Antimicrobial Activity of Essential Oils and Extracts of Oleo-Gum Resins from *Boswellia papyrifera* (Tarak tarak) Grown in Some Parts of the Sudan

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Abstract: Three samples (Kordofan, Damazine and Nagawa) of oleo-gum resins of *Boswellia papyrifera* grown in some parts of Sudan were subjected to screening with the objective of evaluating their antimicrobial activity. The essential oils of the three samples showed high antibacterial activity against all tested bacteria (*Basillus subtilis*, *Staphylococcus aureus*, *Echercshia coli*, *Pseudomonas aeruginosa* and *Salmonella typhi*) with minimum inhibition concentration (MIC) of 5 - 10 µg/ ml. In addition, they demonstrated antifungal activity against *Aspergillus niger*, *Aspergillus flavus* and *Candida albicans* with MIC of 5 µg/ ml. Petroleum ether extracts and acid fractions derived from the three samples showed high antibacterial activity against *Staphylococcus aureus*, *Echercshia coli* and *Basillus subtilis*. Chloroform extracts and non-acid fractions of both Kordofan and Damazine frankincense suppressed the growth of *Basillus subtilis*, *Echercshia coli* and *Pseudomonas aeruginosa*. *Salmonella typhi* showed resistance to all used materials except the non-acid fraction from Kordofan frankincense. Furthermore, all tested bacteria (excluding *Basillus subtilis*) and fungi (except *Candida albicans*) showed resistance to the methanolic and water extracts. The essential oils and various extracts from Sudanese *Boswellia papyrifera* can be of potential use as antimicrobial agents.

Keywords: *Boswellia papyrifera*; antimicrobial activity; essential oils; resins; olibanum; acid fraction; extracts.

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INTRODUCTION

Several species belonging to the genera *Boswellia* and *Commiphora* of the family Burseraceae are well known for producing commercially important resins. The resins of *Boswellia spp*. are commonly recognized as frankincense or olibanum. *Boswellia serrata*, *B. papyrifera*, *B. frereana* and *B.carterii* (syn. *B. carteri* Birdw.) are reported to be the most important commercial sources of olibanum of the various species of *Boswellia* that grow in Arabia, India and the eastern coast of Africa (Hairfield *et al*, 1989). Verghese (1988) reported that Sudanese olibanum is obtained from *Boswellia papyrifera* (Del.).

Olibanum contains a rich array of terpenes. The natural oleo-gum-resin that exude from tappings in the bark of Boswellia trees is a complex mixture composed of about 5–9% highly aromatic essential oil (mono and sesquiterpenes), 65–85% alcohol-soluble resins (diterpenes and triterpenes), and the remaining water-soluble gums (polysaccharides) (Tucker, 1986; Khan and Farooqi, 1991).

Olibanum is used as incense and it is also used in folk medicine in the treatment of cough and asthma, as an ingredient of embalming fluid, a diuretic stimulant and an emmenagogue, but its essential oil and absolute oil are used as fixatives in perfumes, soaps, creams, lotions and detergents (Abdel Wahab *et al*., 1987). Scientific research showed that *B. carterii* has significant anti-arthritic and anti-inflammatory effects (Fan *et al*., 2005).

Few studies investigated the antibacterial effects of oleo-gum resins. The hydro distilled oil of *B. papyrifera* exerted moderate inhibition against S*taphyllococcus carnosas*, *Micrococcus luteus*, *Basillus subtilis* and *Echercshia coli*, but a strong activity against *Salmonella typhimurium* (Mustafa, 1997). Recently, the antimicrobial activity of the essential oils of some *Boswellia* species e.g. *B carteri*, *B papyrifera*, *B serrata* and *B rivae* were also examined (Dorman and Deans, 2000; Sokmen *et al*., 2004; Camarda *et al*., 2007). Mothana and Lindequist (2005) found that both *B. elongata* and *B. ameero* exhibited a strong antimicrobial effect only against Gram positive bacteria. Furthermore, it was reported that the extract of *B. serrata* showed an effect against some bacterial strains (Weckesser *et al*., 2007). Antimicrobial activities of *Boswellia dioscorides* methanolic and hot aqueous extracts against three Gram-positive strains, two Gram-negative strains, one fungal strain and three multiresistant *Staphylococcus* strains were also studied (Mothana *et al*., 2009).

