Journal of Food Research; Vol. 10, No. 6; 2021
ISSN 1927-0887 E-ISSN 1927-0895
Published by Canadian Center of Science and Education

An *in Vitro* Antifungal and Antiaflatoxigenic Properties of *Commiphora myrrha* and *Prunus mahaleb*

Saifeldin A. F. El-Nagerabi[1, 2], Mohammed S. R. Al-Maqbali[2], Khalid M. S. Alabri[2] & Abdulkadir E. Elshafie[3]

[1] Department of Biology, School of Applied and Industrial Sciences, University of Juba, Juba, P.O. Box 82, Republic of South Sudan

[2] Department of Biological Sciences and Chemistry, College of Arts and Sciences, University of Nizwa, P.O. Box 33, PC 616, Birkat Al Mouz, Nizwa, Oman

[3] Department of Biology, College of Science, Sultan Qaboos University, P.O. Box 36, PC 123, Al Khoud, Muscat, Oman

Correspondence: Saifeldin A. F. El-Nagerabi, Department of Biology, School of Applied and Industrial Sciences, University of Juba, Juba, P.O. Box 82, Republic of South Sudan. Tel: 211-918-829-908. E-mail: nagerabi@hotmail.om; nagerabisaf@gmail.com

Received: September 22, 2021 Accepted: November 9, 2021 Online Published: November 21, 2021

doi:10.5539/jfr.v10n6p10 URL: https://doi.org/10.5539/jfr.v10n6p10

Abstract

Aflatoxins and especially aflatoxin B, are the devastating contaminant of food and feed products with hazardous effects to mankind and his domestic animals. These investigations were set to evaluate the effect of various levels of *Commiphora myrrha* resin (1.0, 1.25, 2.25, and 3.25 g/100 ml) and *Prunus mahaleb* seed extract *(*0.75, 1.5, 2.5, and 3.5 g/100 ml) on the growth and aflatoxin secretion by two aflatoxigenic strains of *Aspergillus flavus* and *A. parasiticus*. The two plant extracts significantly (p<0.05) decreased aflatoxin secretion, and inhibited the fungal growth. Resin of *C. myrrha* displayed 51.9-95.7% reduction in total aflatoxin secretion by *A. flavus*, and 46.9-92% for *A. parasiticus*, and *S*eed extract of *P. mahaleb* decreased aflatoxin up to 53.7-95.8% and 40-94.7%, respectively. The inhibition of aflatoxin B (B_1 and B_2) by myrrh resin and seed extract of mahaleb ranged between 51.7-93.5, 50-93.6% (*A. flavus*) and 39.5-89.7%, 37.9-93% (*A. parasiticus*). The mycelial dry weight of *A. flavus* and *A. parasiticus* ws decreased up to 46.1-58.7%, 28.9-51.3% (Myrrh resin), and between 45-56.9%, 33.3-55.9% (Mahaleb seed extract). Nonetheless, the two plant extracts did not detoxify aflatoxin B_1. Therefore, it apparent that the resin of *C. myrrha* and seed extract of *P. mahaleb* affected the biosynthesis pathway of aflatoxins. Thus, they can be recommended as effective natural plant biopreservative against aflatoxin contamination of food and feed products.

Keywords: Aflatoxigenic, *Aspergillus flavus, A. parasiticus, Commiphora myrrha, Prunus mahaleb*

1. Introduction

Commiphora myrrha (Nees) Engl. (syn. *C. molmol*), myrrh (Mor Hijazi, in Arabic) of the family Burseraceae, is small tree or large shrub which found in dry and arid regions of Ethiopia, Somalia, North Kenya, North Africa, and Middle East (Abd-Ulgadir *et al.,* 2015; Ali, 2007; Omer *et al.*, 2011; Su *et al.*, 2011). Myrrh gum-resin is the dried resinous exudate from plant stem of different *Commiphora* species. *C. myrrha* has various traditional uses in food and drink as flavoring, perfumes, and as fragrance in other cosmetics (Ali, 2007; Marshall, 2004). The natural gums are of high biocompatibility, available at low cost, low toxicity, and eco-friendly compared to the synthetic ones (Yusuf and Usman, 2011). Medicinally, myrrh gum has been extensively used for treatment of various diseases (El Ashry *et al.,* 2003; Shen and Lou, 2008), rheumatic complaints, tooth decay, gum disease, and helminth infection (Abd-Ulgadir *et al.,* 2015; Haffor *et al.,* 2010), antiseptic, carminative, anti-inflammatory, and tonic in dyspepsia (Omer el al., 2011; Su *et al.,* 2012). It exhibited numerous biological activities as anti-inflammatory, antibacterial, antifungal, antimicrobial, antioxidant, hepatoprotective, smooth muscles relaxing, antimalarial, anticandidal, antischistosomal, larvicidal, molluscicidal, anticancer, and hypolipidemic effect (Al-Abdalall, 2013; Al-Daihan *et al.,* 2013; Ali *et al.,* 2008; Dolara *et al.*, 2000; Gadir *et al.,* 2014; Shen *et al.,* 2012; Shulan el al., 2011). Its antimicrobial activity, food preservation, pharmaceuticals, alternative medicine and natural therapies has been reported by many authors (Abd-Ulgadir *et al.,* 2015). Antimicrobial activity against gram-positive organisms, *Candida albicans,* and other microorganisms was observed (Al-Daihan *et al.,*

2013; Dolara *et al.,* 2000; Omer *et al.,* 2011; Shuaib *et al.,* 2013).

Prunus mahaleb L. (sync. *Cerasus mahaleb* L. Mill.) of the family Rosacease is known as English cherry, Rock cherry, St. Lucie cherry and "mahleb, mahaleb, mahlab" in Arabic which grown abundantly in West Asia, North Africa, Middle East, and sometimes found in Eastern and Central Europe (Leri *et al.,* 2012; Özcelik and Koka, 2012; Seyyednejad *et al.,* 2008; Shams and Schmidt, 2007). Various products from seed kernels and fruits of mahaleb tree have many uses as pleasing spice in patisseries mixed with flour for their special fragrance, home baking and candy industry (Özcelik and Koca, 2012). It has been used in folk medicine in various ailments as tonic for sensory organs, heart diseases, asthma, blood pressure, diabetes, swelling of stomach, relieving pains arising from liver, kidney swelling, anti-kidney stones, inflammation, oxidative stress diseases, gastrointestinal problem, diarrhea, and for scenting and preservation purposes (Gerardi *et al.,* 2010; Oskoueian *et al.,* 2012; Shams *et al.,* 2007). These plants are of significant potential in therapeutic applications against human pathogens including bacteria, fungi, and viruses (Holetz *et al.,* 2002; Perez, 2003; Syyednejad, 208). All methanol extracts from different parts of mahaleb including flowers, leaves, branches, fruits, fruit stalks, seed and seed coat showed antibacterial and antifungal activities (Özcelik and Koca, 2012). The ethanolic extracts of mahaleb had antibacterial activity against *Proteus mirabilis*, *Bacillus anthracis*, *and Staphylococcus aureus* (Seyyednejad *et al.,* 2008).

Plant and animal products are prone to infestation with various mycotoxins producers *molds* (El-Nagerabi *et al.,* 2012, 2013; Herzallah 2009; Salim and Ahmad 2010; Wagacha and Muthomi, 2008). Of these mycotoxins, aflatoxins are the most hazardous contaminants associated with adverse effects on health (Kumar *et al.,* 2008). They are the most devastating pathogens of various crops and milks (Abdulkadir *et al.,* 2004; El-Nagerabi *et al.,* 2012; Elshafie *et al.,* 2002; Payne 1998; Santacrose *et al.,* 2008). Aflatoxin B_1 is mutagenic, teratogenic and carcinogenic secondary metabolites of *Aspergillus flavus, A. parasiticus, A. nominus* and *A. pseudotamorii* (El-Nagerabi *et al.,* 2013; Sidhu *et al.,* 2009).

