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# Top Edible Wild Plants of Eastern Mediterranean Region. Part IV: Antimicrobial and Antiviral Activities.

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**ABSTRACT**

In the first three parts of this series of review articles, we presented the anticancer, anti-inflammatory and antidiabetic activities of the most important (eaten) wild edible plants of eastern Mediterranean region, which we named as the "Deca-plants" (D-P). In this review article, we will present the antibacterial, antifungal, and antiviral activities of these very important plants. The D-P published literature of these activities is vast, with large differences between the species. Moreover, in most articles there are reports of the chemical compositions of the plant parts, extracts or essential oils (EO). These compositions are very interesting, but we will present only small part of them, otherwise, this article could be very long. Special attention will be given in the introduction to antibiotics resistance and its consequences. To provide an almost comprehensive and comparative presentation, in the last part of this article, selected Non-Deca-Plants with reported antibacterial/antiviral activity will be shortly reviewed, when the criteria of selection are wild and edible.

**Keywords**: antibacterial, antiviral, infectious diseases, MIC, inhibition zone, antifungal, antibiotics resistance, plant extracts, essential oils, hydrodistillation.

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## INTRODUCTION

Microorganisms and viruses are present around, on and inside human body ever since. Some of the bacteria that live in the human body and often named microbiota, are very important for health of humans [1], but in this review article, we will discuss only harmful bacteria and viruses.

Harmful bacteria and viruses had their adverse effect on humans since the dawn of humanity. Archeological research found this effect in humans remains from ancient Egypt [2]. Among the most important examples we can find plague, or "black death" caused by *Yersinia pestis* bacterium [3]. And the eruption of plague in central Eurasia during the 14$^{th}$ century, is considered one of the worst pandemics in human history [4]. And in our times, the most recent example is COVID-19 pandemic caused by various mutation of the Corona virus. According to the World Health Organization (WHO), has claimed 6.9 million victims until last week of September 2023 [5]. In addition to major viral pandemics (Swine flu, Bird flu, Ebola) outburst in the last 50 years, influenza virus kills around 470000 humans, in average, every year [6].

The fight between humans and bacteria had a turning point after its discovery by A. van Leeuwenhoek in 1677 [7]: the race for antibiotics turned into systematic science. The same thing can be said about the development of antiviral agents, that reached a milestone after the discovery of viruses by D.I. Ivanovsky in 1892 [8].

Many researchers consider the production of atoxyl (**Figure 1**) by A. Béchamp as the first synthesis of antibacterial or antibiotic agent, even though, the active compound is arsanilic acid (**Figure 1**) and not its sodium salt, atoxyl [9].

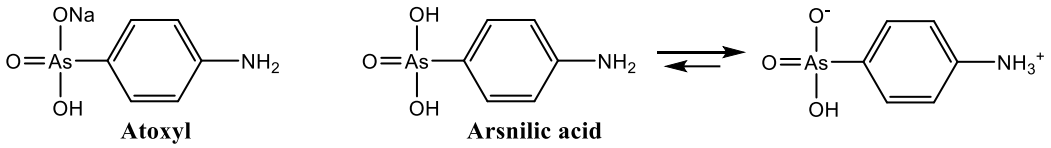


**Figure 1: Atoxyl and arsnilic acid which is considered the first antibiotics [9]**

The success of antibiotics was tremendous in reduction of mortality rates caused by infectious diseases [10]. But with this success, three major challenging outcomes emerged: antibiotics resistance of the bacteria, adverse effects of the antibiotics and removal of antibiotics waste from the environments, especially water sources. The third problem will be presented in the **Discussion** section.

Antibiotic resistance was defined in several ways, but it can be said that it is the ability of a microorganism to survive and/or grow certain concentration of antibiotic agent, which is usually effective for killing or inhibition of the same species [11]. And consequently, antibiotics resistance is one of major threats to humanity [12]. Antibiotic resistance is developed by various factor, where genetic changes and mutations in the bacteria is on the top of them [13]. But bacteria take one or more of the following actions that result in antibiotic resistance [14]. Blocking the entrance of antibiotic to the bacteria cell; expelling the antibiotic from the cell; inactivation of the antibiotic by changing its structure or degradation; and, changing the antibiotic target within the bacterium cell. Another important aspect of antibiotics resistance is the fact that some bacteria developed multidrug resistance, meaning that they are immune to several types of antibiotics [15].

Adverse or negative side effects of antibiotics use were studied and published by many researchers. P.D. Tamma and her colleagues found that at least 20% of antibiotics users experienced antibiotic-associated adverse drug events, ADEs [16]. These ADEs included diarrhea, nausea and vomiting, hematologic event, hepatobiliary effects, renal complications, dermatologic problems, cardiac effects, severe allergies (anaphylaxis) and muscle inflammations (myositis). S. Shekhar and F.C. Petersen name antibiotics "unavoidable drug" but they found that it has adverse effect on immune system of infants [17]. K. Dinan and T. Dinan warn of focusing on antibiotic-resistance while developing new antibiotics, since these might have adverse effect on brain-gut-microbiota, as they have summarized in their review article [18].

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To provide more focused image of the adverse effects of antibiotics, we will give as examples two of the most frequently used in a global scale: amoxicillin and doxycycline [19]. The structures of these compounds are shown in **Figure 2**.

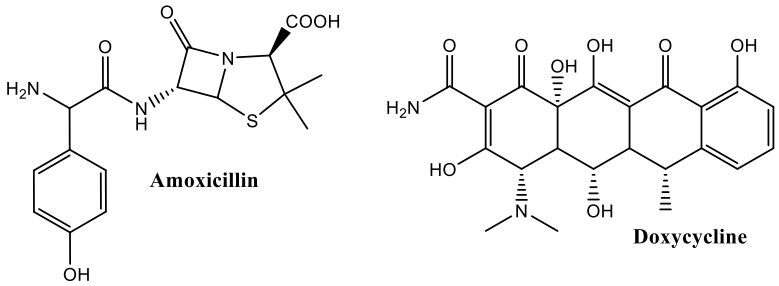


**Figure 2:** Amoxicillin and doxycycline, two of the most frequently used antibiotics [19]

M. Gillies and his colleagues summarized the adverse effects of amoxicillin in a review article, and these included: nausea, vomiting, diarrhea, candidiasis and rash [20]. N.E. Holmes and P.G. Charles reviewed the negative side effects of doxycycline, and their major findings were: gastrointestinal (nausea, vomiting, diarrhea and epigastric burning), dermatological (photosensitivity and photo-onycholysis), bones and teeth (discolouration of teeth, reduction in fibular bone growth) [21].

In addition to the mentioned above major issues that are part of antibiotics use, it is important to take into account the economic burden of this use: from USD 21.1 to 34.8 billion, between 2000 and 2015 [22]. For these reasons and the problems of treating antibiotics hazardous waste (**Section 4**), it is highly important to replace synthetic antibiotics with natural products.

The use of medicinal plants started with human existence, and the earliest recorded use dates into the Sumerian era, around 5000 years before our time [23]. The Ebers Papyrus of ancient Egypt that dates from approximately the same time, listed 700 plant-based drugs, including gargles, pills, infusions and ointments [24]. The knowledge of traditional medicines that was achieved during 5 millennia, proved to have significant scientific basis when tested for antibacterial activity [25]. Moreover, screening publications about plants with proven activity against antibiotic resistant bacteria, yields a list of more than two dozens, about a decade ago [26]. Few years later, the mechanisms of action of plant-based products that treated antibiotic resistant bacteria became more and more clear [27]. And recently, there is increasing knowledge of the active natural products (NPs) that are responsible for this crucial activity [28].

Finally, the D-P are *Arum palaestinum* (Araceae), *Cichorium pumilum* (Syn. *Cichorium endivia*, Asteraceae), *Cyclamen persicum* (Primulaceae), *Foeniculum vulgare* (Apiaceae), *Gundelia tournefortii* (Asteraceae), *Majorana syriaca* (Syn. *Origanum syriacum*, Lamiaceae), *Malva sylvestris* (Malvaceae), *Micromeria fruticosa* (Lamiaceae), *Salvia fruticosa* (Syn. *S. triloba*, *S. libanotica*, *S. cypria*, *S. lobryana*, Lamiaceae), *Sinapis alba* (Brassicaceae).

**Ethnomedicinal Antibacterial and Antiviral Activities of the Deca-Plants**

Despite the fact that bacterial and viral diseases existed along with humans, ethnomedicinal practitioners did not know the cause of these diseases: bacteria and viruses. They treated infectious diseases with plants in the same way they treated other illnesses [29,30]. But in the written or unwritten knowledge of traditional medicines, there is no evidence that healers knew that these diseases were caused by microorganisms and viruses.

**Antibacterial and Antiviral Activities of the Deca-Plants and Their Natural Products**

Modern science has acknowledged the great potential of the D-P as antibacterial and/or antiviral, so we found many published articles. In a very few cases, we chose not to cite some articles, since there finding and/or their methods seemed unreliable. A summary of modern science of antibacterial and/or antiviral activities of the D-P is presented in **Table 1**.

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**Table 1: Antibacterial and Antiviral Activities of the D-P in Eastern Mediterranean region.**

| Testing Method, Results and Reference/s |
|---|
| ***Arum palaestinum*** |
| The aim of this study was to find correlation between radical scavenging (antioxidant) and antibacterial activities. Values of antioxidant activity are listed while values of antibacterial activity are only presented in a not so clear graph. Leaves were extracted with water or methanol (polar extracts) and ethyl acetate or *n*-hexane (nonpolar extracts). For polar extracts, a vague negative correlation was found and for nonpolar extracts, a vague positive correlation was found. [31] |
| Flowers aqueous extract was tested against *P. vulgaris* and *E. faecium* and MIC (minimum inhibitory concentration) values were 6.25 mg/mL for both bacteria. Ampicillin was used a reference, MIC=18 mg/ml, respectively. Ampicillin has very similar structure to amoxicillin but has no hydroxyl group on the aromatic ring. [32] |
| Identical to the previous work. [33] |
| Leaves were separately extracted with water and $CH_3OH/CH_2Cl_2$ (1:1, v/v), and both extracts were tested against four bacteria strains. Very weak effect for both extracts. [34] |
| Leaves were extracted with 70% aqueous ethanol, and extract had strong activity against several bacterial strains. [35] |
| Methanolic leaves extract and its major components (GC-MS, Gas Chromatography Mass Spectrometry) were tested against corona virus proteins, $3CL^{pro}$ and Nsp15. Among 19 compounds, β-sitosterol, androstan-3-one, phenobarbital, maltose, and α-tocopherol (**Figure 3**), had the strongest binding. [36] |
| ***Cichorium pumilum*** |
| Leaves extracts. See detailed description for his reference in *Arum palaestinum*. [31] |
| Aqueous and ethanolic extracts were prepared from callus grown from leaves. Aqueous extract had very weak activity against several gram-positive and gram-negative bacteria, while ethanolic extract showed notable activity. [37] |
| Seeds, roots and leaves were combinedly extracted with water, methanol and chloroform (3 extracts). Extracts were tested against: *S. aureus*, *B. cereus* (gram-positive), *S. typhimurium*, *E. coli* (gram-negative), *C. Albicans*, *A. niger* (fungi). Aqueous extract was most active against bacteria and methanolic extract was most active against fungi. [38] |
| Aerial parts were extracted with 80% aqueous methanol, and extract showed moderate activity against some of 19 tested fungi species. [39] |
| Follow-up of previous study. Similar results. [40] |
| Leaves aqueous extract was tested against three *Aspergillus* spp: *A. flavus*, *A. ochraceus* and *A. parasiticus*. It had no effect against first fungus but had strong activity against the second and the third fungi. [41] |
| Shoots were separately extracted with 70% aqueous ethanol, methanol, acetone and water. All extracts were tested against two fungi species: *A. ochraceus* and *A. alfatoxiformans*. Methanolic extract had highest inhibition activity. [42] |
| ***Cyclamen persicum*** |
| Leaves extracts. See detailed description for his reference in *Arum palaestinum*. [31] |
| Tubers were separately extracted with water, methanol, ethanol and *n*-hexane. All extracts were tested against two species of garam-positive and two species of gram-negative bacteria. Only methanolic extract had significant activity and only against gram-positive bacteria. [43] |
| Tubers were separately extracted with water, methanol, ethanol and acetone. All extracts were tested against 5 gram-positive bacteria species, 7 gram-negative bacteria species and 4 *Candida* species (antifungal activity). Except for aqueous extracts, organic extracts were very active in the three tests. In this study, hyptatic acid-A (**Figure 4**) derivatives isolated and characterized. [44] |
| ***Foeniculum vulgare*** |
| Leaf and stem extracts. See detailed description for his reference in *Arum palaestinum*. [31] |
| Aerial parts EO was prepared by hydrodistillation and tested against 25 bacteria species. It was active against all bacteria, where the highest activity was against *C. perfringens*. EO was analyzed by gas chromatography (GC) and the three major ingredients are shown in **Figure 5**. [45] |
| Six compounds (**Figure 6**) were obtained by analysis of stems methanolic extract, and were tested for antibacterial (*E. coli*, *B. subtilis*) and antifungal (*A. niger*, *C. cladosporioides*) activities. All compounds were active and scopoletin was most potent. [46] |
| Fruits EO was prepared by hydrodistillation, tested against 29 bacteria species, and found active against most of them. The chemical composition of this EO was analyzed (GC-MS) and the major components were: linalool, *p*-cymene, α-pinene (see **Figure 5**) and nerol (**Figure 7**). [47] |