The use of natural antimicrobial compounds is important not only in the control of human and plant diseases of microbial origin but also in the preservation of food. Bacterial and fungal infections pose a greater threat to health, most notably in immunocompromised subjects, hence the need to find cheap and effective antimicrobial agents. Therefore, the main objective of this research is screening for the antimicrobial activity of the essential oils and oleo-gums extracts against some standard food hazardous strains viz. *Staphylococcus aureus*, *Escherichia coli*, *Salmonella spp*, *Aspergillus flavus*, *A niger* and *Candida albicans* as well as some standard pathogens such as *Pseudomonas aeruginosa*, *Bacillus subtilis*.

MATERIAL AND METHODS

Material collection

Two authenticated samples of oleo-gum resins of *Boswellia papyrifera* were obtained from Elobied Agricultural Research Station (ARS), North Kordofan State (*Kordofan* sample) and Eldamazine Agricultural Research Station, Blue Nile State (*Damazine* sample). In addition to a commercial sample (*Nagawa*) kindly offered by an oleo-gum exporter in Khartoum. Samples were identified by experts from the Forestry Department, Ministry of Agriculture and Forestry as well as Agricultural Research Stations of Elobied and Eldamazine.

Preparation of extracts

Successive solvent extraction:

Solvent extracts were prepared according to Mothana *et al*. (2006). The air dried and powdered oleogum resin (50 g) was extracted under shaking at room temperature successively with petroleum ether (petroleum ether extract, PE), chloroform (chloroform extract, ChE), 90% methanol (methanolic extract, MEs) and finally with hot (70 °C) water (water extract, WEs). For each solvent, the extraction was carried overnight and repeated 3 times. Extracts obtained were filtered and the solvents were then evaporated using rotary evaporator or freeze dryer in the case of the water extracts to give the crude dried extracts.

Water extraction:

The water extracts (WEc) of the crude air dried and powdered oleogum resins (50 g) were obtained by shaking the resins with distilled water for two hours at 70 °C. The extracts were then filtered and dried using a freeze dryer.

Extraction with methanol:

The methanolic extracts (ME) of the crude air dried and powdered oleogum resins (50 g) were obtained by shaking the resins with methanol for 12 hours at room temperature. The extracts were then filtered and dried using the rotary evaporator.

Isolation of the acid fractions

The acid fraction (AF) of the resin was isolated by 2% KOH extraction according to the method described by Basar (2005). 10 g olibanum was extracted by shaking with 50 mL methanol for 12 hours. After filtration, the extract was concentrated using rotary evaporator to nearly 30 mL until it becomes a thick solution. The concentrated solution was dissolved in 100 mL of 2% KOH aqueous solution and extracted five times with 30 mL ethyl acetate. Every time the aqueous phase was separated from the organic phase (non acidic fraction, nAF) using separating funnel. The aqueous phase was then neutralized with 2% HCl to pH 6. The acid fraction was isolated from the aqueous phase by extraction five times with 30 mL ethyl acetate. Every time the organic phase (acidic fraction) was collected separately. Finally, the two fractions were washed with distilled water, dried over anhydrous Na_2SO_4 and the solvent was evaporated to dryness.

Extraction of the volatile oil

The oleo-gum resin (500 g) was subjected to hydrodistillation using Clevenger's apparatus until complete exhaustion. The obtained colorless oil was collected, dried over magnesium sulphate and kept at 4 °C for analysis (Al-Harrasi and Al-Saidi, 2008).