Different plant extracts inhibit the fungal growth and aflatoxins production by *A. flavus* and *A. parasiticus* which suggest their antifungal and antiaflatoxigenic activities (El-Nagerabi *et al.,* 2012). Many plants were examined such as *Hibiscus sabdariffa* (Al-Shayeb and Mabrook, 1984; El-Nagerabi *et al.,* 2012), herbals (Gowda *et al.,* 2004), and *Garcinia cowa* and *G. pendunculata* fruits (Joseph *et al*., 2005), *Syzigium aromaticum*, *Cucuma longa*, *Allium sativum*, and *Ocimum sanctum* (Reddy *et al.,* 2009). Essential oils from anise, caraway, cinnamon, black cinum, fennel plants, and Ne*gella sativa* displayed similar effects (Bullerman *et al.,* 1977; El-Nagerabi *et al.,* 2012; Farag *et al.,* 1989; Hasan, 1994; Maraqa *et al.* 2007; Montes-Belmont and Carvajal, 1998; Patkar *et al.,* 1993; Soher, 1999; Soliman and Badeaa, 2002). Investigations using different extracts from *Acacia seyal*, *Boswellia sacra*, *Balanites aegyptiaca*, *Moringa stenopetala*, *Tamaridus indica*, and *Adansonia digitata* revealed different inhibitory effects on aflatoxin secretion by aflatoxigenic fungi (El-Nagerabi *et al.,* 2012, 2013, 2016).

Different detoxification procedures have been tested for their inhibitory effect on the fungal growth and aflatoxin production (El-Nagerabi *et al.,* 2016; Oguz, 2011). Numerous chemicals and physical factors were evaluated for their decontamination properties (Kumar *et al.,* 2009). Nonetheless, safety issues and undesirable impacts on humans, animals and their environment restricted their use in food industries (Szczerbanik *et al.,* 2007; Vijayanandraj *et al.,* 2014). On the other hand, the biological detoxification of aflatoxin using different microorganisms was attempted by many authors (e.g. El-Nezami *et al.,* 1998; Shantha, 1999). Nonetheless, these microorganisms consumed nutrients from food for their growth and secrete toxic metabolites (Vijayanandraj *et al.,* 2014). Therefore, this supports the need for eco-friendly plant extracts as biocontrol method. However, the antifungal and detoxification property of *Commiphora myrrha* and *Prunus mahaleb* on the aflatoxigenic fungi was not tested. This study aiming at investigation of the effects of *C. myrrha* gum and *P. mahaleb* seed extract on two aflatoxigenic strains namely, *A. flavus* (SQU21) and *A. parasiticus* (CBS921.7) [NRRL22999]. The findings will build the knowledge on the bioactivities of these plants and their uses for the advancement in food and feed industries.

2. Materials and Methods

2.1 Aspergillus Flavus and A. Parasiticus Strains

Aspergillus flavus (SQU21) and *A. parasiticus* (CBS921.7)[NRRL22999] strains from previous study were used (El-Nagerabi *et al.,* 2016) as identified by Raper and Fennell (1965).

2.2 Collection and Characteristics of C. Myrrha Resin and Seeds of P. Mahaleb

The resin granules of *C. myrrha* and the seeds of *P. mahaleb* were purchased from the local market of Nizwa, Oman, and were stored at 25-33 ℃. The resin from the myrrh stem is a yellow fragrant oleo-gum with aromatic

odour (Orwa *et al.,* 2009; Shuaib *et al.,* 2014; Shulan *et al.,* 2011). Ribose and galacturonic acid are the major constituents isolated from *C. myrrha* oleo-gum-resin (Ammar *et al.,* 2010). The oleo-gum resin contains about 2-8% volatile oil, 23-40% alcohol-soluble resin, 40-60% gum. Chemically it contains series of metabolites such as anti-inflammatory triterpenes (Carvalho *et al.,* 2008; Hanuš *et al.,* 2008; Refat *et al.,* 2011; Shuaib *et al.,* 2014; Shulan *et al.,* 2011;). It decreases blood lipids and cholesterol and the guggulsterones act as antagonist ligands (Carvalho *et al.,* 2008). The oil composed of α-pinene, dipentene, limonene, cuminaldehyde, cinnamic aldehyde, eugeno, m-cresol, heerabolene, cadinene, sesquiterpene, abicyclic sesquiterpene, formic acid, acetic acid, myrrholic acid, and palmitic acid. The resin composed of acetate, 3-epi-lupenyl acetate, lupeone, 3-epi-α-amirin, α-amirone, acetyl β-eudesmol and a sesquiterpenoid lactone. It is a mixture of furanoeudesma-1,3-dien and lindestrene and dihydropyrocurzeren of a resinous myrrh odor (Mrongiu *et al.,* 2005). It contains about 15 amino acids and high yields of mixture sugars and acidic oligosaccharides, where in fractions of D-galactose, L-arabinose, and 4-methyl D-glucuronic acid were detected. Two aldobiuronic acids, which present as 6-O-(4-O-methyl-β-D-glucuronosyl)-D-galactose and 4-O-(4-O-methyl-α-D-glucuronsyl)-D-galactose were detected (Hanuš *et al.,* 2008; Soni *et al.,* 2013). Medicinally, it is used for treating various diseases and exhibited interesting biological activities such as anti-inflammatory, antibacterial, antifungal, antimicrobial, antimycobacterial, antioxidant, hepatoprotective, smooth muscle relaxing, antimalarial, anticandidal, antischistosomal, larvicidal, molluscicidal, anticancer, antiulcer and hypolipidemic effects (Ali *et al.,* 2008; Shulan *et al.,* 2011). The dry kernel of mahaleb contains 3.2% crude fat, 2.8% crude protein, 6.3% ash, 5.7% fiber, 82.0% soluble carbohydrates, and trace amounts of fats and protein (Herrera et al, 1981). The seeds have high protein content (31%), cyanogenic glucoside and coumarins including herniarin (7-methoxycoumarin) and coumarin. It was found to contain 31% oil which is abundant in α-eleostearic (38.32%), oleic (31.29%), and linoleic (22.96%) (Sbihi *et al.,* 214). In addition to tannins, traces of hydrocyanic acid, dihydrocoumarin and cyanogenic glucosides of amygdaline (mandelonitrile-β-gentio-bioside) (Özçelik *et al.,* 2012; Patton *et al.,* 1997; Jerković, 2011). The kernels contain 27-40% fatty oil with unusual composition of conjugated fatty acids including 9, 11, 13-octadecatrienoic acid, conjugated linoleic acid (38.81%), oleic acid (28.45%), linoleic acid (20.67%), palmitic acid (3.74%), stearic acid (2.25%) and arachidic acid (0.3%). Aliphatic hydrocarbons, alcohols, carbonyls, fatty acids (dodecanoic, tretradecanoic, hexadecanoic and linoleic acids), terpenes, C13-norisoprenoids and phenylpropane derivatives (Coumarin 0.3-2.4%) were detected (Jerković, 2011). Terpenes, norisoprenoids and benzene derivatives, minor percentages of aliphatic compounds and furan derivatives were extracted (Oral, 2014).