Seeds EO was prepared and tested against several *Streptococcus* mutants and found active. Authors refer this activity to the major component of this EO: *E*-anethole. [48]
Aerial parts EO was prepared and tested against 30 bacterial strains and found active against all of them. Major components of this EO were: *trans*-anethole (64.08%), α-phellandrene (14.54%), and α-pinene (9.38%). [49]
Seeds EO and methanolic and ethanolic extracts were prepared and tested against 10 bacteria species. The three materials were active, but EO was more potent. Major component of EO was *trans*-anethole, while the major components of the alcoholic extracts were fatty acids: linoleic, palmitic and oleic (**Figure 8**). [50]
Seeds aqueous and acetone extracts were prepared and found active against 11 bacteria species. General chemical compositions were determined. [51]
Seeds EO and methanolic, 80 aqueous methanolic, ethanolic and 80% aqueous ethanolic extracts were prepared. The five materials were tested against 5 bacteria strains, and only EO was active. Major components of EO were (%): *trans*-anethole 68.1, fenchone 9.50, estragole 4.92 and limonene 4.50. [52]
Seeds EO was prepared and tested against 10 bacteria strains. EO had excellent activity compared with synthetic drugs tetracycline (**Figure 9**) and rifampicin. Major components of this EO were: estragole (see **Figure 5**), limonene and fenchone (**Figure 9**). [53]
EO's of aerial parts and seeds were separately obtained by hydrodistillation, and none or very weak activity was recorded against several bacteria species. [54]
Aerial parts EO and *n*-hexane extract were prepared, and both were found against several bacterial strains. *E*-anethole was the major component of EO and extract. [55]
Seeds were extracted with 80% aqueous ethanol, and extract was active against *S. aureus*, *B. subtilis*, *E. coli* and *S. typhi*. MIC values were (mg/mL): 6.4, 12.8, 3.2 and 6.4. [56]
Aerial parts DCM:Methanol (1:1, v/v) extract was prepared and found active against 9 bacteria species (DCM, dichloromethane). Analysis of the extract yielded 7 known compounds (**Figure 10**) that were isolated from this plant for the first time. [57]
EOs were obtained by hydrodistillation from fruits of three organically cultivated cultivars: var. *vulgare*, var. *azoricum* and var. *dulce*. There were no significant differences in antibacterial activity of the three cultivars. Analysis of the three EOs revealed clear differences: in var. *vulgare*, estragole was the major component, while in the other two cultivars, *E*-anethole was the major component. [58]
Leaves EO was obtained with hydrodistillation and had very strong activity against 14 bacteria species, gram-positive and gram-negative. Major ingredients of this EO were previously mentioned, in addition to thymol. [59]
Stems and leaves were extracted with *n*-hexane and analyzed for chemical composition. The extract and the components had low activity, but one compound had moderate activity, 5-hydroxyfuranocoumarin, the demethylation product of bergapten shown in **Figure 6**. [60]
Leaves EO was produced by hydrodistillation and analyzed for chemical composition. It had very strong activity against several bacteria and fungi species. [61]
Seeds were extracted with 80% aqueous methanol, and extract had mild activity against four bacterial strains. Analysis of extract revealed the presence of five major phenolic compounds shown in **Figure 11**. [62]
Seeds were separately extracted with methanol, ethanol, diethyl ether and *n*-hexane, and extracts were tested against several bacteria and fungi species, showing concentration dependent moderate activity. Extracts were analyzed for chemical compositions where polar extracts contained mainly phenolics and fatty acids, while the nonpolar extracts contained mainly oxygenated monoterpenes. [63]
Seeds were hydrodistilled and the resulting EO was tested against 7 bacteria species. It was active against all of them, but there were clear differences in MIC measurements (mg/mL): from 0.125 for *S. Dysenteriae* to 0.25 for *E. coli*. The major components of this EO were: *E*-anethole (68.53%) and estragole (10.42%). [64]
Seeds EO was obtained by steam distillation and it was tested against 36 antibiotics-resistant bacteria species that were isolated from human patients urine. The activity was compared with 7 standard, knowns antibiotics, and it was moderately active against most of them. [65]
EOs were prepared from fruits taken from 6 different localities in Portugal. Analysis of these EOs showed differences in their chemical composition, mainly the percentages of major components. The antibacterial (9 species) and antifungal (6 species) were approximately the same. [66]
Seeds EO was produced by hydrodistillation and was active against 6 bacterial strains. This EO its major components (**Figure 12**) were (%): 9-octadecenoic acid (18.56), *o*-benzene dicarboxylic acid (14.47), 1,3,3-trimethyl-2-vinyl-1-cyclohexene (10.77), 1H-benzocycloheptene (10.71). [67]

Fruits EOs of 23 samples of the plant from Iran and Europe were obtained by hydrodistillation, and tested against *E. coli*, *S. typhimurium*, *B. subtilis*, and *S. aureus*. Excellent results (MIC) were recorded, especially against *E. coli*: 31.5 µg/mL. *trans*-Anethole was the major ingredient of these EOs. [68]
Seeds methanolic extract was active against several bacteria species. General chemical composition was determined in this study. [69]
Aerial parts EO was obtained by hydrodistillation, and tested against several bacteria strains, showing good activities. *E*-Anethole was the major ingredient of this EO. [70,71]
Commercial EO from aerial parts (hydrodistillation) of organically grown plants had moderate activity against *L. innocua* and *P. fluorescens*. Major components of this EO were limonene, fenchone and *E*-anethole. [72]
EOs were obtained by hydrodistillation from seeds of three organically cultivated cultivars: var. *vulgare*, var. *azoricum* and var. *dulce*. There were no significant differences in antibacterial (4 species) and antifungal (2 species) activities of the three cultivars. Analysis of the three EOs revealed clear differences: in var. *vulgare*, estragole was the major component, *E*-anethole in var. *azoricum* and limonene in var. *dulce*. [73]
Seeds were separately extracted with methanol and water, and both extracts were tested against 20 bacterial strains. Aqueous extract had activity against 12 species, while the methanolic extract had activity only against 4 species. [74]
Seeds were separately extracted with methanol and *n*-hexane. Both extracts were tested against four bacteria and two fungi species. In average, methanolic extract was more active (zone of inhibition). [75]
Seeds EO was obtained by hydrodistillation, and tested against three bacteria (*S. aureus*, *E. coli*, *P. aeruginosa*) and three fungi (*A. flavus*, *A. niger*, *M. canis*) species, revealing strong activities (MIC). [76]
Ethanolic seeds extract had various notable activity against four bacteria species, in dose dependent tests. [77]
Seeds EO was prepared using steam distillation. It was tested against several bacteria species alone, or in combination with 13 known antibiotics. EO was active alone, but the combinations showed synergistic effect that exceeded the antibiotics effect. [78]
Fixed oil was produced by extracting seeds with *n*-hexane, solvent removal and esterification of the resulting liquid with methanol. It was tested (before esterification) against four bacteria species and one fungus, showing stronger activity than two standard antibiotics: ampicilin and gentamycin. The major constituents of the fixed oil were 9-octadecenoic acid methyl ester and 9,12-octadecadienoic acid methyl ester. [79]
Four EOs were separately prepared by hydrodistillation from seeds, flowers, aerial parts before flowering and whole plant before flowering. All EOs were tested against seven bacteria and three fungi species, showing significant activities in most tests. [80]
Leaves EO was prepared and tested against three bacteria species and a fungus, resulting significant inhibition compared with four known antibiotics. *Trans*-Anethole was the major compound in this EO. [81]
Methanolic and ethanolic extracts of aerial parts were prepared and tested against 8 bacterial species. Compared with 29 antibiotics, extracts showed moderate to weak activities, when ethanolic extract was more potent. [82]
Seeds were separately extracted with water, chloroform, methanol and 80% aqueous methanol. Extracts were tested against four bacteria species, showing the following results: chloroform and aqueous extracts were inactive; pure methanolic extract was more active than 80% aqueous methanolic, but both had weak activity. [83]
EO was prepared by steam distillation of aerial parts, and tested against *Candida albicans*, showing significant activity, in dose dependent experiments. The major components of this EO were: *o*-cymene, *α*-phellandrene, *α*-pinene and estragole. [84]
Fruits were hydrodistilled yielding EO with weak activity against two bacteria and two fungi species. Major components of this EO were: *E*-anethole, fenchone and estragole. [85]
EO was prepared by hydrodistillation of aerial parts and was tested against *Streptococcus mutans*, resulting significant activity, compared with EOs of other plants used in this research. *E*-anethole and fenchone were the major constituents of this EO. [86]
Seeds extraction with buffer pH=7 afforded a protein that had activity against 4 bacteria and 4 fungi species. The estimated molecular weight of the protein is 60 kDa, but the structure was not reported. [87]
Leaves were defatted with petroleum ether and separately extracted with chloroform, methanol and chloroform/methanol (1:1, v:v). Leaves EO was also prepared, where *Z*-anethole and estragole were its

major components. The four crude extracts were tested against two bacteria and two fungi species showing weak to moderate activities, and the EO was completely inactive. [88]
Seeds were used to prepare two EOs, by hydrodistillation and by extraction with cyclohexane. Both EOs were tested against 5 bacterial strains resulting high activity for both, and higher for the cyclohexane extract. *E*-anethole and fenchone were the major constituents of both EO. [89]
EOs were prepared by hydrodistillation from seeds harvested in 16 different localities in Tunisia. All EOs were tested against six bacteria and two fungi species showing significant activities and similar results for some microorganisms, but notable differences for others. The chemical compositions of the EOs were clearly different in terms of compounds families (i.e., oxygenated monoterpenes) and single compounds (i.e., estragole). [90]
Seed were extracted with hot water and microwave assistance, and the resulting extract was fractionized with *n*-hexane, ethyl acetate and methanol. The three fractions were tested separately and in combination with Augmentin antibiotics (combination of amoxicillin, **Figure 2** and clavulanic acid), against *B. cereus*, *P. aeruginosa*, and *B. melitensis*. The synergistic effect was weak where Augmentin alone was more active than the combination in most tests. [91]
Seeds from three different locations in Iran were hydrodistilled resulting three EOs. These were tested against three bacteria species and a fungus: no significant differences were discovered. The chemical compositions of the EOs were close with major components of *trans*-anethole, fenchone and limonene. [92]
Seeds EO was prepared by hydrodistillation and found active against six bacterial strains, with varying levels of activities and concentrations. The major compounds of this EO were *trans*-anethole, fenchone and limonene. [93]
Leaves EO was prepared by hydrodistillation and tested against 8 bacteria species, resulting wide range of activity (MIC), from very weak to very strong. The major constituents of this EO were *p*-cymene (**Figure 7**), cuminal and β-pinene (**Figure 13**). [94]
Seeds were extracted with 80% aqueous ethanol. This extract was tested against *E. coli* according to the following procedures: alone, in combination with Nisin (antibacterial peptide isolated from *L. lactis* bacterium) and in combination with sodium diacetate [$NaH(CH_3COO)_2$ , antibacterial agent). It was found that the combination of extract with nisin is more potent than each of the materials, separately, but the combination with sodium diacetate had no synergistic effect. [95]
Seeds were hydrodistilled to obtain EO that was tested against several bacterial strains, showing moderate inhibition. The major components of this EO were *trans*-anethole and estragole. [96]
Seeds EO (steam distillation) had significant inhibition of *E. faecalis* (bacterium) and *C. albicans* (fungus). [97]
Leaves aqueous ethanolic (96%) extract had activity against *Pseudomonas aeruginosa*, in concentration dependent inhibition. [98]
Commercial seeds EO was highly active against 4 bacteria and 4 fungi species. Major ingredients of this EO were (%): *E*-anethole (73.6), fenchone (6) and limonene (5.7). [99]
EO of fresh fruits was prepared by hydrodistillation and was tested against 5 bacteria and fungi species and influenza (H1N1) virus, resulting high activity. Estragole was the major component of this EO (84.5%). [100]
Seeds ethanolic extract was active against *Staphylococcus aureus*. No numerical results presented. [101]
Seeds were separately extracted with methanol, ethyl acetate and benzene, and extracts were tested against *S. aureus*, *S. typhi* and *E. coli*. All extracts showed significant activities, where the benzene extract was most active, in average. [102]
Fruits EO was prepared by hydrodistillation and was tested against four bacteria and two fungi species, resulting excellent (against fungi) to significant activities (against bacteria). *E*-Anethole, estragole and limonene were the major components of this EO. [103]
Fresh leaves were hydrodistilled to obtain EO, and was tested against *E. coli*, *B. subtilis*, *P. aeruginosa,* and *C. albicans*, resulting moderate activity. The major ingredients (**Figure 14**) of this EO were (%): *trans*-anethole (41.18), *cis*-anethole (26.49), α-copaene (13.66) and β-phellandrene (5.38). [104]
Fresh leaves were hydrodistilled to obtain EO, and was tested against 6 bacteria species, including biofilm forming, resulting weak activity. The major components of this EO: *trans*-anethole, α-pinene and estragole. [105]
Leaves EO (hydrodistillation) had weak synergistic effect with silver nanoparticles (AgNPs), since the activity of AgNPs is much stronger than EO. The testing was against six bacterial strains. [106]
Seeds were successively extracted with methanol, petroleum ether, acetone and water. The extract was tested against four bacteria species, and compared with four synthetic antibiotics, extract had moderate activities. [107]