Antibacterial activity

Antibacterial activity against Gram positive and Gram negative strains was determined using the cup plate agar diffusion technique (Kavanagh, 1972).The anti-bacterial activity was tested against standard American Type Culture Collection (ATCC) food hazardous strains (*Staphylococcus aureus*, *Escherichia coli*, *Salmonella* spp.) as well as standard (ATCC) pathogens (*Pseudomonas aeruginosa*, *Bacillus subtilis*). The inoculum was prepared at the concentration of 10^8-10^9 colony forming units per ml of suspension (cfu/ml). The bacterial inoculum of each strain was obtained from fresh colonies grown on Mueller Hinton agar plates. Each strain was inoculated into 5 ml of Mueller Hinton broth in order to obtain a concentration of 1.5×10^5 cfu/ml. The inoculum was then diluted to 1.5×10^2 cfu/ml. Two ml of the bacterial suspension was inoculated into 20 ml nutrient agar then transferred to sterile Petri-dish. The agar was left to dry. Three cups (10 mm in diameter) were cut using a sterile cork borer (No. 4). The

agar disks were removed. Alternate cup was filled with 0.1 ml of each extract using transfer pipette adjustable volume automatic micro pipette and allowed to diffuse at room temperature for two hours. The plates were then incubated at 37 °C for 18 hours. Positive controls involving the addition of the respective solvents instead of extracts were carried out separately. The mean diameters of the resultant growth inhibition zones (MDIZ) were measured and tabulated.

Antifungal activity:

The tested organisms (*Aspergillus flavus*, *A. niger* and *Candida albicans*) maintained on potato dextrose agar at 25 °C were inoculated into malt extract broth, manipulated and incubated for 5 days at 25 °C.

The same method used for bacteria was adopted for antifungal activity, but sabouraud dextrose agar was used instead of nutrient agar.

The minimum inhibitory concentration (MIC)

The minimum inhibitory concentration (MIC) was defined as the lowest concentration (highest dilution) of the extract at which the microorganism does not demonstrate visible growth (Gachkar *et al*., 2007). MICs of the essential oils were obtained by the agar dilution method (Hammer *et al*., 1999). Briefly, a series of twofold dilutions of each oil ranging from 2% (v/v) to 0.03% (v/v) were prepared in Mueller Hinton agar with 0.5% (v/v) Tween-20. Plates were dried at 35 °C for 30 min prior to inoculation with 1–2 spots containing approximately 10^8 microorganisms per ml, using a multipoint replicator (Mast Laboratories Ltd, Liverpool, UK). Mueller Hinton agar with 0·5% (v/v) Tween-20 but no oil, was used as positive growth control. Inoculated plates were incubated at 35 °C for 48 hours. Minimum inhibitory concentrations (MICs) were determined after 24 hours for the bacteria and after 48 h for fungi. The MICs were determined as the lowest concentration of oil inhibiting the visible growth of each organism on the agar plate. The presence of one or two colonies was disregarded.

RESULTS AND DISCUSSION:

The antibacterial activity of the different extracts as well as the acid fractions, non acid fractions and essential oils obtained from the three studied samples is demonstrated in Table 1.

Kordofan oleo-gum resin, petroleum ether extract (PE) was found to possess high antibacterial activity against *Bacillus subtilis* and *E. coli* (MDIZ > 15 mm); moderate activity against *Staphylococcus aureus* (MDIZ 15 mm) and no activity against *Pseudomonas aeruginosa* and

Salmonilla typhi (MDIZ < 15 mm). Nevertheless, *B. subtilis*, *E. coli*, *P. aeruginosa* and *S. typhi* were proved to be insensitive to *Damazine* PE. The extract was moderately active against *S. aureus* (MDIZ 14 mm). Conversely, *Nagawa* PE was only active towards *E. coli* and *P. aeruginosa* (MDIZ of 15 and 16 mm, respectively).