2.3 Growth of Aspergilli Strains on Media Enriched with Myrrha Resin and Mahaleb Extract

The strains of *A. flavus* and *A. parasiticus* were grown on Potato Dextrose Agar (PDA) and incubated for 7 days at ambient temperature (25-32 ℃). Glass tubes of 5 mm in diameter were sterilized and used to cut several discs from each of the growing fungal colonies. Inoculum from the growing colonies were added to 250 flasks containing 200 ml of yeast malt broth with different concentrations of *myrrh* resin (0.0%, 1.0%, 1.25%, 2.5% and 3.25% w/v), and *mahaleb* extract (0.0%, 0.75%, 1.5%, 2.5%, and 3.5% w/v). Three replicates were incubated at 25-32^{o}C for 15 days. Other sets were kept to measure the dry weight of the fungal mycelia using Oven method.

2.4 Effect of the Extracts on Synthetic Aflatoxin B_1

Pure aflatoxin B_1 of 885 ppb concentration was prepared in 100 ml sterile distilled water. The highest concentrations of resin (3.25%) and mahaleb (3.5%) were separately added to flasks containing pure aflatoxin B_1. As a control, flask containing aflatoxin B_1 was left without any extract. The flasks were incubated at 25-32^{o}C for 7 days and aflatoxin concentrations were assessed.

2.5 Extraction and Assay of Aflatoxin

Alfa Test-P Affinity method was used for aflatoxin extraction and detection as described by many authors and adopted in our previous study (El-Nagerabi *et al.,* 2012). To the 200 ml fungal culture, 5g of sodium chloride in addition to 100 ml methanol:water (70:30 V/V) as extraction solution were added. To the filterate, 15 ml distilled water were added, mixed, filtered with glass microfilters. Ten ml from the diluted filtrate were passed via Afla-Test-P Affinity Column and the column was cleaned by 10 ml distilled water. The extracted aflatoxin was eluted with one ml methanol (HPLC grade) and one ml of AflaTest developer was added to elute in the cuvette, and vortexed. The aflatoxin concentration was measured by calibrated Vicam fluorometer (Series-4EX) (El-Nagerabi *et al.,* 2016; Elshafie and Al-Shally, 1998).

2.6 Statistical Analysis

One-way ANOVA test (correlation coefficient) under SPSS software (version 11.0) was used to determine the

variation between the effects of different concentrations of *C. myrrha* resin gum and *P. mahaleb* seed extract on aflatoxin inhibition-detoxification and fugal growth.

3. Results and Discussion

3.1 Effect of Mryrrh Resin and Mahaleb Extract on Fungal Growth and Aflatoxin Secretion

Worldwide, researchers evaluating the uses of different plant products and microorganisms for biological control of aflatoxigenic molds (ex: Reddy *et al.,* 2009; Shantha, 1999; Suleiman *et al.,* 2008). Numerous herbals, medicinal and aromatic plants were screened for their antifungal properties (El-Nagerabi *et al.,* 2012, 2013, 2016; Gandomi *et al.,* 2009; Maraqa *et al.,* 2007; Montes-Belmont and Carvajal, 1998; Patker *et al.,* 1993; Soher, 1999; Soliman and Badeaa, 2002). In the present studies, the effect of *C. myrrha* resin, *P. mahaleb* seed extract on the aflatoxigenic *Aspergillus flavus* and *A. parasiticus* was evaluated. The results showed that the total aflatoxin produced by the two *Aspergillus* strains was significantly (p<0.05) inhibited by different concentrations of resin (1, 1.25, 2.5, and 3.25g/100 ml). The total aflatoxin was decreased by 51.9-95.7% (*A. flavus*) and 46.9-92% (*A. parasiticus*) (Fig. 1), and aflatoxin B (B_1 and B_2) was inhibited by 51.7-93.5% and 39-89.7%, respectively (Fig. 2). The mycelial dry weights of the two species were significantly (p<0.05) decreased with concentrations of resin (Fig. 3). The mycelial dry weight was decreased by 46.1-58.7% (*A. flavus*), and 28.9-51.3% (*A. parasiticus)*. On the other hand, the total aflatoxin was significantly (p<0.05) inhibited by all tested concentrations of mahaleb seed extracts (0.75, 1.5, 2.5, 3.5g/100 ml) compared to the control. The total aflatoxin inhibition ranged between 53.7-95.6% for *A. flavus*, and 40-94.7% for *A. parasiticus* (Fig. 4), whereas aflatoxin B inhibition was 50-93.6% for *A. flavus* and decreased by 37.9-93% for *A. parasiticus* (Fig. 5). The mycelial dry weight decreased by 45-56.9% for *A. flavus*, and 33.3-55.9% for *A. parasiticus* (Fig. 6).

About 50% of *Aspergilli* are aflatoxin producers including the two strains used in this study (El-Nagerabi *et al.,* 2016). There are some investigations on the uses of myrrh resin for diseases treatment (Abd-Ulgadir *et al.,* 2015; Al Ashry *et al.,* 2003; Haffor, 2010; Shen and Lou, 2008), antiseptic carminative, and anti-inflammatory tonic in dyspepsia (Omer *et al.,* 2011), various biological activities such as antibacterial, antifungal (Al-Abdalall, 2013; Al-Daihan *et al.,* 2013; Ali *et al.,* 2008; Dolara *et al.,* 2000; Gadir *et al.,* 2014; Shen *et al.,* 2012; Shulan el al., 2011), as food preservative (Abd-Ulgadir *et al.,* 2015), and antimicrobial activity against gram-positive bacteria, *Candida albicans*, and other microorganisms (Al-Daihan *et al.,* 2013; Dolara *et al.,* 2000; Omer *et al.,* 2011; Shuaib *et al.,* 2013). On the other hand, *P. mahaleb* used as spice in home baking (Özcelik and Koca, 2012), folk medicine (Gerardi *et al.,* 2010; Oskoueian *et al.,* 2012; Shams *et al.,* 2007), and against human pathogenic bacteria, fungi, and viruses (Holetz *et al.,* 2002; Perez, 2003; Syyednejad, 2008). Extract from different plant parts showed antibacterial and antifungal properties (Özcelik and Koca, 2012), and antibacterial activities against *Proteus mirabilis, Bacillus anthracis, Staphylococcus aureus* (Seyyednijad *et al.,* 2008). The effect of *C. myrrha* resin and *P. mahaleb* extracts on aflatoxigenic molds was not investigated yet. This encouraged the need for testing their inhibitory nature. The *C. myrrha* resin of between 1-3.25% resulted in 51.9-95.7% inhibition of total aflatoxin production (*A. flavus)* and 46.9-92% (*A. parasiticus*). Aflatoxin B (B_1 and B_2) was decreased by 51.7-93.5% for *A. flavus* and 39.5-89.7% for *A. parasiticus* strain. Similarly, *P. mahaleb* seed extracts inhibited the total aflatoxin up to 53.7-95.6% for *A. flavus*, and 40-94.7% for *A. parasiticus*, whereas aflatoxin B inhibition was 50-93.6% and 37.9-93%, respectively. In similar studies using different plant extracts showed apparent inhibition of the fungal growth and aflatoxin production by aflatoxigenic fungi. *Syzigium aromaticum,* cinnamon, *Curcuma longa, Allium sativum, Ocimum sanctum, Garcinia cowa, A. digitata* (baobab), *Boswellia sacra, Tamaridus indica and Hebiscus sabdariffa* effectively inhibit the growth of *A. flavus* and aflatoxin production (Al-Shayeb and Mabrook, 1984; Bullerman *et al.,* 1977; El-Nagerabi *et al.,* 2012, 2013; Joseph *et al.,* 2005; Reddy *et al.,* 2009). The present results showed that the highest inhibition (92-95.7%, 94.7-95.6%) at 3.25% myrrh resin, and 3.5% mahaleb. These findings point the high possibility for the presence of various aflatoxin inhibitors in myrrh resin and mahaleb seed extract which affect the biochemical synthesis of aflatoxin. These chemicals are responsible for the biological properties of these plant extracts (Büchele, *et al.,* 2003; El-Nagerabi *et al.,* 2012, 2013, 2016; Safayhi and Sailer, 1997; Singh *et al.,* 2008;). On the other hand, the addition of different concentrations of *C. myrrha* resin and *P. mahaleb* seed extract to the yeast malt broth inoculated with the two strains, evidently inhibited their growth performance (Fig. 3, 6). Similarly, C. myrrha extracts inhibited the growth of both bacterial and fungal standard species (Abd-Ulgadir *et al.,* 2015; Omer, *et al.,* 2011), whereas the oil of *C. myrrha* and *C. molmol* showed antibacterial and antifungal activities and inhibited the growth of *Aspergillus flavus, A. niger* and *Penicillium citrinum* (Al-Abdalall, 2013; Al-Daihan *et al.,* 2013; Ali, 2007; Dolara *et al.,* 2000; Gadir and Ahmed, 2014; Shuaib *et al.,* 2013). Extract from different parts of *P. mahaleb* showed inhibitory effect against gram-positive, gram-negative bacteria and fungal standard strains (Özcelik and Koca, 2012; Seyyednejad *et al.,* 2008). On the contrary, the fungal growth was enhanced by the high nutritive