Seeds EO was tested against 4 bacteria species, showing significant activity. The major components of this EO: *trans*-anethole, fenchone and estragole. [108]
Seeds (?) methanolic had moderate activity against three microorganisms. The major ingredients of this extract were *E*-anethole, estragole, benzoic acid and fenchone. [109]
Liquid fermentation product of seeds was tested against *S. aureus*, *E. coli* and *S. typhi* showing medium activity. General chemical composition of the liquid is reported. [110]
Stems and leaves EO was obtained by hydrodistillation tested against several bacterial strains, showing moderate activity compared with other EOs tested in this study. The major components of this EO were α-pinene, α-phellandrene and estragole. [111]
Seeds were hydrodistilled to produce EO which was tested against 3 fungal and 5 bacterial species, showing moderate (against fungi) to high (against bacteria) activity. [112]
Seeds EO (hydrodistillation) was prepared and tested against bacterial disease agents *R. radiobacter*, *P. savastanoi* pv. *savastanoi* and *P. savastanoi* pv. *nerri* (pv. stands for pathovar). Activity was moderate compared with other plants that were investigated in this study, and the major compound contained in this EO was *E*-anethole, 82.8%. [113]
EO was obtained by seeds hydrodistillation and was tested against *S. sclerotiorum* fungus, resulting very high activity, both in contact or as volatile form, in concentrations (μg/mL) of 1.6 and 0.2, respectively. [114]
Seeds cold press EO was produced and tested against 18 bacteria species and found inactive. Major component of this EO (88.95%) was *trans*-anethole. [115]
Seeds were extracted with 60% aqueous ethanol. This extract was tested against 3 fungi and 6 bacteria species, showing moderate activity compared with positive control (ketoconazole and gentamycin, respectively). It was also tested against HSV and CoxB4 viruses showing moderate effect. *E*-Anethole was the major component of this extract. [116]
Seeds EO was produced by hydrodistillation and tested against six fungi species, showing significant activity (MIC). *trans*-Anethole, α-pinene and fenchone were the major components of this EO. Authors propose that the mechanism of action of this EO is damaging the plasma membrane and inhibit the enzymes of the mitochondria. [117]
Seeds EO (hydrodistillation) and methanolic extract were prepared against 5 strains of plants fungi, resulting high to excellent inhibition, and EO was more potent, in average. The major components of EO were (%): estragole (76.2), α-thujone (9.6, **Figure 17**) and limonene (8.6); and of methanolic extract (ppm, **Figure 17**): cirsiliol (27.1), protocatchuic acid (11.97) and quinic acid (4.7). [118]
Seeds were hydrodistillation afforded EO that had significant activity against potato virus X, tobacco mosaic virus and tobacco ring spot virus. [119]
Seeds EO (hydrodistillation) and acetone extract were prepared and applied againstpapaya ring spot virus, showing moderate activity, in several concentrations. [120]
Aerial parts were hydrodistilled to produce EO which was tested against two virus and 12 bacteria species. In this study, several active components such as *E*-anethole were tested against the same microorganisms and viruses. For antiviral activity, EO was comparable with pure natural products, but more potent for antibacterial activity. [121]
Seeds were extracted with 70% aqueous methanol, and major compounds isolated from this extract were quercetin (**Figure 11**) and isoquercetin (3-*O*-1-β-D-glucosyl quercetin). These compounds were tested against *Bluetongue virus*, resulting moderate activity for both compounds and higher activity of isoquercetin. [122]
Seeds were extracted with 98% aqueous ethanol. Extract was tested against influenza virus resulting high inhibition (82.8%) in concentration of 300 μg/μL. [123]
Aerial parts and bulbs from different locations in Egypt were used to prepare EOs, either by hydrodistillation or headspace. EOs were tested against hepatitis A and C viruses, showing very high activity. In this study, comprehensive chemical compositions were presented, and were compared with chemical compositions from Spain and Holland. *E*-Anethole was the major component of the Egyptian plant sample. In addition, molecular docking simulation of six major components binding to the virus polymerase. [124]

***Gundelia tournefortii***

Stems extracts. See detailed description for his reference in *Arum palaestinum*. [31]
Bulbs were extracted with methanol and this extract was separately fractionized with *n*-hexane and ethyl acetate. Fractions were tested against five bacterial strains, showing high activity (inhibition zone), compared with tetracycline as positive control. The chemical composition of the ethyl acetate fraction were some free fatty acids but mainly their esters, and *n*-butylspiropentane (**Figure 18**). [125]

Commercial active compounds identified in another research, were purchased and tested against *S. choleraesuis*: *E*-2-dodecenal was most active (MIC = 6.25 μg/mL). There are some issues with this report. Please see **Discussion** section (4). [126]
Stems ethanolic extract was tested against *S. aureus* and *E. coli*, showing moderate activity (MIC, μg/mL, 62.5 and 31.25, respectively). [127]
Aerial parts were successively extracted with chloroform, ethyl acetate, methanol and water. All extracts were tested against 9 bacterial strains and had high activities (inhibition zone), compared with three known antibiotics. EO of aerial parts was also produced by hydrodistillation, and its chemical composition is reported, but it was not tested for antibacterial activity. [128]
Aqueous extracts of leaves and roots were separately prepared, and the EO of combined plant parts was obtained by hydrodistillation. The three materials were tested against 8 bacterial and fungal species, showing significant activity. [129]
Seeds aqueous extract was prepared and tested against 8 bacterial and fungal species, showing significant activity (MIC). Major compounds of this extract were diethyl phthalate, 1-tetradecanol and 1-hexadecene (**Figure 19**). [130]
Methanolic extract of aerial parts had weak activity (MIC) against 13 bacterial species, compared with other plants used in this study and antibiotics of chloramphenicol. [131]
Whole plant methanolic extract was tested in combination with seven common antibiotics, against *E. coli*, resulting clear enhancement of the activities of these antibiotics. [132]

***Majorana syriaca***

Leaf and stem extracts. See detailed description for his reference in *Arum palaestinum*. [31]
Leaves were extracted with 70% aqueous ethanol, and extract had strong activity against several bacterial strains. [35]
Leavess EO (hydrodistillation) was prepared and tested against bacterial disease agents *R. radiobacter*, *P. savastanoi* pv. *savastanoi* and *P. savastanoi* pv. *nerri* (pv. stands for pathovar). Activity was excellent compared with other plants that were investigated in this study, and the major compounds (**Figure 15**) contained in this EO were (%): carvacrol (79.8), p-cymene (8.15) and γ-terpinene (4.7). [113]
EO was obtained by leaves hydrodistillation and was tested against *S. sclerotiorum* fungus, resulting very high activity, both as volatile form or in contact, in concentrations (μg/mL) of 0.3 and 3.2, respectively. [114]
Leaves methanolic extract was tested in combination with seven common antibiotics, against *E. coli*, resulting clear enhancement of the activities of these antibiotics. [132]
Leaves EO was prepared by steam distillation and tested against 13 bacterial strains, resulting high activity (in average), compared with three commonly used antibiotics. The major components of this EO were (%): γ-terpinene (28), carvacrol (27), *p*-cymene (16) and β-caryophyllene (13). [133]
Ethyl acetate leaves extract inhibited the growth of several *Pseudomonas* sp. (moderate) and lactic acid bacteria (significant), on minced and packed yellow fin tuna. [134]
Commercial EO (66.64% carvacrol) had significant activity against *S. aureus*, *S. pneumoniae* and *C. albicans*. [135]
Leaves EO was obtained by hydrodistillation and tested against 3 bacterial and 5 fungal species. Both activities were compared with those of pure compounds isolated from the same EO (major components): thymol, carvacrol, α-terpinene and *p*-cymene. EO antifungal activity matched that of pure compounds, but the antibacterial activity was weaker, despite being very strong. [136]
Aerial parts EO was produced by hydrodistillation and tested against 4 bacterial strains. Compared with six known antibiotics, EO had high activity (MIC). [137]
EO was produced from aerial parts by steam distillation and tested against 4 bacteria and 3 fungi species, showing significant activities. [138]
Whole plants, wild and cultivated in Sinai desert, were hydrodistilled to obtain EOs. These EOs were tested against 4 bacterial and 8 fungal species, resulting significant activity for both, and higher for EO produced from the wild plants. Very notable differences were detected in the chemical compositions. Here are the concentrations of major components (cultivated, wild, %): α-terpinene (1.2, 5.5), *p*-cymene (8.5, 3.9), γ-terpinene (2, 14.3), linalool (0.2, 9.5), 4-terpineol (0.9, 7.7), α-terpineol (0.2, 5.5), thymol (0.4, 31.7), carvacrol (81.4, 3.9). [139]
Leaves methanolic extracts had excellent activity (MIC = 1 mg/mL) against *S. aureus*, *P. aeruginosa*, and *C. albicans*, also compared with other plants used in this study. [140]
Stems and leaves were hydrodistilled resulting EO, that was analyzed for its components. EO and 15 of its components were tested against seven species of gram-negative bacteria. In average, EO had stronger activity than most of its ingredients. The major constituents of this EO were (%): β-myrcene 22, γ-terpinene 5.3, thymol 7.4, *p*-anisaldehyde 7.6 and carvacrol 19.6 (**Figure 20**). [141]