Chloroform extracts (ChE) derived from both *Kordofan* and *Damazine* olibanum were found to be highly active against *B. subtilis* (MDIZ 16 and 18 mm, sequentially), moderately effective against *E. coli*

Table (1): Antibacterial activity (MDIZ mm) of the different extracts

Extract	***Bacillus subtilis***			***Staphylococcus aureus***			***Escherichia coli***			***Pseudomonas aeruginosa***			***Salmonilla typhi***		
	K	D	N	K	D	N	K	D	N	K	D	N	K	D	N
PE	21	12	13	15	14	12	16	12	15	14	11	16	-	-	-
ChE	18	16	16	14	14	-	15	15	-	15	15	-	-	-	-
MEs	20	17	29	-	11	-	-	-	-	-	-	-	-	-	-
WEs	-	11	-	11	11	11	11	-	11	-	-	-	-	-	-
ME	25	30	20	-	11	11	-	-	-	-	-	11	-	-	-
WE	11	18	13	11	11	11	-	-	-	11	14	11	-	-	-
AF	18	-	25	18	20	15	16	19	18	22	18	11	-	-	-
NAF	20	19	24	-	15	-	-	14	-	-	14	-	-	-	-
Ess	50	48	50	20	21	21	18	20	20	17	20	20	17	17	19

K: *Kordofan* D: *Damazine* N: *Nagawa*

PE: Petroleum ether extract ChE: Chloroform extract ME: Methanolic extract WE: Water extract AF: Acid fraction NAF: Non acid fraction Ess: Essential oil MEs: Methanolic extract by successive extraction; WEs: Water extract by successive extraction

MDIZ: Mean diameter of inhibition zone; MDIZ < 14 inactive (resistant) MDIZ 14-15 moderate activity (intermediate); MDIZ >15 High activity (sensitive) and *P. aeruginosa* (MDIZ 15 mm each), but showed low activity with *S. typhi* (MDIZ < 15 mm). *S. aureus* showed intermediate sensitivity for *Damazine* ChE (MDIZ 14 mm), but the microbe was not influenced by *Kordofan* ChE. However, *Nagawa* chloroform extract was just active against *B. subtilis* (MDIZ 16 mm).

The methanolic extracts obtained either by successive (MEs) or direct extraction (ME) from the three types of olegum resin exerted high activity just against *B. subtilis* (MDIZ > 15 mm).Whereas the remaining bacteria were not affected. Interestingly, all tested organisms were confirmed to be resistant to the successively prepared water extract (WE) as well as the water extracts of the crude samples (WEc), excluding *B. subtilis* and *P. aeruginosa* with *Damazine* WEc (MDIZ 18 and 14 mm, respectively).

The acid fraction of *Kordofan* olibanum (AF) exhibited high antibacterial action against *B. subtilis*, *S. aureus*, *E. coli* and *P. aeruginosa* (MDIZ 16-22 mm), but it was noticed to be inactive against *S. typhi*. In the same way, *Damazine* AF possessed notable antimicrobial activity against *S. aureus*, *E. coli* and *P. aeruginosa* (MDIZ 18 – 20 mm), but *B. subtilis* and *S. typhi* were resistant to this fraction. However, *Nagawa* AF remarkably inhibited the growth of *B. subtilis* (MDIZ 25 mm) and *E. coli* (MDIZ 18 mm), moderately suppressed *S. aureus* (MDIZ 15 mm) and showed no activity towards *P. aeruginosa* and *S. typhi*. From Table 1, it was clear that *Salmonilla typhi* is resistant to the acidic fraction of the oleo-gum resins from *Boswellia papyrifera*, while *B. subtilis* was highly sensitive to the same fraction.