extract from fruit of *Balanites aegyptiaca* and *Tamarindus indica* (El-Nagerabi *et al.*, 2013). On the other hand, different concentrations of calyx extract (5-12.5%) from *H. sabdariffa* did not inhibit or enhance the mycelial growth of *Aspergillus* species (El-Nagerabi *et al.*, 2012). Other studies showed different effects on the mold growth and aflatoxin production (Bullerman *et al.*, 1977; Guerin and Reveillere, 1984; Joseph *et al.*, 2005; Reddy *et al.*, 2009).). Therefore, it is evident that *C. myrrha* resin and *P. mahaleb* seed extracts contains different chemical inhibitors which affect the biochemical synthesis of aflatoxin as concluded in many studies (Büchele *et al.*, 2003; Da Costa *et al.*, 2010; El-Nagerabi *et al.*, 2012, 2013. 2016; Safayhi and Sailer, 1997; Singh *et al.*, 2008).

3.2 Detoxification of Aflatoxin B_1 by Resin of Myrrh and Seed Extract of Mahaleb

The natural plant extracts are biologically safe and ecofriendly for detoxification comparable to the other methods (Alberts *et al.*, 2009; El-Nagerabi *et al.* 2012, 2013, 2016; Kumar *et al.* 2009; Oguz, 2011; Prakash *et al.*, 2011). The ability of different herbal, medicinal and aromatic plants as biodegraders to aflatoxin has been reported (Sandosskumar *et al.*, 2007). Root extracts of garlic (*Allium sativum*) and onion (*Allium cepa*) degrade aflatoxin B_1 up to 58.5% (Velazhahan *et al.*, 2010). *Trachyspermum ammi* seed extract degrades 90% of aflatoxin G_1 by modification of lactone ring in the toxin (Velazhahan *et al.*, 2010). Medicinally, *C. myrrha* resin has been used for treatment of various diseases (Al Ashry *et al.*, 2003; Shen and Lou, 2008); rheumatic complaints, tooth decay, gum disease, and helminth infection (Haffor *et al.*, 2010; Abd-Ulgadir *et al.*, 2015), antiseptic, carminative, anti-inflammatory, and tonic in dyspepsia (Omer *el al.*, 2011). It showed many biological activities as antibacterial, antifungal, antimicrobial, antimalarial, anticandidal, antischistosomal, larvicidal, and molluscicidal (Al-Abdalall, 2013; Abd-Ulgadir *et al.*, 2015; Al-Daihan *et al.*, 2013; Ali *et al.*, 2008; Dolara *et al.*, 2000; Gadir *et al.*, 2014; Shen *et al.*, 2012; Shulan *el al.*, 2011). Antimicrobial activity against *Candida albican*, and other microorganisms was reported (Al-Daihan *et al.*, 2013; Dolara *et al.*, 2000; Omer *et al.*, 2011; Shuaib *et al.*, 2013). On the other hand, *P. mahaleb* has been used in many folk medicine and preservation purposes (Gerardi *et al.*, 2010; Oskoueian *et al.*, 2012; Shams *et al.*, 2007). It is used against human pathogenic bacteria, fungi, and viruses (Holetz *et al.*, 2002; Perez, 2003; Syyednejad, 2008). Alcohol extract from different part of the plant showed antibacterial and antifungal activities (Özcelik and Koca, 2012). It showed antibacterial activity against *Proteus mirabilis, Bacillus anthracis, and Staphylococcus aureus* (Seyyednejad *et al.*, 2008). In the present investigations, 3.25% (w/v) of *C. myrrha* resin and 3.5% (v/v) of *P. mahaleb* had no significant effect on synthetic aflatoxin, which indicates the lack of detoxification properties compared to their inhibitory effects on aflatoxin production, and fungal growth as concluded by many authors (e.g. Da Costa *et al.*, 2010; El-Nagerabi *et al.*, 2016; Paranagama *et al.*, 2003; Sandosskumar et al. 2007).

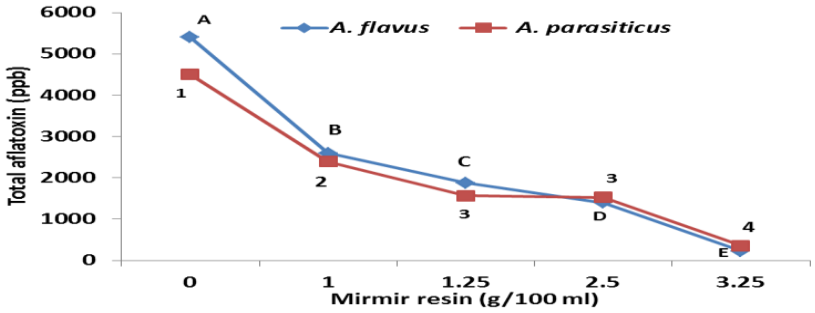

Figure 1. Total aflatoxin production of *A. flavus* strain SQU21 and *A. parasiticus* strain CBS921.7 at different concentrations of *Commiphora myrrha* resin extract (Identical numbers and letters indicate no significant diffrence, $p<0.05$)

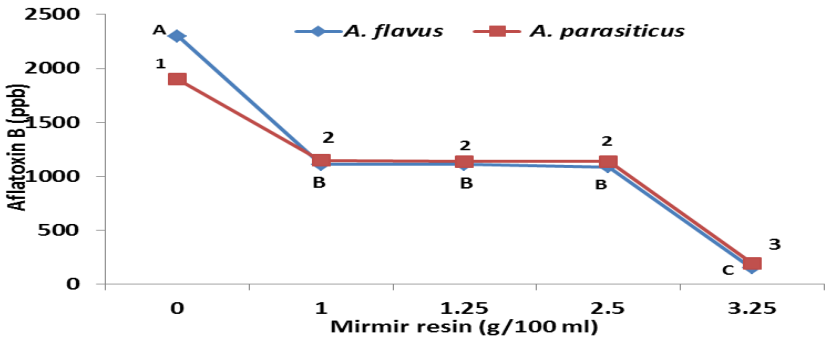

Figure 2. Aflatoxin B production of *A. flavus* and *A. parasiticus* strains at different concentrations of *C. myrrha* resin xtract (Identical numbers and letters indicate no significant diffrence, $p<0.05$)