Leaves EO was obtained using microwave-ultrasonic assisted hydrodistillation (MUAHD), and had notable activity against 5 bacterial strains. Major components of this EO were α-terpinene, γ-terpinene, thymol, carvacrol and caryophyllene. [142]
Leaves were hydrodistilled to produce an EO that was tested against 12 bacteria species and *C. albicans*. Compared with commonly used antibiotics, EO had notable activity. [143]
Aerial parts were brought from three localities and EOs were prepared by hydrodistillation and tested against *S. aureus*, *S. Mutans* and *C. albicans*. Results showed strong activity (MIC), with no significant differences between the three EOs. [144]
Leaves (local subspecies, *M. syriaca* ssp. *sinaicum*) EO was prepared and had significant activity (inhibition zone) against four bacteria and a fungus. The major component of this EO (95.37%) was carvacrol. [145]
Commercial EO was applied against several bacterial species grown on cooked chicken meat. This EO was tested separately and in combination with *Rosmarinus officinalis* EO. Compared with a combination of two synthetic antibacterial agents, BHA-BHT (butylated hydroxy anisole, butylated hydroxy toluene, **Figure 21**), each one of the EOs had significant activity, and their combination was more potent. [146]
Leaves and flowers hydrodistillation afforded EO that was tested against three fungal species (*A. niger, Penicillium* spp. and *F. oxysporum*), resulting high activity. [147]
Leaves EO was prepared by hydrodistillation and was tested against 6 *Candida* ssp., showing notable activity (MIC). Thymol, carvacrol and *p*-cymene were the major components of this EO. [148]
EO was produced by hydrodistillation (plant part/s not indicated) and had significant activity against *F. oxysporum*, *M. phaseolina*, *B. cinerea* and *E. turcicum*. [149]
Flowering tops were hydrodistilled and an EO was obtained and tested against two bacteria and two fungi species. Some of the pure compounds isolated from this EO were also tested against the same microorganisms. In average, EO activity was higher than pure components. Thymol, γ-terpinene and *p*-cymene were the major ingredients of this EO. [150]

***Malva sylvestris***

Leaves extracts. See detailed description for his reference in *Arum palaestinum*. [31]
Anthocyanin-rich extract (plant part/s, solvent/s and extraction method/s are not indicated) had significant inhibition of *S. aureus*, in a concentration-dependent activity. [151]
Flowers and leaves were separately extracted with *n*-hexane, dichloromethane, and methanol, successively. Both extracts were tested against 6 bacterial and 5 fungal species, showing moderate activities (MIC, inhibition zone), compared with three synthetic antibiotics. [152]
Aerial parts and roots were separately extracted with 70% aqueous ethanol, and both extracts were tested against six bacterial strains. Results showed that aerial parts extract inhibited more bacteria, but roots extract was more potent (MIC). [153]
Leaves ethanolic extract was fractionized with *n*-hexane, ethyl acetate and chloroform. The crude extract and the chloroform fraction were tested against *A. actinomycetemcomitans*, *F. nucleatum*, *P. intermedia* and *P. gingivalis*. Chloroform fraction was more active. [154]
Leaves and flowers of cultivated plants were separately steam-distilled yielding two EOs, that were tested against *P. larvae*, *M. plutonius* and *B. subtilis*. Several fractions of these EOs were also tested, and EOs were in average more active than fractions. Notable differences were detected between the chemical compositions of the EOs. The major components of these EOs are presented in **Figure 22** (flowers, leaves, %): eugenol (10.3,46.7), *E*-phytol (5.7,34.4), tricosane (7.7,0.2), 3-methyltricosane (14.9,0.1), pentacosane (8.2,0.2). [155]
Leaves and roots were separately extracted with 75% aqueous methanol, and these extracts had no activity against *S. aureus*, *P. aeruginosa* and *L. monocytogenesis*. [156]
Flowers 50% aqueous ethanol had moderate activity against *A. actinomycetemcomitans* (MIC = 1.67 mg/mL), compared with two antibiotics (chlorhexidine, doxycycline). [157]
Methanolic leaves extract had moderate activity against four bacterial strains, compared with three synthetic antibiotics. The major components of this extract were determined by GC-MS: tetradecenol, oxirane, octadecatrienoic acid and phytol (see **Discussion**). [158]
Aerial parts were hydrodistilled to produce an EO that was tested against eight bacterial strains, showing high activity (MIC), comparing with chlorhexidine as a reference. The detailed chemical composition of this EO was obtained by GC-MS: hexadecenoic acid, 2-methoxy-4-vinylphenol, pentacosane, heptacosane, linoleic acid and phenanthrene. [159]
Leaves ethanolic extract had no effect against *S. aureus*. [160]
Leaves ethanolic extract had moderate activity against *G. vaginalis* isolated from vaginal secretions, but did not inhibit *Candida* spp. The major components of this extract (>5%) were fatty acids. [161]

Seeds were extracted with acetonitrile/water/formic acid solution, 10:9:1 (volumes), and from the resulting extract, nanofibers were prepared. These nanofibers were active against *P. Aeruginosa*, *E. coli*, *E. faecalis* and *S. aureus*. Major components of the extract are listed but no percentages or concentrations are indicated. Most of them are phenolics. [162]

Leaves 70% aqueous ethanolic extract was prepared and applied against *S. enterica* and *E. coli*, resulting moderate inhibition (MIC). [163]

Aerial parts methanolic extract had strong inhibition (MIC, inhibition zone) and antibiofilm against five bacterial strains, compared with two reference antibiotics. The extract major components were (%): 1-heptacosanol 38.41, 17-Pentatriacontene 19.78 and 6,9,12,15-docosatetraenoic acid, methyl ester 8.08%. [164]

Leaves were successively extracted with *n*-hexane, ethyl acetate, and methanol, and separately with acetone and water. Except ethyl acetate extract, other extracts were tested against *S. aureus*, *E. coli*, *P. aeruginosa*, *S. sonnei* and *P. vulgaris*. Results showed moderate activity compared with three other *Malva* species used in this study. [165]

Aerial parts were extracted with 50% aqueous ethanol, and extract was added to several food to test inhibition of two bacterial and two fungal species, that the foods were infected with. Results showed moderate activities (zone inhibition, MIC, respectively). [166]

Leaves aqueous and ethanolic extracts were prepared and had significant activity against herpes (SuHV-1) and bovine (BoHV-1) viruses. [167]

Leaves were extracted with ethanol and fractionized with *n*-hexane, chloroform and ethyl acetate. The remaining material was considered the aqueous fraction. This fraction had notable activity against HIV-1 BaL virus. [168]

Tea that was prepared from flowers of *M. sylvestris* and parts of other four plants, had very notable activity (such as cough stop after five days) on COVID-19 patients. [169]

***Micromeria fruticosa***

Leaf and stem extracts. See detailed description for his reference in *Arum palaestinum*. [31]

EO was produced by hydrodistillation (plant part/s not indicated) and had significant activity against *F. oxysporum*, *M. phaseolina*, *B. cinerea* and *E. turcicum*. [149]

Aerial parts were hydrodistilled to produce and EO and leaves were extracted with methanol. Both materials were tested against 14 bacterial and 3 fungi species, resulting moderate activity of the EO and no activity of the extract. Major component of the EO were (%): piperitenone 50.61, pulegone 29.19, isomenthone 3.92 and piperitone 3.12 (**Figure 23**). [170]

Aerial parts were extracted with 70% aqueous ethanol and extract was tested against four bacteria and two fungal species. Compared with two antibiotics, extract had weak to no activity. The major ingredients of this extracts were: chlorogenic acid, hesperetin, naringenin, quercetin and ellagic acid (**Figure 24**). [171]

Aerial parts (from several localities) EO was prepared ultrasound hydrodistillation and was tested against 13 bacterial and fungal species. Comparing with four antibiotics (azithromycin, levofloxacin, doxycycline and cefuroxime), EO had moderate activity. [172]

Pollen was extracted with 70% aqueous ethanol and this extract was applied against *E. coli*, *P. aeruginosa*, *S. aureus* and *S. faecalis*. Compared with extracts of two other plants (*Achillea fragrantissima* and *Phoenix dactylifera*), this extract had significant and higher activity. [173]

Defatted (petroleum ether) leaves and stems were extracted with methanol, and resulting extract was fractionized with water, chloroform and *n*-butanol and *n*-hexane. Extracts were tested against nine bacterial species, and apart from *n*-hexane fraction, all other extracts had moderate activity, compared with reference antibiotics of gentamycin. [174]

Leaves, stems, flowers and roots were separately and successively extracted with *n*-hexane, ethanol and water (12 extracts). Aqueous, ethanolic and *n*-hexane extracts were tested against three bacterial and a fungal species, resulting ethanolic extract as most active and *n*-hexane extract was the weakest. Major components of the combined extracts were: menthone, menthol, pulegone and oleamide (**Figure 25**). [175]

***Salvia fruticosa***

Leaf and stem extracts. See detailed description for his reference in *Arum palaestinum*. [31]

EO was produced by hydrodistillation (plant part/s not indicated) and had significant activity against *F. oxysporum*, *M. phaseolina*, *B. cinerea* and *E. turcicum*. [149]

Leaves were hydrodistilled and an EO was obtained and tested against two bacteria and two fungi species. Some of the pure compounds isolated from this EO were also tested against the same microorganisms. In average, EO activity was higher than pure components. Eucalyptol, β-caryophyllene and camphor (**Figure 26**) were the major ingredients of this EO. [150]

Flowers aqueous extract was tested against *S. aureus*, *C. albicans*, *E. coli*, *B. subtilis* and *P. Aeruginosa*, and found inactive. [176]

EO of aerial parts was produced by hydrodistillation and tested against 17 bacteria species, resulting very strong activity (MIC). The major ingredients of this EO were (%, **Figure 26**): eucalyptole 15.7, α-thujone 20.1, camphor 12.6, β-caryophyllene 11.8, α-humulene 7.52 and viridiflorol 6.34. [177]

Aerial parts were hydrodistilled affording EO that was tested against 10 bacterial species, resulting high activity (inhibition zone). The chemical composition of this EO similar to the previous report. [178]

Leaves and stems were extracted with 90% aqueous ethanol and extract was tested against four bacterial and fungal species, resulting significant activity. [179]

Aerial parts EO was prepared by hydrodistillation and was tested against eight bacterial and eight fungal species. The test included activity of some natural products isolated from EO. Results (MIC) showed that these compounds were very highly active, and they exceeded the EO. The major constituents of this EO were (%): eucalyptol 49.34, camphor 7.53,
β-pinene 7.38, myrcene 7.38 and α-pinene 5.15. [180]

Leaves were extracted with 80% aqueous ethanol and the extract was tested against *S. aureus*. Comparing with two commonly used antibiotics (vancomycin and oxacillin), extract had strong activity (MIC = 0.25-0.5 mg/mL). [181]

EO (plant part/s not indicated) was prepared by hydrodistillation, and tested against *S. aureus, S. epidermidis, E. faecalis, B. cereus*, *E. coli* and *C. albicans*. The EO was tested separately and as 2% of mouthwash formulation, that contained EOs of other plants. Compared with other EOs, it had moderate activity. [182]

Aerial parts were separately extracted with water and ethanol, and both extracts were tested against four bacterial strains, resulting the same high activity (MIC). [183]

Leaves were extracted with 70% aqueous ethanol and extract was fractionized with other solvents, but fractions were not tested for antibacterial activity. The crude extract was tested separately or in combinations with olive and balsam oil, against five bacteria species. Results showed significant activities with moderate synergistic effect. [184]

Aerial parts were hydrodistilled to produce EO that was used to prepare three mouthwash formulations, in various concentrations, with EOs of *Elettaria cardamomum* and *Lavandula angustifolia*. Each one of the three EOs and each one of the formulations was tested against four bacteria species showing weak to moderate inhibition. [185]

Aerial parts from three different location were hydrodistilled to obtain EOs, that were applied against adhesion of *Klebsiella pneumonia*. Slight differences were found in the activities (significant) or the compositions of these EOs, where the major component was eucalyptol. [186]

Leaves EO was obtained by hydrodistillation and was tested against *K. pneumoniae*, *E. coli*, *S. aureus*, *B. subtilis*, *C. albicans* and *C. parapsilosis*. Compared with the EO of *Salvia aramiensis*, both species showed strong inhibition but *S. fruticosa* had stronger effect. Chemical compositions were almost the same, as shown in figure 26. [187]

Aerial parts EO was produced by steam distillation and tested against seven bacterial strains. The tests were performed separately and in combination with two antibiotics: amikacin and ciprofloxacin. When the EO was tested separately, comparing to the EO of *Salvia ringens*, both materials had almost the same activity, and both were very weak compared to antibiotics. When tested in combination with each one of the antibiotics, clear synergism was detected. The major compounds in this EO were (%): β-thujone 54.2, γ-cadinene 9.2 and β-caryophyllene 5.1 (**Figure 26**). [188]

Seeds EO was prepared by hydrodistillation and fixed oil (FO) was prepared by extraction with *n*-hexane. Both materials were tested against 7 bacteria and 3 fungi species, resulting weak activities. FO contained mainly fatty acids and alkanes, while the major components of EO were (%): palmitic acid 5.27, sclareol oxide 14.5, di-*n*-butylphthalate 9.21, geranyl linalool 9.11 and β- cadinene 16.9 (**Figure 27**). [189]