The non acid fraction of frankincense from *Kordofan* (NAF) showed evidently high inhibitory influence (MDIZ 20 mm) towards all investigated bacteria. On the other hand, *Nagawa* nAF exhibited only high activity for *Bacillus subtilis* (MDIZ 24 mm). Where as that of *Damazine* sample demonstrated high antibacterial effect against *B. subtilis* (MDIZ 19 mm), moderate activity against *S. aureus*, *E. coli* in addition to *P. aeruginosa* (MDIZ 14 - 15 mm). However, *Damazine* nAF has no effect on *S. typhi*. However, this finding is in agreement with Parekh and Chanda (2007) who tested twelve species of Indian medicinal plants and found that *S. typhimurium* and *P. aeruginosa* were resistant to all tested plants.

For *Commiphora myrrha*, Ahmed (2011) reported that the petroleum ether extract has high activity (17 - 20 mm) against *S. aureus*, *Pseudomonas aeruginosa*, *B. subtilis* and *E. coli*, while the methanolic extract showed slight antibacterial activity only against *B. subtilis*. On the other hand, water extract showed antibacterial activities ranging between 15 and 18 mm against *S. aureus*, *Pseudomonas aeruginosa* and *B. subtilis*. *B. socotrana* and B. *dioscorides* extracts were found to be effectively active against three Gram-positive strains namely, *Bacillus subtilis*, *Staphylococcus aureus*, *Micrococuss flavus* and two Gram-negative strains namely, *Escherichia coli*, *Pseudomonas aeruginosa*, in addition to three multiresistant *Staphylococcus* strains namely,

Staphylococcus aureus, *Staphylococcus epidermidis* and *Staphylococcus haemolyticus* with inhibition zones > 15 mm. The most efficient plant was *B. socotrana*, of which the methanolic and aqueous extracts demonstrated the greatest antimicrobial effect against all tested microorganisms. The essential oils and the terpenoids detected are mostly responsible for this effect. However, *Commiphora ornifolia* showed similar antimicrobial activities (Mothana *et al*., 2009).

The essential oil of the three samples (Table 1) showed exceptionally prominent antibacterial activity against *B. subtilis* (MDIZ 48 - 50 mm) as well as reasonably high activity against *S. aureus*, *E. coli*, *P. aeruginosa* and *S. typhi* (MDIZ 17-21 mm). These results were quite relevant to the findings of El-Ashry *et al*. (2003) and Dolara *et al*. (2000) who reported an elevated antibacterial activity of *Commiphora myrrha* essential oil against *S. aureus*, *E. coli* and *Pseudomonas aeruginosa*. Interestingly, *B. papyrifera* and *B. rivae* essential oils were found to be active against *Staphylococcal biofilm* (Schillaci *et al*., 2008).

The significant antibacterial effect of the examined oleo-gum resins and their volatile oils could be attributed to presence of high percentage of oxygenated monoterpenes as well the existence of other active compounds. This suggestion is true according to Carson and Riley (1995), Pattnaik *et al*. (1997), and Ben Marzoug *et al* .(2011), who reported that, Oxygenated monoterpenes such as camphor, borneol, linalool and α-terpineol, were responsible for the antimicrobial activity of several essential oils. Rahman *et al*. (2008) ascribed the antibacterial activity of *C. molmol* to the prevalence of terpenes in its oleo-resin. Previous studies attributed the antibacterial activity of various *Commiphora spp* to occurrence of different active constituents. The commonly reported active constituents include phenolic compounds, alkaloids, saponins, tannins, flavonoids, anthraquinones and cardiac glycosides, terpenes, sesquiterpenes, esters, cumunic aldehyde, eugenol, steroids, resin acids and proteins (Hanus *et al*., 2005). Recently, Weckesser *et al*. (2007) concluded that the remarked antibacterial effect of *C. ornifolia* could be attributed to the high percentage of oxygenated monoterpenes such as camphor, α-fenchol, fenchon, borneol and α-terpineol. Possible synergistic effect of some compounds in the oils e.g. oxygenated sesquiterpenes (caryophyllene oxide, β-eudesmol, bulnesol and T-cadinol) as well as aliphatic acids e.g. hexadecanoic acid should also be taken in consideration.