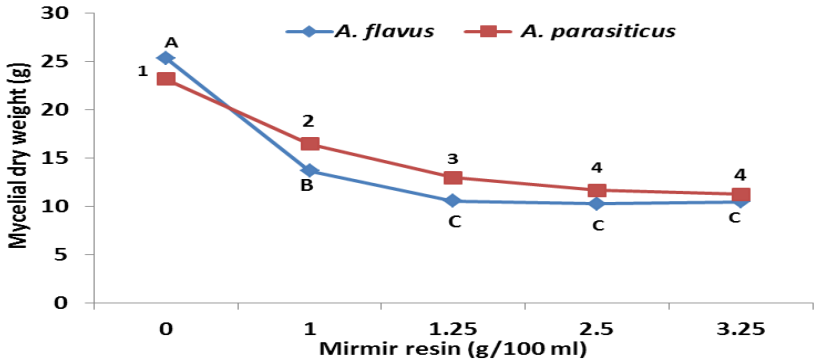

Figure 3. Mycelial dry weight of *A. flavus* and *A. parasiticus* strains at different concentrations of *C. myrrha* resin *e*xtract (Identical numbers and letters indicate no significant diffrence, $p<0.05$)

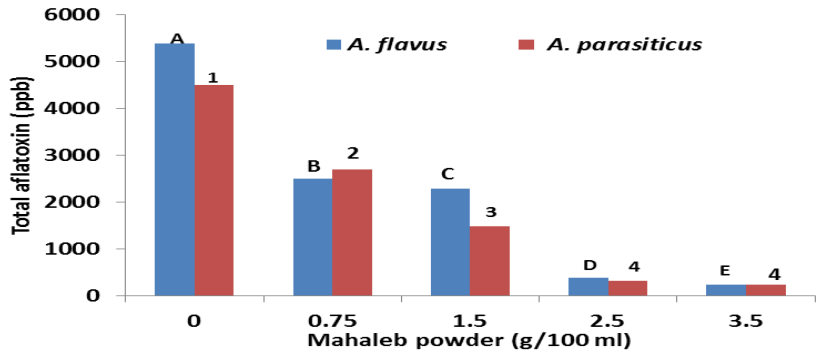

Figure 4. Total aflatoxin secretion by *A. flavus* and *A. parasiticus* strains at different concentrations of *Prunus mahaleb* (Similar numbers and letters indicate showed no significant diffrence, $p<0.05$)

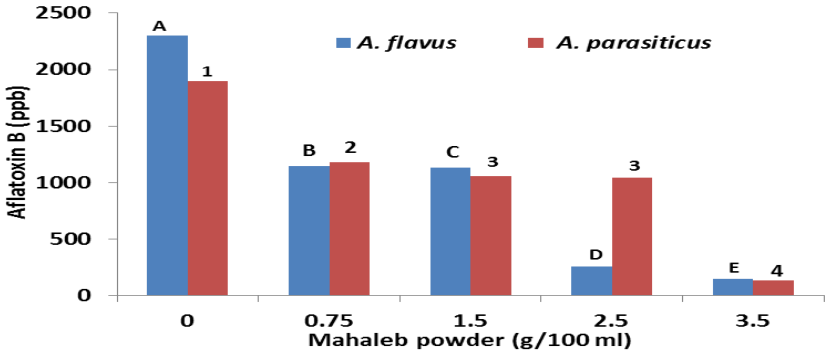

Figure 5. Aflatoxin B secretion of by *A. flavus* and *A. parasiticus* under different concentrations of *P. mahaleb* seed extract (Different numbers and letters indicate significant diffrence, $p<0.05$)

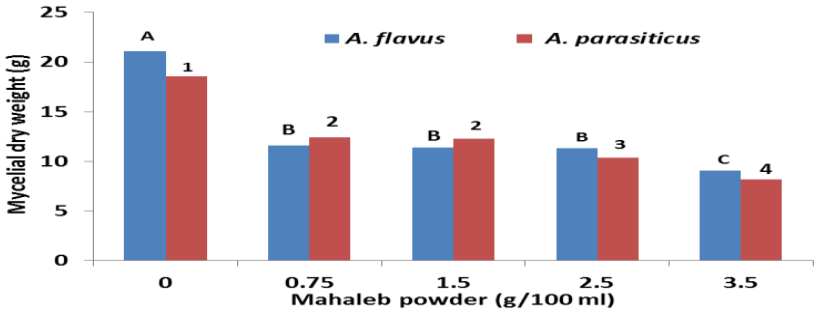

Figure 6. Mycelial dry weight of *A. flavus* and *A. parasiticus* at different concentrations of *P. mahaleb* extract (Different numbers and letters indicate significant diffrence, $p<0.05$)

4. Conclusion

We screened the biological activities of different concentrations of *C. myrrha* resin and *P. mahaleb* seed extract on the growth and aflatoxin production by *A. flavus* (SQU21) and *A. parasiticus* (CBS921.7). These two plant extracts evidently reduce aflatoxin production and the fungal growth which may suggests the inhibitory effect to aflatoxin biochemical synthesis pathway. None of the two extracts detoxify pure aflatoxin B_1 as suggested by many researchers (Abulmajeed, 2011; Banno *et al.*, 2006; El-Nagerabi *et al.*, 2012, 2013, 2016; Gupta *et al.*, 2001; Langmead and Rampton 2006; Miller & Morris, 2004; Mothana et. al. 2011; Suhail et al. 2011). Therefore, toxicity of biologically active chemical components which reduce aflatoxin production needs more attention. This will build the data on their applications in food preservation industry and pharmaceutical activities.

Acknowledgements

This research was supported by University of Nizwa and Sultan Qaboos University. We thank the Department of Biological Sciences and Chemistry, College of arts and Sciences, University of Nizwa, and Department of Biology, College of Science**,** Sultan Qaboos University for providing facilities and space to carry this research.

References

Abd-Ulgadir, K. S., El Tahir, A. S., Ahmed, H. H., El Shiekh, H. E., Rakaz, M. A., Abosali, K. O., Abdelsalam, K. A., & Saatti, A. B. (2015). An *in vitro* antimicrobial potential of various extracts of *Commiphora myrrha. Journal of Biomedical and Pharmaceutical Research, 4*(2), 15-19.

Abdulkadir, A. H. W., Al-Ali, A. A., Al-Kildi, A. M., & Al-Jedah, J. H. (2014). Mycotoxins in food products available in Qatar. *Food Control, 15*, 543-548. https://doi.org/10.1016/j.foodcont.2003.08.008

Al-Abdalall, A. H. A. (2013). Antibacterial properties and phytochemical analysis of aqueous extract of oleo-gum resins of *Commiphora myrrha* and *Commiphora molmol*. *Canadian Journal of Pure and Applied Science, 7*(2), 2315-2323.

