetic compounds as they are natural and nontoxic to humans and animals alike (Soliman and Badeaa, 2002; Bluma et al., 2007). The antiaflatoxigenic actions of EO may be related to inhibition of the ternary steps of aflatoxin biosynthesis involving lipid peroxidation and oxygenation (Bluma et al., 2007)

INHIBITION OF AFLATOXIN DAMAGE BY ESSENTIAL OIL

The essential oils can decrease the damaged effect of aflatoxins by two different ways. Firstly, DNA binding formation of aflatoxins is reduced by essential oils. Secondly, aflatoxins cause increase of reactive oxygen species and essential oils react with ROS. Therefore, essential oils protect the cells from harmful impact of aflatoxins.

Recently, the natural products such as plant extracts have been identified as potential candidates against AFB_1. A few study show that essential oils reduce DNA binding of aflatoxin. Essential oils from common spices such as nutmeg, ginger, cardamom, celery, xanthoxylum, black pepper, cumin and coriander were tested for their ability to suppress the formation of DNA adducts by AFB_1 *in vitro* in a microsomal enzyme-mediated reaction. All oils were found to inhibit adduct formation very significantly and in a dose-dependent manner. The adduct formation appeared to be modulated through the action on microsomal enzymes, because an effective inhibition on the formation of activated metabolite was observed with each oil. The enzymatic modulation is perhaps due to the chemical constituents of the oils and this could form a basis for their potential anticarcinogenic roles (Hashim et al., 1994). In another research, the effects of garlic oil, such as diallyl disulfide (DADS) and diallyl sulfide (DAS) on AFB_1-induced DNA damage in cultured primary rat hepatocytes are shown. About 0.5 and 2 mM DAS or 0.5 and 1 mM DADS significantly decreased the DNA damage induced by AFB_1 as compared with the AFB_1 control, according to the unscheduled DNA synthesis test (Shenn et al., 2001).

CONCLUSION

These results indicate the potential of essential oils as natural preservatives in food against *A. parasiticus* and *A. flavus*, the well known casual agents of foodborne diseases and food poisonings. There are a few research on aflatoxin-induced oxidative damage and essential oil interaction. Therefore, this area needs more study.

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