It is clear from this study that essential oils from *B. papyrifera* have potentiality to be used as antibacterial agents in both cosmetic and pharmaceutical products. Further, as some of these

plants and oils are also used in the bush-food industry their inclusion may have added benefit as natural antimicrobials and food preservatives.

Antifungal activity:

The different extracts as well as the acid fractions, non acid fractions and essential oils originated from the three frankincense samples were studied for their antifungal activities versus *Aspergillus flavus*, *Aspergillus niger* and *Candida albicans*. Results are shown in Table 2.

Table (2): Antifungal activity (MDIZ mm) of the different extracts

Extract	***Aspergillus niger***			***Aspergillus flavus***			***Candida albicans***		
	K	**D**	**N**	**K**	**D**	**N**	**K**	**D**	**N**
PE	-	-	13	-	-	-	-	-	13
ChE	13	-	-	-	-	-	14	-	13
MEs	-	-	-	-	-	-	-	-	-
WEs	-	-	-	-	-	-	-	-	12
ME	-	-	-	-	-	-	12	-	-
WE	-	-	11	-	-	-	-	-	-
AF	-	-	-	-	-	-	-	-	-
NAF	-	-	11	-	-	-	18	-	11
Ess	50	50	50	50	50	50	50	50	50

K: *Kordofan* D: *Damazine* N: *Nagawa*

PE: Petroleum ether extract ChE: Chloroform extract ME: Methanolic extract WE: Water extrac, AF: Acid fraction , NAF: Non acid fraction, Ess: Essential oil,MEs: Methanolic extract by successive extraction

WEs: Water extract by successive extraction

MDIZ: Mean diameter of inhibition zone; MDIZ < 14 inactive (resistant)

MDIZ 14-15 moderate activity (intermediate); MDIZ >15 High activity (sensitive)

All organisms under investigation showed resistance to the used materials except *Candida albicans*, which demonstrated intermediate sensitivity towards the chloroform extract of *Kordofan* olibanum (MDIZ 14 mm) as well as high sensitivity (MDIZ 18 mm) for the non acid fraction of the same sample. However, the methanolic extract of *C. myrrha* oleo-gum resin showed slight activity against *A. niger* and no activity against *Candida albicans*, whereas the petroleum extract revealed high activity against the same two fungi (Ahmed, 2011). However, *B.*

socotrana and B. *dioscorides* extracts showed remarkable antifungal activity against *Candida maltosa* (Mothana *et al*., 2009). On the other hand, *B. serrata* showed no activity against *C. albicans* or *C. krusei* (Weckesser *et al*. 2007).

As shown in Table 2, the volatile oils hydrodistillated from *Kordofan*, *Damazine* and *Nagawa* oleo-gum resins were verified to possess extremely high antifungal activity (MDIZ 50 mm, each) against the three tested fungi. Present results were supported by the findings of Schillaci *et al*. (2008) who found that *B. papyrifera* and *B. rivae* essential oils were active against *C. albicans* biofilm. Also, Baratta *et al*. (1998) reported that the volatile oil of *B. thurifera* exhibited considerable inhibitory effect against *A. niger*. However, Camarda *et al*. (2007) reported that the essential oil obtained from *B. papyrifera* exhibits considerable activities against some spoilage fungi.

Minimum inhibition concentration (MIC) of the essential oils:

MIC test was carried out only for the essential oils due to their appreciably higher antimicrobial activity compared to the other examined materials.