Alberts, J., Gelderblom, W. C. A., Botha, A., & Van Zyl, W. H. (2009). Degradation of aflatoxin B1 by fungal laccaze enzymes. *International Journal of Food Microbiology, 135*, 47-52.

https://doi.org/10.1016/j.ijfoodmicro.2009.07.022

Al-Daihan, S., El-Faham, M., Al-shawi, N., Almayman, R., Brnawi, A., Zargar, S., & Bhat, R. S. (2013). Antibacterial activity and phytochemical screening of some medicinal plants commonly used in Saudi Arabia against selected pathogenic microorganisms. *Journal of King Saud University – Science, 25*, 115-120. https://doi.org/10.1016/j.jksus.2012.11.003

Ali, B. Z. (2007). Evaluation of myrrh (*Commiphora molmol*) essential oil activity against some storage fungi. *Journal of Al-Nahrain University, 10*(2), 107-111. https://doi.org/10.22401/JNUS.10.2.19

Ali, N. A. A., Wurster, M., Arnold, N., Lindequist, U., & Wessjohan, L. (2008). Essential oil composition from oleogum resin of *Soqotraen Commiphora kua*. *Records of Natural Products, 2*(3), 70-75.

Al-Shayeb, N. M., & Mabrook, S. S. (1984). Utilization of some edible and medical plants to inhibit aflatoxin formation. *Nutrition Report International, 29,* 273-282.

Ammar, N. M., El-Hawary, S. S., & Hussein, R. A. (2010). Study of Polysaccharides Isolated from The Oleo-Gum-Resins of *Boswellia Carteri* And *Commiphora Myrrha* And Their Immuno-Modulatory Activity. *Journal of the Arab Society for Medical Research, 5*(1), 1-7.

Büchele, B., Zugmaier, W., & Simmet, T. (2003). Analysis of pentacyclic triterpenic acids from frankincense gum resins and related pharmaceuticals by high performance liquid chromatography. Identification of lupeolic acid, a novel pentacyclic triterpene. *Journal of Chromatography B, 791,* 21-30. https://doi.org/10.1016/S1570-0232(03)00160-0

Bullerman, L. B., Lieu, F. Y., & Seier, A. S. (1977). Inhibition of growth and aflatoxin production by cinnamon and clove oils, cinamic aldehyde and eugenol. *Journal of Food Science, 42,* 1107-1108. https://doi.org/10.1111/j.1365-2621.1977.tb12677.x

Carvalho, C. C. R., & Caramujo, M. J. (2008). Ancient Procedures for the High-Tech World: Health Benefits and Antimicrobial Compounds from the Mediterranean Empires. *The Open Biotechnology Journal, 2*, 235-246. https://doi.org/10.2174/1874070700802010235

Da Costa, C. L., Geraldo, M. R. F., Arrotéia, C. C., & Kemmelmeier, C. (2010). *In vitro* activity of neem oil [*Azadirachta indica* A. Juss (*Meliaceae*)] on *Aspergillus flavus* growth, sporulation, viability of spores, morphology and aflatoxins B_1 and B_2 production. *Advances in Bioscience and Biotechnology, 1,* 292-299. https://doi.org/10.4236/abb.2010.14038

Dolara, P., Corte, B., Ghelardini, C., Pgliese, A. M., Cerbai, E., Menichetti, S., & Lo Nostro, A. (2000). Local anaesthetic, antibacterial and antifungal properties of sesquiterpenes from myrrh. *Planta Medica, 66*(4), 356-358. https://doi.org/10.1055/s-2000-8532

El Ashry, S. E., Rashed, N., Salama, O. M., & saleh, A. (203). Components, therapeutic value and uses of myrrh. *Phamazie, 58,* 163-168.

El-Nagerabi, S. A. F., Al-Bahry, S. N., Elshafie, A. E., & AlHilali, S. (2012). Effect of *Hibiscus sabdariffa* extract and *Nigella sativa* oil on the growth and aflatoxin B_1 production of *Aspergillus flavus* and *Aspergillus parasiticus* strains. *Food Control, 25*, 59-63. https://doi.org/10.1016/j.foodcont.2011.09.033

El-Nagerabi, S. A. F., Alhajri, A. O. S., & Elshafie, A. E. (2016). Assessment for the activities of *Acacia seyal* gum and *Moringa stenopetala* seeds extract on the growth and aflatoxin production by aflatoxigenic Aspergillus species. *International Journal of Applied and Pure Science and Agriculture, 2*(6), 77-88.

El-Nagerabi, S. A. F., Elshafie, A. E., & Elamin, M. R. (2013). *In Vitro* Activity of *Balanites aegyptiaca* and *Tamarindus indica* fruit extracts on growth and aflatoxigenicity of *Aspergillus flavus* and *A. parasiticus*. *Journal of Food Research, 2(*4), 68-80. https://doi.org/10.5539/jfr.v2n4p68

El-Nagerabi, S. A. F., Elshafie, A. E., AlKhanjari, S. S., Al-Bahry, S. N., & Elamin, M. R. (2013). Biological activities of *Boswellia sacra* extracts on the growth and aflatoxins secretion of two aflatoxigenic species of *Aspergillus* species. *Food Control, 34*(2), 763-769. https://doi.org/10.1016/j.foodcont.2013.06.039

El-Nagerabi, S. A. F., Elshafie, A. E., Alkhanjari, S. S., Al-Bahry, S. N., & Elamin, M. R. (2013). The potential of baobab (*Adansonia digitata* L.) extracts as biocontrol on the growth and aflatoxin production by *Aspergillus flavus* and *A. parasiticus*. *Journal of Food Research, 2*, 93-103. http://dx.doi.org/10.5539/jfr.v2n3p93

El-Nezami, H., Kankaanpaa, P., Salminen, S., & Ahokas, J. (1998). Ability of dairy strains of lactic acid bacteria to bind a common food carcinogen, aflatoxin B_1. *Food Chem Toxicol, 36,* 321-326. https://doi.org/10.1016/S0278-6915(97)00160-9

Elshafie, A. E., & Al-Shally, N. S. (1998). Mycoflora and mycotoxigenic moulds of pistachio nuts for human consumption in the Sultanate of Oman. *Science Technology, 3*, 1-6. https://doi.org/10.24200/squjs.vol3iss0pp1-6

Elshafie, A. E., Al Rashdi, T. A., Al Bahry, S. N., & Bakheit, C. (2002). Fungi and aflatoxins associated with spices in the Sultanate of Oman. *Mycopathologia, 155*, 155-160. https://doi.org/10.1023/A:1020427527963

Faizi, S., Siddiqui, B. S., Salam, R., Siddiqui, S., Aftab, K., & Gilan, H. A. (1994). Fully acetylated carbamate and hypotensive thiocarbamate glycosides from *Moringa oleifera*. *Phytochemistry, 38*, 957-963. https//doi.org/10.1016/0031-9422(94)00729-d

Farag, R., Daw, Z., & Abo-Raya, S. (1989). Influence of some spice essential oil on *A. parasiticus* growth and production of aflatoxins in a synthetic medium. *Journal of Food Science, 54*(1), 74-76. https://doi.org/10.1111/j.1365-2621.1989.tb08571.x

Gadir, S. A., & Ahmed, I. M. (2014). *Commiphora myrrha* and *Commiphora africana* essential oils. *Journal of Chemical and Phrmaceutical Research, 6*(7), 151-156.

Gandomi, H., Misaghi, A., Basti, A. A., Bokaei, S., Khosravi, A., Abbasifar, A., & Javan, A. J. (2009). Effect of *Zataria multifora* Bioss. Essential oil on growth and aflatoxin formation by *Aspergillus flavus* in culture media and cheese. *Food and Chemical Toxicology, 47*, 2397-2400. https//doi.org/10.1016/j.fct.2009.05.024

Gerardi, C., Blando, F., Mul è, F., Ali, K., & Verpoorte, R. (2010). *Metabolic characterization of Prunus cerasus L. and Prunus mahaleb L. fruits*. XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): international Symposium on the Challenge for Sustainable Production, Protection, and Consumption of Mediterranean Fruits and Nuts. Acta Horticultre.