Aerial parts were separately extracted with cyclohexane (CHX), ethyl acetate (EA), dichloromethane (DCM) and methanol (MeOH). Extracts were applied against seven bacteria species, resulting moderate activity, where CHX extract was most active and EA was least active. A total of 123 compounds were identified in these extracts with six compounds that were isolated for the first time from this plant (**Figure 28**). [190]

Ethanolic extract of aerial parts was prepared and tested against 42 bacterial and fungal species, in two doses: 50 and 200 μL. Results showed moderate inhibition zones or no activity at all, contrary to many antibiotics that wee used as positive control. The major constituents of this extract were (%): camphor 20.27, borneol 9.59, β-caryophyllene 8.11 and lupeol acetate 6.28 (**Figure 29**). [191]

Aerial parts were extracted in two procedures: successively with DCM, EA and methanol; and separately with ethanol and water. The aqueous and ethanolic extracts were tested against 11 bacteria (reference: streptomycin) and 7 fungi species (reference: ketoconazole). Compared with reference, weak activities were recorded. [192]

Leaves EO was produced by hydrodistillation and tested against *M. Furfur*, *T. Rubrum* and *T. beigelii* fungi. Some major ingredients of this EO were tested for the same activity. Results showed that EO had strong activity, slightly more than its single components. Major components of this EO were β-caryophyllene and camphor. [193]

Aerial parts EO was obtained by hydrodistillation and analyzed for its composition. This EO and some of its major components were tested against 5 fungal species showing high potency. The major components were as reported in previous works in this table. [194]

Aerial parts EO (hydrodistillation) and some of its major components were tested against 8 bacterial strains, where components had higher activity. EO and components had notable activity against against herpes simplex virus 1. The major ingredients of this EO were as indicated above. [195]

Leaves EOs of three plants (*Coridothymus capitatus*, *Origanum dictamnus* and *Salvia fruticosa*) were produced by hydrodistillation, and applied in several combinations against viral strains that infect respiratory system. Results ranged from none to high activity. [196]

***Sinapis alba***

Leaves extracts. See detailed description for his reference in *Arum palaestinum*. [31]

Seeds cold press EO was produced and tested against 18 bacteria species and found inactive. Major components of this EO were (%): A, 48.7 and B, 42.08 (**Figure 16**). [115]

Seeds methanolic extract was active against *E. coli*, *S. enteritidis* and *S. aureus*, but authors did not provide numerical values. Two of the major components of this extract, 4-hydroxy-3-nitrophenylacetic and sinapic Acids (**Figure 30**), were also tested and found highly active (MIC). [197]

Seeds were grinded to enable the enzymatic hydrolysis of sinalbin to produce 4-hydroxybenzyl isothiocayante (4HBITC, **Figure 31**). This compound was extracted with super critical carbon-dioxide and stabilized to obtain an active, commercial antibacterial formulation. It was added to several foods tested and found active against 7 bacteria species that usually infect these foods. [198]

Seeds were extracted with super-critical $CO_2$ to produce an EO, which was analyzed yielding phenethyl isothiocyanate, $C_6H_5CH_2CH_2NCS$ (PEITC, major ingredient) and some of its derivatives. Compared with tetracycline, the EO and PEITC had strong activity against *P. asaccharolytica*, *P. gingivalis*, *S. mutans* and *S. sobrinus*. The derivatives that had high activity were: benzyl isothiocyanate $C_6H_5CH_2NCS$ and benzoyl isothiocyanate $C_6H_5CONCS$ . [199]

Seeds EO was produced by hydrodistillation and was active against *E*. coli, *K. pneumoniae*, *P. vulgaris* and *S. epidermidis*, but not against *B. cereus*, *E. faecalis* and *S. marcescens*. The major components of this EO were (%): benzyl nitrile $C_6H_5CH_2CN$ 12.05, thymol (figure 20) 7.20, benzyl isothiocyanate $C_6H_5CH_2NCS$ 64.89 and 2-phyenyl isothiocyanate $C_6H_5CH_2CH_2NCS$ 6.5. [200]

Commercial roots extract was active against *Xanthomonas perforans*, a pathogen that causes damages to tomato plants (*Solanum lycopersicum*). [201]

Seeds *n*-hexane extract had weak activity against three bacteria species, and significant activity against two fungi species. [202]

Seeds were extracted by steam distillation to obtain an EO, which was tested against nine bacterial strains, in two procedures: EO separately or encapsulated in genipin-strengthened capsules. The second activity was referred to allyl isothiocyanate (AITC), the major component (71.06%) of the EO. The capsules had stronger effect. The other major component was cyclopropyl isothiocyante (12.16%). [203]

Seeds aqueous extract had no activity (three concentrations) against *B. cereus*, *L. monocytogenes, E. coli* and *S. typhimurium*. In this study, it was also reported that *F. vulgare* leaves aqueous extract had no activity in the same procedure. [204]

Fruits were hydrodistilled to afford an EO, and the fruits EO of Brassica juncea was obtained and studied, comparatively. Both EOs and oleoresins obtained from the fruits of the two plants, were tested against five fungal and four bacterial species, showing moderate activities. The major component of *S. alba* EO was 1-butene-4-isothiocyanate. [205]

Fresh leaves and fresh seeds were separately extracted (ultrasound-assisted) with aqueous ethanol in several ratios, but only the 80% extract was tested against five bacterial and a fungal species, showing moderate results. As salad preservative, extract had significant activity. [206]

70% Aqueous ethanol was used to prepare an extraction (plant part not indicated), and it was tested against *C. albicans*, showing moderate activity. [207]

Roots, stems, leaves and flowers, were separately and successively extracted with petroleum ether, ethanol and DCM. All (12) extracts were tested against *E. coli*, *S. aureus* and *P. aeruginosa*, showing either weak or no activity. [208]
Leaves were separately extracted with *n*-hexane, ethanol and water, and the three extracts were applied against *E. Coli*, *S. aureus* and *C. albicans*. Results showed moderate to high activity, where ethanolic extract was most active. [209]
Commercial EO containing 12% 4HBITC was tested separately or in combination with thymol or carvacrol, against *Salmonella* ssp. Results revealed moderate activity of the EO alone, and moderate synergistic when applied in combination with thymol or carvacrol. Results were dose dependent. [210]
Seeds were extracted with *n*-hexane and ethanol, and each extract was tested against *B. subtilis*, *P. aeruginosa* and *C. albicans*, in three different concentrations. Compared with controls (ciprofloxacin, fluconazole and erythromycin), results ranged from no to moderate activity. [211]
Commercial EO was tested separately and in combination with carvacrol against *Salmonella* ssp. in refrigerated, ground chicken meat, in variety of concentrations of each material. Moderate effect wad detected. [212]
Leaves, flowers and fruits were separately extracted with chloroform and 70% aqueous methanol, but only the methanolic extract was tested against *S. aureus*, *E. coli* and *P. aeruginosa*. Activity ranged from no to weak activity, compared to three references. [213]
Seeds aqueous extract was used to prepare a hydrogel that was tested against *S. aureus*, *C. albicans*, *E. faecalis* and *S. mutants*, resulting moderate activities. [214]
Seed powder solution (10%) in DMSO was tested against HSV-1 and HAV-7 viruses, resulting low (23%) to moderate (54.3%), virucidal effect, respectively. [215]

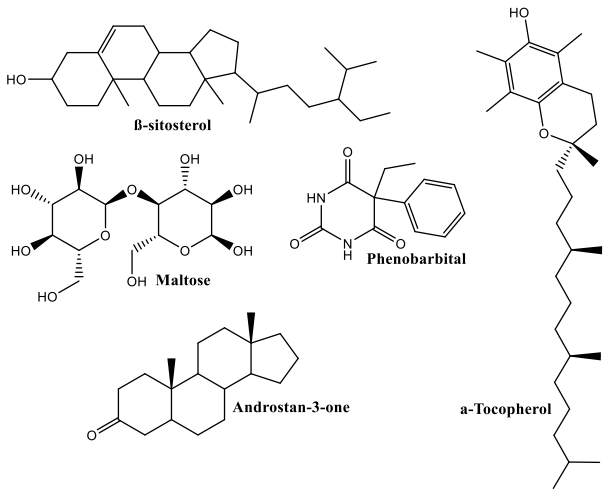


**Figure 3: Antiviral agents from *A. palaestinum* [36]**

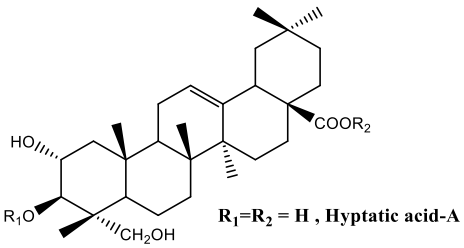


**Figure 4: General structure of saponins isolated from *C. persicum* tuber [44]**

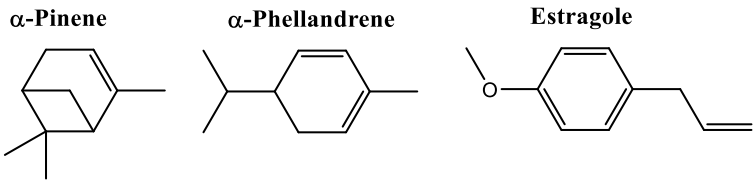


**Figure 5: Major components of aerial parts EO of *F. vulgare* [45]**

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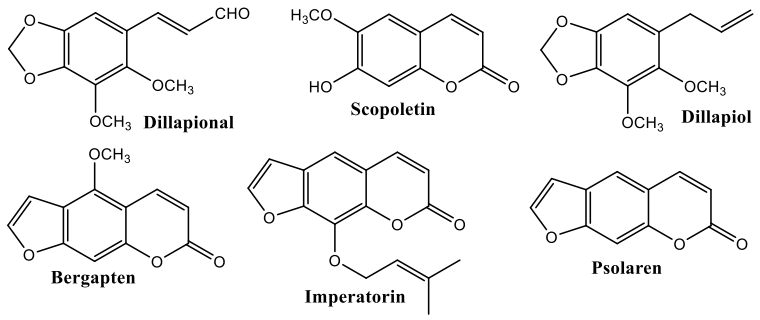


**Figure 6: Antibacterial NPs from the stem methanolic extract of *F. vulgare* [46]**

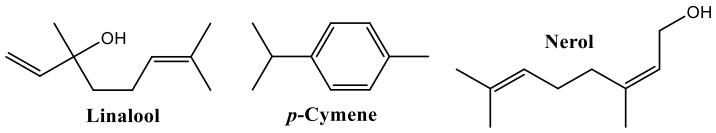


**Figure 7: Major components of fruits EO of *F. vulgare* [47]**

*cis*,*cis*-$CH_3(CH_2)_4CH{=}CHCH_2CH{=}CH(CH_2)_7COOH$ **Linoleic acid**

$CH_3(CH_2)_{14}COOH$ **Palmitic acid** *cis*-$CH_3(CH_2)_7CH{=}CH(CH_2)_7COOH$ **Oleic acid**