As described in Table 3, volatile oil of *Kordofan* sample showed minimum inhibition concentration (MIC) of 5 µg/ ml for all inspected bacteria. Likewise, *Nagawa* sample essential oil exhibited MIC of 10 µg/ ml towards every checked bacterium excluding *B. subtilis* (5 µg/ ml). However, *Damazine* frankincense essential oil demonstrated 5 µg/ ml MIC against *B. subtilis* and *S. typhi*, but higher MIC of 10 µg/ ml in case of *S. aureus*, *E. coli* and *P. aeruginosa*. Volatile oils obtained from the three kinds of oleo-gum resin acquired identical MIC of 5 µg/ ml related to *B. subtilis*. Equally, *Damazine* and *Nagawa* oils showed the same MIC (10 µg/ ml) associated with *S. aureus*, *E. coli* and *P. aeruginosa*. On the other hand, the essential oils obtained from both *Kordofan* and *Damazine* samples gained similar MIC values (5 µg/ ml) against *Salmonella typhi*.

Current results were in conformity with the findings of Ahmed (2011) who reported MIC value of 5.5 µg /ml for *C. myrrha* fraction against *E. coli*. Present results were also relevant to the MIC values ranging from 0.40 to 8.75 µg/ ml recorded for *C. ornifolia and C. parvifoila* essential oils against *S. aureus, B. subtilis, E. coli and Pseudomonas aeruginosa* (Mothana *et al*., 2010). However, *C. molmol* and *B. papyrifera* exhibited MIC values of 31.25 - 250 and 62.5 - 500 µg/ml, respectively against *S. aureus* and methicillin-resistant *Staphylococcus aureus* MRSA stains.

Table (3): Minimum inhibition concentration (MIC) of essential oils for bacteria (µg/ml)

Sample	***Bacillus subtilis***	***Staphylococcus aureus***	***Escherichia coli***	***Pseudomonas aeruginosa***	***Salmonilla typhi***
Kordofan	*5*	*5*	*5*	*5*	*5*
Damazine	*5*	*10*	*10*	*10*	*5*
Nagawa	*5*	*10*	*10*	*10*	*10*

Concerning fungi, all studied volatile oils demonstrated the same minimum inhibition concentration of 5 µg/ ml towards *Aspergillus flavus*, *Aspergillus niger* and *Candida albicans* (Table 4). Above mentioned results were in consistency with the findings of Ahmed (2011) who reported MIC values of 4.0 and 4.5 µg /ml for *C. myrrha* fraction against *A. niger* and *Candida albicans*, consecutively. Similar observations were found by Camarda *et al*. (2007) who reported that the essential oils with the best activity against fungi strains were those obtained from *B. carteri* and *B. papyrifera* with MIC values as low as 6.20 µg /ml. The same author reported that the essential oil of *B. rivae* showed the best activity against *C. albicans* with a MIC value of 2.65 µg /ml.

According to Salvat *et al*. (2004) MIC's values less than/or around 0.5 mg/ml indicates good antibacterial activity. Based on this, it can be concluded that the volatile oils of the three used samples exhibited good antimicrobial activity against all tested organisms.

Table (4): Minimum inhibition concentration (MIC) of essential oil for fungi (µg/ml)

Sample	***Aspergillus niger***	***Aspergillus flavus***	***Candida albicans***
Kordofan	*5*	*5*	*5*
Damazine	*5*	*5*	*5*
Nagawa	*5*	*5*	*5*

Conclusion

The essential oils of the three samples showed exceptionally prominent antibacterial activity against *B. subtilis* as well as reasonably high activity against *S. aureus*, *E. coli*, *P. aeruginosa* and *S. typhi* with minimum inhibition concentration (MIC) of 5 - 10 µg/ ml. Also, they demonstrated extremely high antifungal activity against *Aspergillus niger*, *Aspergillus flavus* and *Candida albicans* with MIC of 5 µg/ ml. Acid fractions derived from the three samples demonstrated reasonable antibacterial power towards *S. aureus*, *E. coli* and *B. subtilis*.

Chloroform extracts and non acid fractions of both *Kordofan* and *Damazine* frankincense greatly suppressed the growth of *B. subtilis* and *P. aeruginosa*. However, the same extracts from *Nagawa* sample were just effective against *B.*

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