Gowda, N. K. S., Malathi, V., & Suganthi, R. U. (2004). Effect of some chemical and herbal compounds on growth of *Aspergillus parasiticus* and aflatoxin production. *Animal Feed Science and Technology, 116*, 281-291. https://doi.org/10.1016/j.anifeedsci.2004.02.008

Guerin, J. C., & Reveillere, H. P. (1984). Antifungal activity of plant extracts used in therapy. 1. Study of 41 plants extracts against 9 fungal species. *Annals Pharmaceutiques Francaises, 42*, 553-559. https//dx.doi.org/10.1046/j.1439-0507.1999.00499.x

Haffor, A. S. A. (2010). Effect of *Commiphora molmol* on leukocytes proliferation in relation to histological alteration before and during healing from injury. *Saudi Journal of Biological Sciences, 17*(2), 139-146. https://doi.org/10.1016/j.sjbs.2010.02.007

Hanuš, L. O., Řezanka, T., Dembitsky, V. M., & Moussaieff, A. (2008). *Myrrh – Commiphora* chemistry. *Biomedical Papers, 149*(1), 3-28. https://doi.org/10.5507/bp.2005.001

Hasan, H. A. H. (1994). Inhibition of mycoflora and zearalenone on rice by selected essential oils. *Pakistan Journal of Scientific and Industrial Research, 37*(11), 471-473.

Herzallah, S. M. (2009). Determination of aflatoxins in eggs, milk, meat and meat products using HPLC fluorescent and UV detectors. *Food Chemistry, 114*, 1141-1146. https://doi.org/10.1016/j.foodchem.2008.10.077

Holetz, F. B., Pessini, G. L., Sanches, N. R., Cortez, D. A. G., Nakamura, C. V., & Filho, B. P. D. (2002). Screening of some plants used in the Brazilian folk medicine for treatment of infectious diseases. Mem. Inst. *Oswaldo Cruz, 97*, 1027-1031. https//doi.org/10.1590/S0074-02762002000700017

Joseph, G. S., Jayaprakasha, G. K., Selvi, A. T., Sena, B. S., & Sakariah, K. K. (2005). Antiaflatoxigenic and antioxidant activities of *Garcinia e*xtract. *International Journal of Food Microbiology, 101*, 153-160. https://doi.org/10.1016/j.ijfoodmicro.2004.11.001

Kumar, A., Shukla, R., Singh, P., & Dubey, N. K. (2009). Biodeterioration of some herbal raw materials by storage fungi and aflatoxin and assessment of *Cymbopogon flexuous* essential oil and its components as antifungal. *International Biodeterioration and Biodegradation, 63*, 712-726. https://doi.org/10.1016/j.ibiod.2009.03.011

Kumar, V., Basu, M. S., & Rajendran, T. P. (2008). Mycotoxin research and mycoflora in some commercially important agricultural commodities. *Crop Protection, 27*, 891-905. https://doi.org/10.1016/j.cropro.2007.12.011

Leri, F., Pineelli, P., & Romani, A. (2012). Simultaneous determination of anthocyanins, coumarins and phenolic acid in fruits, kernels and liqueur of *Prunus mahaleb* L. *Food Chemistry, 135*, 2157-2162. https//doi.org/10.1016/j.foodchem.2012.07.083

Leuck, M., & Kunz, H. (1998). Synthesis of active principles of the leaves of *Moringa oleifera* using S -pent-4 -ethyl thioglycosides. *Carbohydrate Research, 312*, 33-44. https://doi.org/10.1016/S0008-6215(98)00223-7

Maraqa, A., Alsharoa, N. F., Farah, H., Albjeirami, W. M., Shakya, A. K., & Sallal, A. J. (2007). Effect of *Nigella sativa* extract and oil on aflatoxin production by *Aspergillus flavus*. *Turkish Journal of Biology, 31*, 155-159.

Marongiu, B., Piras, A., Porcedda, S., & SCorciapino, A. (2005). Chemical compositionof the essential oil and supercritical CO2 extract of *Commiphora myrrha* (Nees) Engl. and of *Acorus calamus* L. *Journal of Agricultural Food Chemistry, 53*(20), 7939-43. https://doi.org/10.1021/jf051100x

Marshall, S. (2004). Myrrh: Magi, Medicine and mortality. *The Pharmaceutical Journal, 273*, 919-921.

Montes-Belmont, R., & Carvajal, M. (1998). Control of *Aspergillus flavus* in maize with plant essential oils and their components. *Journal of Food Protection, 61*(5), 616-619. https://doi.org/10.4315/0362-028X-61.5.616

Oguz, H. (2011). A review from experimental trials on detoxification of aflatoxin in poultry feed. *Eurasian Journal of Veterinary Sciences, 27*, 1-12.

Omer, S. A., Adam, S. E. I., & Mohamed, O. B. (2011). Antimicrobial activity of *Commiphora myrrha* against some bacteria and *Candida albican*s isolated from Gazelles at King Khalid Wildlife Research Centre. *Research Journal of Medicinal Plant, 5*(1), 65-71. https://doi.org/10.3923/rjmp.2011.65.71

Oral, R. A. (2014). Identification of some characteristic features of white mahaleb (*Prunus mahaleb L.*) kernel and fatty acid composition of kernel oil. *Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi, 30*(1), 63-65.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Anthony, S. (2009). *Commiphora myrrha*. Agroofrestree Database: a tree reference and selection guide, 4, 1-5.

Orwa, C., Mutua, A., Kindt, R., Jamnadass, R., & Simons, A. (2009). Agroforestry Database: a tree reference and selection guide, 4, 1-2.

Özcelik, B., & Koka, U. (2012). Evaluation of *in vitro* bioactivity of mahaleb cherry (*Prunus mahaleb* L.). *Romanian Biotechnology Letters, 17*(6), 7863-7872.

Paranagama, P. A., Abeysekera, K. H. T., Abeywickrama, K. P., & Nugaliyadde, L. (2003). Fungicidal and anti-aflatoxigenic effects of the essential oil of *Cymbopogon citrates* (DC) Straps. (Lemongrass) against *Aspergillus flavus* link isolated from stored rice. *Letters in Applied Microbiology, 37*, 86-90. https://doi.org/10.1046/j.1472-765X.2003.01351.x

Patkar, K., Usha, C., Shetty, H., Poster, N., & Lacey, J. (1993). Effect of spice essential oils on growth and aflatoxin B_1 production by *A. flavus. Letter in Applied Microbiology, 17*(2), 49-51. https://doi.org/10.1111/j.1472-765X.1993.tb00367.x

Patton, C. A., Ranney, T. G., & Burton, J. D. (1997). Natural Pest Resistance of *Prunus* Taxa to Feeding by Adult Japanese Beetles: Role of Endogenous Allelochemicals in Host Plant Resistance. *Journal of the American Society for Horticultural Science, 122*(5), 668-672. https://doi.org/10.21273/JASHS.122.5.668

Payne, G. A. (1998). Process of contamination by aflatoxin-producing fungi and their impacts on crops. In K. K. Sinha & D. Bhatnagar (Eds.), *Mycotoxins in agriculture and food safety* (pp. 279-306). New York: Marcel Dekker.