**Figure 8: Fatty acids from methanolic and ethanolic extracts of *F. vulgare* [50]**

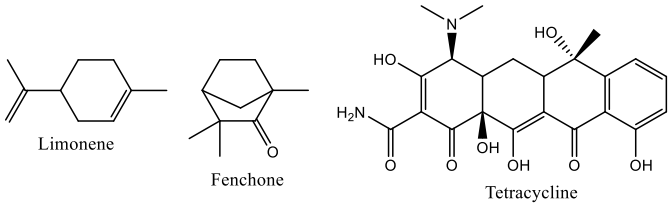


**Figure 9: Major components of seeds EO of *F. vulgare* and tetracycline [53]**

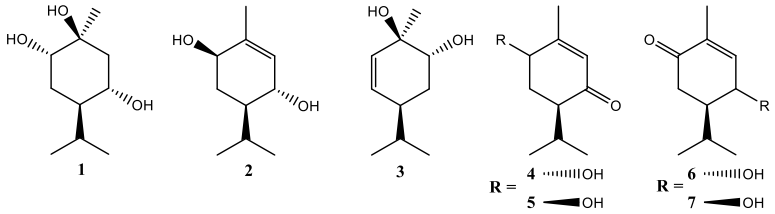


**Figure 10: NPs isolated for the first time from DCM-Methanol extract of *F. vulgare* [57]**

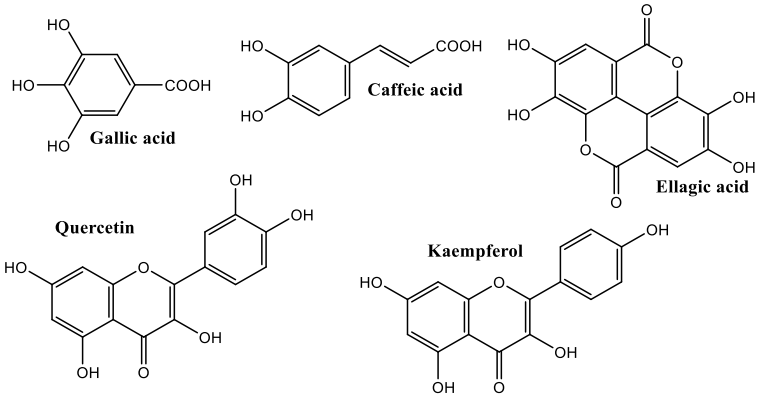


**Figure 11: Major phenolics from the 80% aqueous methanolic extract of *F. vulgare* [62]**

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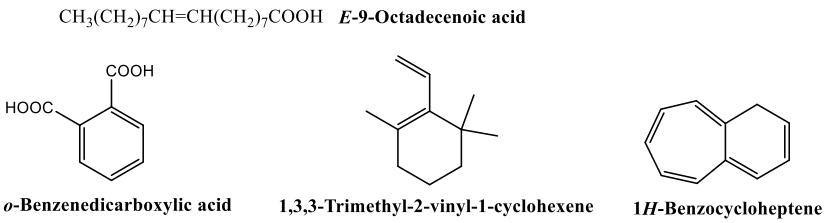



**Figure 12: Major components of EO of *F. vulgare* [67]**

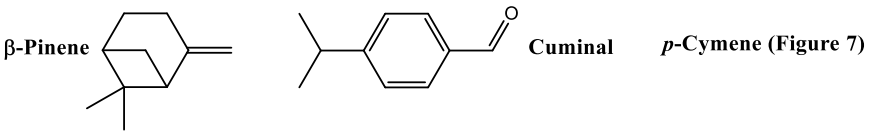



**Figure 13: Major components of leaves EO of *F. vulgare* [94]**

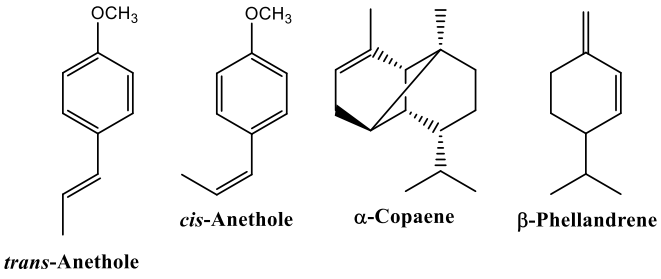



**Figure 14: Major components of fresh leaves EO of *F. vulgare* [104]**

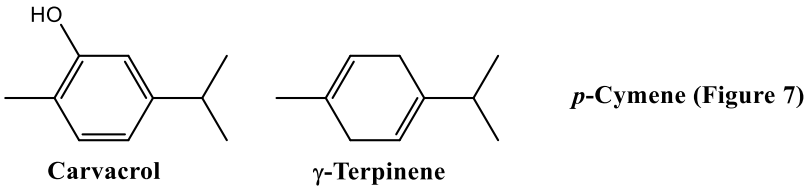
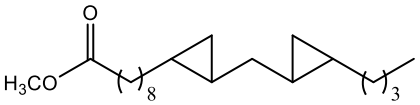
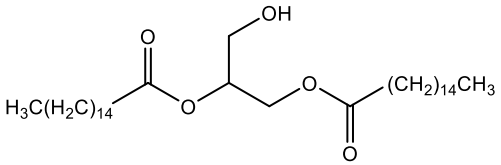



**Figure 15: Major components of leaves EO of *M. syriaca* [113]**




**A, Cyclopropanenonanoic acid, 2-[(2-butylcyclopropyl) methyl]-, methyl ester**




**B, Hexadecanoic acid, 1-(hydroxymethyl)-1,2- ethanediyl ester**

**Figure 16: Major components of leaves cold press EO of *S. alba* [115]**

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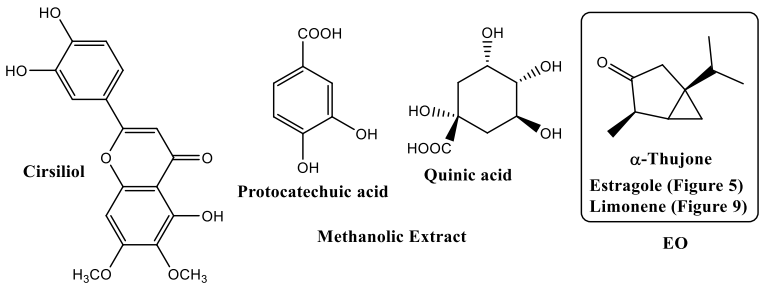


**Figure 17: Major components of seeds EO and methanolic extract of *F. vulgare* [118]**

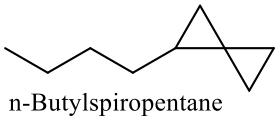


**Figure 18: *n*-Butylspiropentane from methanolic extract of *G. tournefortii* [125]**

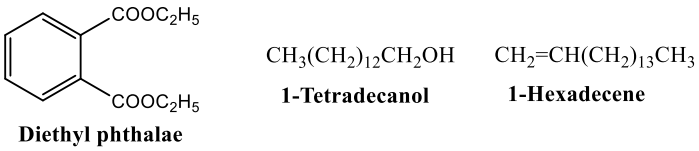


**Figure 19: Major compounds in seeds aqueous extract of *G. tournefortii* [130]**

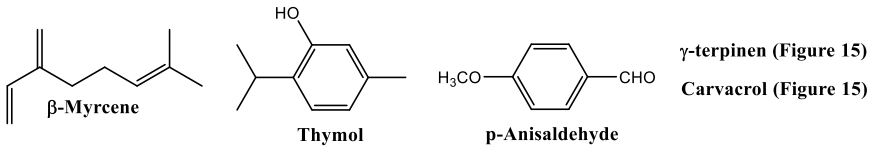


**Figure 20: Major components of leaves and stems EO of *M. syriaca* [141]**


**Figure 21: Synthetic antibacterial agents used as control for activity *M. syriaca* EO [146]**

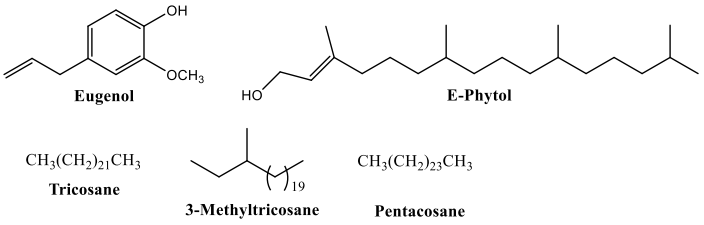


**Figure 22: Major compounds in flowers and leaves of *M. sylvestris* EOs [155]**

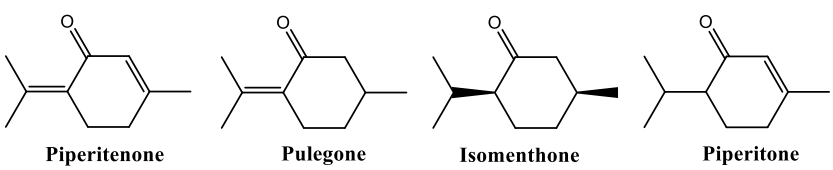


**Figure 23: Major components of leaves EO of *M. fruticosa* [170]**

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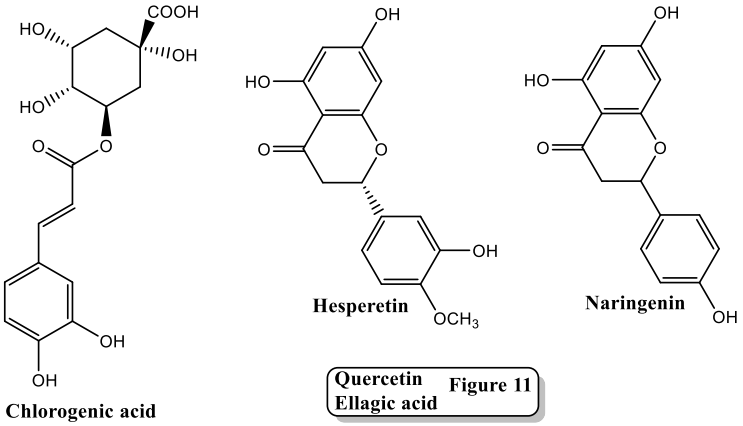


**Figure 24: Major phenolics of aerial parts 70% aqueous ethanol extract of *M. fruticosa* [171]**

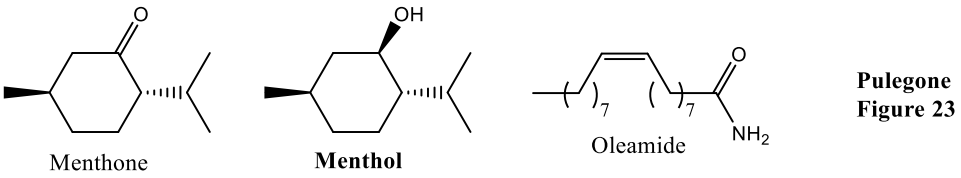


**Figure 25: Major compounds in combined (parts and solvents) extracts of *M. fruticosa* [175]**

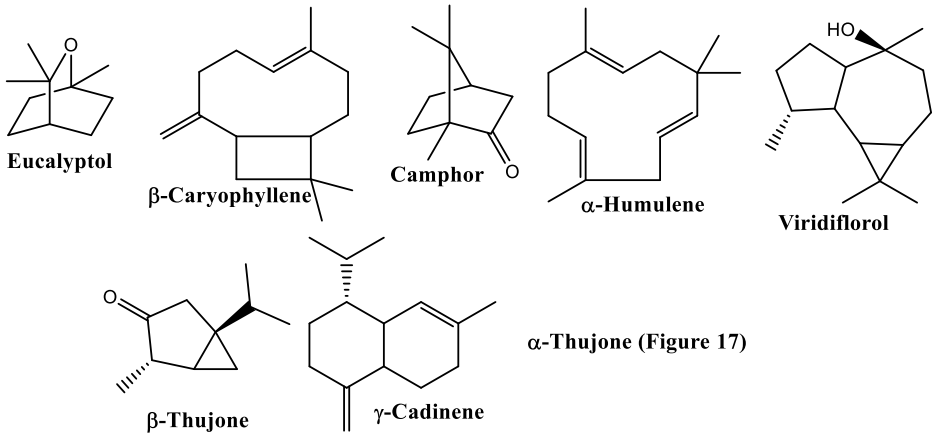


**Figure 26: Major ingredients of *S. fruticosa* aerial parts EO [150,177,188]**

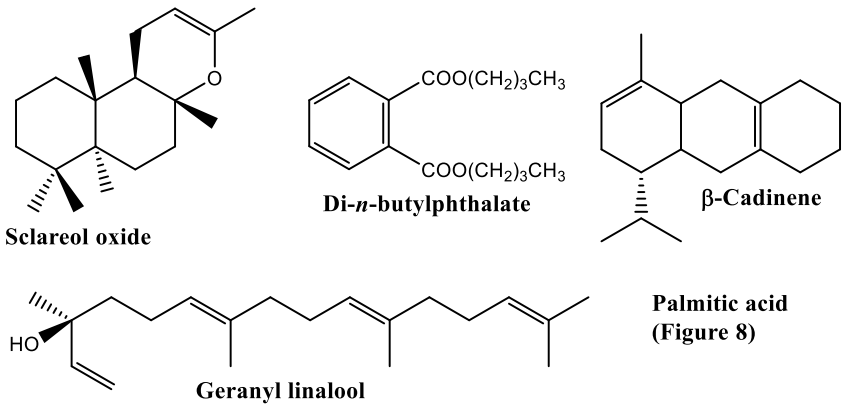


**Figure 27: Major components of *S. fruticosa* seeds EO [189]**

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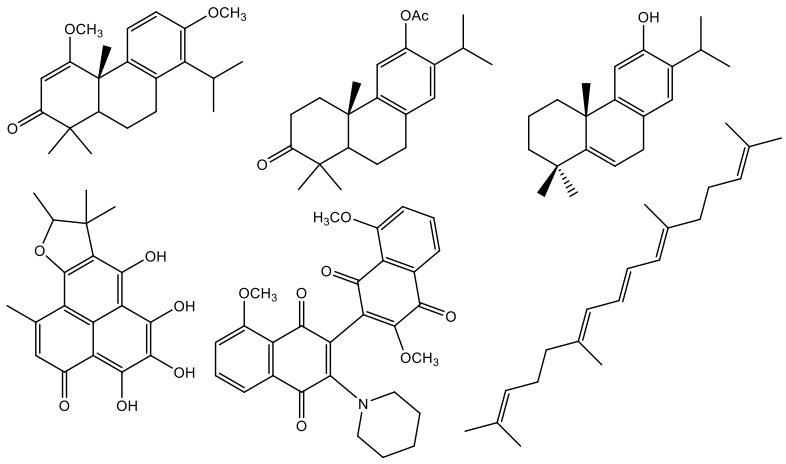

**Figure 28: Components isolated for the first time from *S. fruticosa* aerial parts extracts [190]**

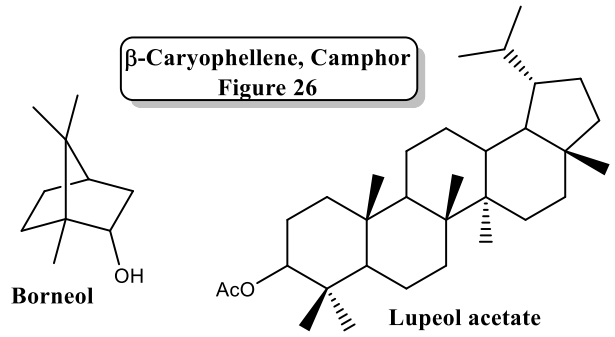


**Figure 29: Major ingredients of *S. fruticosa* aerial parts ethanolic extract [191]**

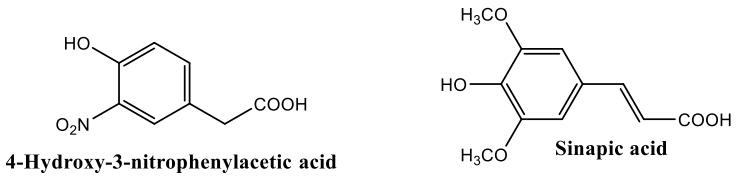


**Figure 30: Antibacterial compounds from *S. alba* seeds methanolic extract [197]**

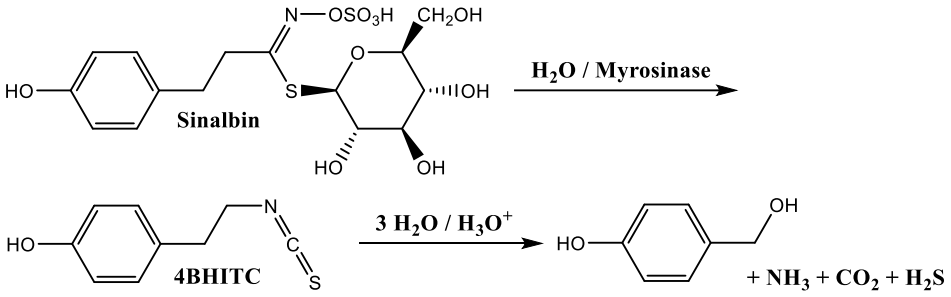


**Figure 31: 4-Hydroxybenzyl isothiocayante (4HBITC) production from enzymatic hydrolysis of sinalbin in *S. alba* seeds EO and its acidic decomposition [198]**

## DISCUSSION

The eruptions of microbial and viral diseases were and still are serious threats to human health along history, and the lats outburst of COVID-19 is an excellent and recent example. There is almost a consensus among researchers and health authorities that humanity on one side, and harmful

microorganisms and viruses on the other side, are in life-or-death combat and race [216]. Antimicrobial resistance to drugs is the major cause of this threat, but drugs (mainly antibiotics) overuse is another important reason [217]. This excessive use is considered by many scholars as one of the major causes of antibiotics resistance [218]. Another important reason of antibiotics resistance is the disposal of untreated antibiotics, like all untreated drugs, to the environment [219].

Disposal of untreated antibiotics, among other drugs, to the environment is becoming an increasing issue of concern due to its adverse consequences [220]. Environmental pollution resulting from untreated antibiotics and their degradation products, has an effect on almost all parts of the environment, especially life forms [221]. In this context, it is important to mention that some of these antibiotics (such as fluoroquinolones: ciprofloxacin and norfloxacin. **Figure 32**) are relatively stable and degrade slowly.

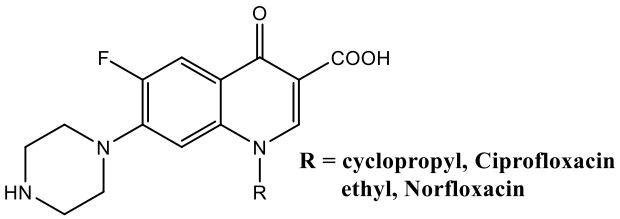


**Figure 32: Stable, slowly degradable fluoroquinolone antibiotics [221]**

Once this pollution caused, the efforts and methods to remove antibiotics from the environment are enormous and costly. For example, A. Huang and colleagues listed more than a dozen methods, chemical, biological and mechanical [222]. M. Segaseta de Ilurdoz and colleagues focused on removal of antibiotics contaminations from aquatic environments, and they presented some efficient but expensive methods, such as use of $H_2O_2$ or $O_3$ in combination with UV-radiation [223]. And in a recent example, H. Shi and colleagues published their results of treating antibiotics pollutions with composite material $Ag/PW_{12}/TiO_2$ and UV radiation, and proposed possible mechanism of degradation [224]. All these considerations lead to the vital need of developing plant-based antimicrobial and antiviral drugs.

*Arum palaestinum* was not frequently published for antimicrobial or antiviral activity, as we saw in **Table 1** [31-36]. L. Abu-Qatouseh and his colleagues have tested the polyphenolic extracts of 8 plants and reported that *A. palaestinum* had the lowest content [225]. They tested these extracts against *Propionibacterium acnes* and found it most active (lowest MIC and highest inhibition zone). According to this report, *Malva sylvestris* had medium phenolics content and very low antibacterial activity. These results raise a few concerns. First, it is reported in the same publication that *Eucalyptus globulus* (leaves) had the highest total phenolic content and the highest antibacterial activity. Second, this result is consistent with the very well-known role of flavonoids as active antibacterial agents [226]. Third, the report of L. Abu-Qatouseh and his colleagues contradicts the finding K.A. Shadid and his colleagues [165], in total phenolic content of leaves methanolic extract of *M. sylvestris* (166 and 21 mg GAE/g extract, respectively); and in antibacterial activity (very low vs. significant), keeping in mind that tests were done against different bacterial species. Fourth, the phenolic content of *E. globulus* leaves methanolic (80%) extract is 21 mg GAE/g extract, while S. Dezsi and his colleagues reported 238 mg GAE/g extract [227], and V. Pereira and her colleagues reported 63 mg GAE/g extract [228].

The number of publications of antimicrobial and antiviral activities of *Cichorium pumilum* is also relatively low in **Table 1**: seven [31,37-42]. Interestingly, leaves of this plant are naturally good habitat for microbial biofilm growing, which enables culturing and isolation of microorganisms [229,230]. As for antimicrobial activity.

The use of nanoparticles as antimicrobial agents is widespread [231], and we have cited studies in **Table 1**: *F. vulgare* EO in combination with AgNPs [106] and *M. sylvestris* extracts nanofibers [162]. But the vast majority of antimicrobial nanoparticles reviewed by D. Susanti and her colleagues [231], are produced using plant extracts, mostly as reducing agents, and the final nanoparticles do not contain plant materials. The D-P were used for these preparations, and a summary of selected reports are presented in **Table 2**.

**Table 2: Antimicrobial Nanoparticles Prepared Using D-P-derived materials**

| Plant/Material | Nanoparticle | Microorganisms/Reference |
|---|---|---|
| *C. pumilum*, leaves aqueous extract | Ag | *A. aflatoxiformans*, *A. ochraceus* [232] |
| *F. vulgare*, seeds aqueous extract | Ag | *S. aureus*, *E. coli*, *P. aeruginosa* [233] |
| *F. vulgare*, seeds aqueous extract | ZnO | *S. aureus*, *E. coli*, *Y. enterocolitica*, *B. cereus* [234] |
| *G. tournefortii*, aerial parts aqueous extract | Ag | *S. aureus*, *B. cereus*, *S. typhimurium*, *E. coli* [235] |
| *G. tournefortii*, fresh leaves aqueous extract | Ag | *S. aureus*, *E. coli*, *C. albicans* [236] |
| *G. tournefortii*, fresh leaves aqueous extract (GT) | Ag@GT AgNPs contain GT | *C. krusei*, *C. guilliermondii*, *C. glabrata*, *C. albicans*, *P. aeruginosa*, *S. aureus*, *S. typhimurium*, *E. coli*, *S. pneumoniae*, *B. subtilis* [237] |
| *G. tournefortii*, fresh leaves aqueous extract (GT) | Au@GT AuNPs contain GT | *C. albicans*, *C. glabrata*, *C. krusei*, *C. guilliermondii*, *P. aeruginosa*, *E. coli*, *B. subtilis*, *S. aureus*, *S. typhimurium*, *S. pneumonia* [238] |
| *G. tournefortii*, fresh leaves aqueous extract | Au | *S. aureus*, *E. coli*, *B. subtilis*, *C. albicans* [239] |
| *M. sylvestris*, flowers aqueous extract | Ag | *E. coli*, *S. aureus*, *S. typhimurium*, *B. subtilis* [240] |
| *M. sylvestris*, flowers aqueous extract | Ag | *E. coli*, *S. aureus* [241] |
| *M. sylvestris*, unknown part/s aqueous extract | $Fe_3O_4$ | *S. aureus*, *K. pneumoniae*, *P. aeruginosa*, *Corynebacterium* [242] |

One of the most noticeable findings that emerges from carefully reading the data in **Table 1**, are the differences between results that were reported about the same plant. For example, comparing the chemical compositions of aerial parts EOs of *F. vulgare*, obtained by the same method of hydrodistillation and from the same plant parts (aerial), shows notable differences between the reports of G. Ruberto and his colleagues [45] vs. M. Araque and her colleagues [49] and M.G. Miguel and her colleagues [54]. In the first report, *trans*-anethole (**Figure 14**) is a minor component while in two other studies it's a major component.

It is important to mention that the study of M.G. Miguel and her colleagues [54] has an additional value: it presents the chemical compositions of *F. vulgare* EOs depending on several variables: time of extraction, plant part, locality (9 different countries), and most important, method of extraction (steam distillation, hydrodistillation, *n*-pentane extraction and *n*-hexane extraction).

Such differences can be understood even when very close extracting solvents are used, as in the cases of M. Gulfraz and colleagues [50], compared with S. Soylu and colleagues [53]. These groups used the same parts of *F. vulgare*, but different extractors: methanol and ethanol, respectively, resulting notable differences in activities and chemical compositions.

Another inconsistency of chemical compositions can be found in the report of R.K. Upadhyay [67], compared with many other reports such as W-R. Diao and his colleagues [64]. The major constituents found by R.K. Upadhyay were 9-octadecenoic acid, *o*-benzenedicarboxylic acid, 1,3,3-trimethyl-2-vinyl-1-cyclohexene, 1H-benzocycloheptene; while many other groups found mainly oxygenated monoterpenes such as *trans*-anethole and estragole. Needless to say, that in all these studies same plant part (seeds) was used and same method of production (hydrodistillation).