Perez, R. M. (2003). Antiviral activity of compounds isolated from plants. *Pharmaceutical Biology, 41*, 107-157. https://doi.org/10.1076/phbi.41.2.107.14240

Prakash, B., Shukla, R., Singh, P., Mishra, P. K., Dubey, N. K., & Kharwar, R. N. (2011). Efficacy of chemically characterized *Ocimum gratissimum* L. essential oil as an antioxidant and a safe plant-based antimicrobial against fungal and aflatoxin B1 contamination of spices. *Food Research International, 44*, 385-390. https://doi.org/10.1016/j.foodres.2010.10.002

Raper, K. B., & Fennell, D. I. (1965). *The genus Aspergillus.* Baltimore: The Williams and Wilkins Company. pp. 686.

Reddy, K. R. N., Reddy, C. S., & Muralidharan, K. (2009). Potential of botanicals and biocontrol agents on growth and aflatoxin production by *Aspergillus flavus* infecting rice grains. *Food Control, 20*, 173-178. https://doi.org/10.1016/j.foodcont.2008.03.009

Refat, N. A. G. A., & Abass, M. A. (2011). Efficacy of *Myrrh* Extract "Mirazid®" to Reduce Lead Acetate Toxicity in Albino Rats with Special Reference to Cerebellum and Testes. *Life Science Journal, 8*(4), 406-414.

Safayhi, H., & Sailer, E. R. (1997). Anti-inflammatory actions of pentacyclic triterpenes. *Planta Medica, 63*, 487-493. https//doi.org/10.1055/s-2006-957748

Salim, N. M., & Ahmad, R. (2010). Mycotoxins in food from Jordan: preliminary survey. *Food Control, 21*, 1099-1103. https://doi.org/10.1016/j.foodcont.2010.01.002

Sandosskumar, R., Karthikeya, M., Mathiyazhaga, S., Mohankumar, M., Chandrasekar, G., & Velazhahan, R. (2007). Inhibition of *Aspergillus flavus* growth and detoxification of aflatoxin B by medicinal plant zimnu (*Allium sativum* L. x *Allium cepa* L.). *World Journal of Microbiology and Biotechnology, 23*, 1007-1014. https://doi.org/10.1007/s11274-006-9327-x

Sbihi, H. M., Nehdi, I. A., & Al-Resayes, S. I. (2014). Characterization of white mahaleb (*Prunus mahaleb* L.) see oil: A rich source of α-eleostearic acid. *Journal of Food Science, 79*, C795-C801. https://doi.org/10.1111/1750-3841.12467

Shams, K. A., & Schmidt, R. (2007). Lipid fraction constituents and evaluation of anti-anaphylactic activity of *Prunus mahaleb* L. kernels. *African Journal of Traditional, Complementary and Alternative Medicine, 4*(3), 289-293. https//doi.org/10.4314/ajtcam.v4i3.31221

Shantha, T. (1999). Fungal degradation of aflatoxin B1. *Nat Toxins, 7*, 175-178. https://doi.org/10.1002/1522-7189(200009/10)7:5<175::AID-NT63>3.0.CO;2-M

Shen, T., & Lou, H. X. (2008). Chemical constituents from resin of *Commiphora* species and their biological activities. *Natural Product Research and Development, 20*, 360-366.

Shen, T., Li, G., Wang, X., & Lou, H. (2012). The genus *Commiphora*: A review of its traditional uses, phytochemistry and pharmacology. *Journal of Ethnopharmacology, 142*, 319-330. https://doi.org/10.1016/j.jep.2012.05.025

Shuaib, M., Ali, A., Ali, M., Panda, B. P., & Ahmad, M. I. (2013). Antibacterial activity of resin rich plant extracts. *Journal of Pharmaceutical and Bivalued Science, 5*(4), 265-269. https://doi.org/10.4103/0975-7406.120073

Shuaib, M., Ali, M., & Naquvi, K. J. (2014). New Lanostene-Type Triterpenes from The Oleo-Gum Resin of *Commiphora myrrha* (Nees) Engl. *International Journal of Pharmacy and Pharmaceutical Sciences, 6*(5), 372-375.

Shulan S., Tuanjie W., Ting C., Jin-ao D., Li Y., & Yuping, T. (2011). Cytotoxicity activity of extracts and compounds from *Commiphora myrrha* resin against human gynecologic cancer cells. *Journal of Medicinal Plants Research, 5*(8), 1382-1389.

Sidhu, O. P., Chandra, H., & Behl, H. M. (2009). Occurrence of aflatoxins in mahua (*Madhuca indica* Gmel.) seeds: Synergistic effect of plant extracts on inhibition of *Aspergillus flavus* growth and aflatoxin production. *Food and Chemical Toxicology, 47*, 774-777. https//doi.org/10.1016/j.fct.2009.01.001

Singh, S., Khajuria, A., Taneja, S. C., Johri, R. K., Singh, J., & Qazi, G. N. (2008). Boswellic acids: A leukotriene inhibitor also effective through topical application in inflammatory disorders. *Phytomedicine, 15*, 400-407. https//doi.org/10.1016/j.phymed.2007.11.019

Soher, E. A. (1999). Prevention of the growth and aflatoxin production of *Aspergillus flavus* by some spice essential oils. *Minufiya Journal of Agriculture Research, 24*(2), 563-576.

Soni, P. D., Upadhyay, S. U., & Upadhyay, U. M. (2013). A review on *Commiphora myyrha. An International Journal of Pharmaceutical Sciences, 4*(3), 171-205.

Su, S., Hua, Y., Wang, Y., Gu, W., Zhou, W., Duan, J., & Jiang, H. (2012). Evaluation of the anti-inflammatory and analgestic properties of individual and combined extracts from *Commiphora myrrha*, and *Boswellia carterii*. *Journal of Ethnopharmacology, 139*, 649-656. https//doi.org/10.1016/j.jep.2011.12.013

Su, S., Wang, T., Duan, J., Zhou, W., Hua, Y, Tang, Y., Yu, L., & Qian, D. (2011). Anti-inflammatory and analgestic activity of different extracts of *Commiphora myrrha. Journal of Ethnopharmacology, 134*, 251-258. https//doi.org/10.1016/j.jep.2010.12.003

Szczerbanik, M., Jobling, J., Morris, S., & Holford, P. (2007). Essential oil vapours control some common postharvest pathogens. *Australian Journal of Experimental Agriculture, 47*, 103-109. https://doi.org/10.1071/EA05236

Velazhahan, R., Vijayanandraj, S., Vijayasamundeeswari, A., Parandidharan, V., Samiyappan, R., Iwamoto, T., Friebe B., & Muthukrishnan, S. (2010). Detoxification of aflatoxin by seed extracts of the medicinal plants,

Trachyspermum ammi (L.) Sprangue ex Turrill-structural analysis and biological toxicity of degradation product of aflatoxin G_2. *Food Control, 21*, 719-725. https://doi.org/10.1016/j.micres.2013.07.008

Vijayanandraj, S., Brinda, R., Kannan, K., Adhithya, R., Vinothini, S., Senthil, K., Chinta, R. R., Paranidharan, V., & Velazhahan, R. (2014). Detoxification of aflatoxin B1 by an aqueous extract from leaves of *Adhatoda vasica* Nees. *Microbiological Research, 169*, 294-300. https://doi.org/10.1016/j.micres.2013.07.008

Wagacha, J. M., & Muthomi, J. W. (2008). Mycotoxin problem in Africa: Current status, implications to food safety and health and possible management strategies. *International Journal of Food Microbiology, 124*, 1-12. https//doi.org/10.1016/j.ijfoodmicro.2008.01.008

Yusuf, A. K., & Usman, H. (2011). Studies on some physicochemical properties of the plant gum exudates of *Acacia senegal* (Dakwara), *Acacia sieberiana* (Fararkaya) and *Acacia nilotica* (Bagaruwa). *Journal of Research in National Development, 9*(2), 10-17.