The work of B. Ayoubi and P. Baradari [126], is an example of inaccurate and very misleading scientific reporting. Authors use the common name of coriander for *Gundelia tournefortii*, which is completely wrong. The common name of coriander belongs to the plant *Coriandrum sativum*, and the common name of *G. tournefortii*, which is tumble thistle. *C. sativum* is a member of the Apiaceae family while *G. tournefortii*, is belongs to the Asteraceae family. And more important, as far as our extensive literature search could reach, we found no scientific report of the presented compounds by B. Ayoubi and P. Baradari,

especially *E*-2-dodecenal or (2*E*)-dodecanal, in *G. tournefortii*. Authors cite I. Kobo and his colleagues [243] for the presence of this and other aldehydes in the "fresh leaves of *Gundelia* genius". But reading the report of I. Kobo *et al*. reveals the fact that they clearly indicate that coriander is *C. sativum*, and it contains *E*-2-dodecenal.

A.N. El Gendy and his colleagues studied the chemical composition and antimicrobial activity of essential oil of wild and cultivated *O. s*yriacum plants grown in Sinai, Egypt [139]. Their findings are quite interesting, and considering the cultivation environment of the plants in the Sinai desert, some of the inconsistencies in **Table 1** can be understood. This means, that the EO or the plant extract is the final product, and its composition and activity depend on many variables. Methods of extraction, solvents, temperature etc., are easily controlled variables. But climate, soil, irrigation and rain, locality, seasonality, ripening stage, cultivation and farming methods (if not wild); are also very important factors.

A.S. Abdelbaky and his colleagues from Egypt as well (like A.N. El Gendy and his colleagues), found clear influence of fertilizers use and types on the yield, chemical composition and activities of EO of *F. vulgare* [244]. M. Abdellaoui and his colleagues found clear differences between the chemical compositions of cultivated and wild EOs of *F. vulgare* (%): estragole 60.01 and *E*-anethole 22.15 in the cultivated plants, while 35.33 and 52.27 in the wild plants [245]. S. Zein and her colleagues from Lebanon tested, among many variables, the fatty acids composition of EOs of *M. syriaca*, wild and cultivated, before and after flowering, and found significant differences [246]. For example, palmitic acid (*n*-$C_{15}H_{31}COOH$) is 14.2% of the EO of wild plants before flowering and 15.12% in cultivated plants, and 5.18% and 3.31%, after flowering, respectively. S. Abu-Lafi and his colleagues from Palestine and Israel found notable differences in the concentrations of terpenoid compounds in the EOs of *M. syriaca* harvested in nine different locations [247]. For example, the concentrations of *p*-cymene were (%): 15.20, 15.83, 17.24, 18.40, 18.98, 19.13, 24.37, 23.87, 26.53. A year earlier, the same research group investigated the seasonality influence on the leaves EO of *M. syriaca* variables: yield and the ratio of thymol to carvacrol concentrations [248]. When EO was produced by steam distillation, the ratio of thymol:carvacrol in February 2004 in a certain location was 1:1.78, while in May it was 1:5.29. C. Dincer and his colleagues from Turkey investigated the phenolic content of 80% aqueous methanolic extract of leaves, as well as yield of EOs, for cultivated and wild plants of *S. fruticosa* [249]. They reported that for wild plants, the total phenolic content was 42.25 mg of gallic acid equivalent (GAE) per 1 g of dry plant matter, and the EO content was 1.82 mL. For cultivated plants the values were 45.21 and 1.48, respectively. In addition, if the dry leaves powder is properly stored, the reported values did not significantly change, but the antioxidant activities were clearly different.

Likewise, storage of dry or fresh plant matter or its products that is a handling variable, the drying process has also clear influence on these products and their activities. M.H. Alqarni and his colleagues from Saudi Arabia and Egypt found notable effect of the drying conditions of aerial parts of *M. fruticosa* on the yield, composition and antimicrobial activity of the EO that was obtained from these parts [250]. Tests were done for fresh parts, freeze-dried and shade-dried, and the results are presenter in **Table 3**.

**Table 3: EO Content, Major Components and Antimicrobial Activity of Aerial Parts of *M. fruticosa* Subjected to Different Drying Conditions [250]**

| Plant Matter | EO content [a] | Two Major components [a] | MIC (µg/mL) [b] |
|---|---|---|---|
| Fresh | 0.28 | pulegone 23.70, *l*-menthone 19.54 | 14.35 |
| Freeze-dried | 0.27 | pulegone 22.14, *l*-menthone 17.47 | 14.35 |
| Shade-dried | 0.07 | *l*-menthone 20.40, pulegone 13.79 | 14.35 |

a) % b) Average against: *E. coli*, *P. Aeruginosa*, *S. aureus*, *B. cereus* and *C. Albicans*

It is important to mention that even though the average MIC values are identical, and the individual value for each microorganism is also identical (12.5, 9.125, 18.25, 18.25 and 9.125, respectively), authors concluded that "oil samples showed stronger activity against *P. aeruginosa* and *C. albicans*".

The last example of the influence of handling plant matter conditions was demonstrated by M. Yousefi and colleagues from Iran [251]. They found out that the heating method (steam, hot air, hot water), temperature, heating duration and cooling ("deheating") duration; all these have significant effects on myrosinase content and antibacterial (*B. subtilis*, *B. coagulans*, *S. cerevisiae* and *Z. rouxi*) activity of *S. alba* seed powder.

The use of *S. alba* seed powder as food preservative was already mentioned in **Table 1**: the work of J.J. Li and colleagues [198]. A. Hosseinvand and A. Sorkhinejad used this powder as ground beef preservative since it had protection activity against *S. aureus* and *E. coli* [252]. J.J. Li and colleagues as well as several other studies, link the antibacterial activity with 4HBITC that is produced in the enzymatic hydrolysis of sinalbin [198, **Figure 31**]. B.G. Shofran and colleagues link this activity to sinigrin and its hydrolysis products, that are shown in **Figure 33** [253]. It is important to indicate that the concentration of sinigrin is much higher than the concentration of sinalbin in seeds of *S. alba* [254].

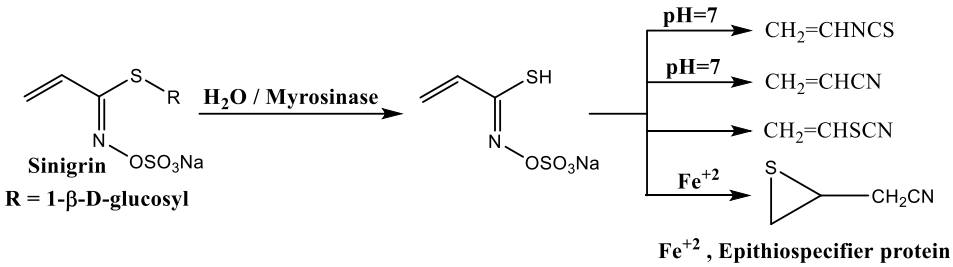


**Figure 33: Enzymatic hydrolysis of sinigrin in *S. alba* seeds powder and its decomposition under different biological conditions [253]**

To conclude the discussion about *S. alba*, we will add two important reports. First, U. Timmerer and her colleagues found out that antibiotics such as enrofloxacin have toxic effect on the germination of *S. alba* roots [255]. This result emphasizes the importance of preventing disposal of antibiotics to the environment. Second, in recent years there were some concerns about possible toxicity of *S. alba* seeds and its food product, mustard, to humans and animals. These concerns were issued mainly due to the presence of bisphenols (**Figure 34**) in the seeds and in mustard [256,257].

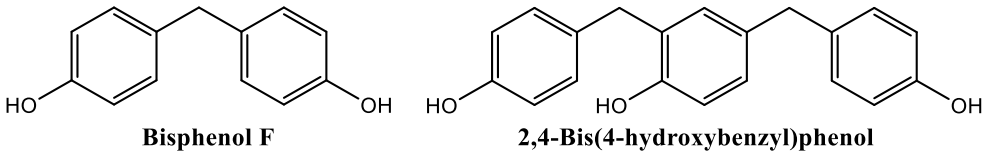


**Figure 34:** Bisphenols in *S. alba* seeds [257]

But recent toxicology studies showed that these compounds are present in safe amounts in average mustard consumption, and *in vivo* (mice) studies revealed no toxic effects of seeds consumption [258].

The mentioned above results bring our discussion, once more, to the importance of accuracy in scientific reporting. For example, the chemical composition of the methanolic extract of *M. sylvestris* leaves reported by S. Dowek and her colleagues [158], is quite confusing. In the results section of this paper, under the title of "GC-MS analysis", authors reported that the major volatile components of the extract are tetradecenol, oxirane, octadecatrienoic acid and phytol. No concentrations or percentages were indicated, but authors direct readers to figure 1, where they presented a chromatogram. Interestingly, these compounds are not listed in table 3 (in the article), where authors presented the "major compounds" in the extract. In addition, it is not obvious to detect oxirane (ethylene oxide) with such high concentration in any plant extract. As for tertadecenol, the stereochemistry of the double bond and the position of the hydroxyl group are not indicated, and this means that the detected compound can be one of many isomers. The same considerations can be applied to the reported octadecatrienoic acid, which in summary, makes this chemical composition report partially useful.

The last part of this discussion will focus on pure or single antibacterial compounds, and we will take D-limonene as representing example. The majority of drugs that were developed from plants, started by using an extract or EO, then identifying the active molecule/s ("hit") and then using it or prepare some more active chemical modifications. Limonene was mentioned in **Table 1** as one of the major components of *F. vulgare* [52,53,72,73,92,93,99,103,118] and shown in **Figure 9**.

Among several reports of the antimicrobial activities of limonene, it was reported to have strong activity against the fungus *Candida parapsilosis*, an aggressive and strong inflammation-inducer fungi is

usually treated with fluconazole (**Figure 35**) [259]. D-Limonene is also powerful antibacterial against *Listeria monocytogenes*, one of the worst (deadly) and most contaminating food pathogens, which is usually treated with (among other drugs) gentamicin (**Figure 35**) [260].

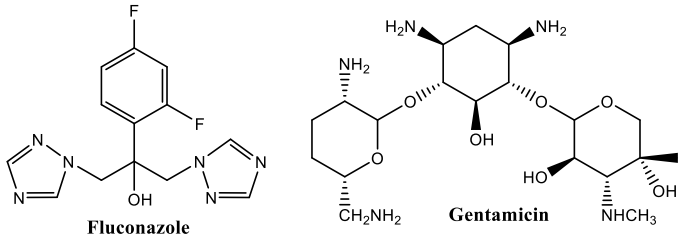


**Figure 35: Fluconazole antifungal and gentamicin antibacterial agents [259,260]**

Fluconazole has some adverse side effects, especially for pregnant women and when co-administered with other drugs [261]. And according to the review article of P. Escribano and J. Guinea, *Candida parapsilosis* is "a new emerging threat in the fungi arena", has developed resistance to fluconazole [262]. Gentamicin also showed some negative side effect, where one of the worst is acute kidney injury, according to epidemiological study of N.M. Selby and his colleagues [263]. And according to the published results of R.M. Hanes and Z. Huang, the gentamicin-resistance of *Listeria monocytogenes* was significantly increased between 2010 and 2021 [264]. All this data highlights the need for development of antimicrobial and antiviral new agents from natural products like D-limonene.

**Selected Wild Edible Non-Deca-Plants with Antimicrobial and Antiviral activity**

Many wild plants of Eastern Mediterranean region possess antimicrobial or antiviral activities. Most of these plants are inedible and even toxic, like antimicrobial *Taraxacum officinale* [265], and antiviral *Solanum nigrum* [266]. And among wild, edible non-D-P, there are also many plants that have these properties. In **Table 4** we present five, randomly selected plants.

**Table 4: Published Antimicrobial Activities of the Non-D-P in Eastern Mediterranean region.**

| Testing Method, Results and Reference/s |
|---|
| ***Allium ampeloprasum*** |
| Roots and stems were extracted with several solvents, but only aqueous extract was tested against *S. aureus* and *P. aeruginosa*. Compared with three commonly used antibiotics, this extract had moderate activity. [267] |
| ***Capparis spinosa*** |
| Leaves were extracted with chloroform, acetone, water and methanol. Aqueous and methanolic extracts were tested against four bacterial strains, and the activities (MIC) were compared with two antibiotics, showing moderate results. [268] |
| ***Matricaria aurea*** |
| Flowers were separately extracted with chloroform, ethyl acetate, acetone, ethanol and methanol, and all extracts were tested against 7 bacteria and 6 fungi species. All extracts were active but ethanolic and methanolic extracts were most potent. [269] |
| ***Portulaca oleracea*** |
| Leaves and stems were defatted with petroleum ether and extracted with 95% aqueous ethanol, ultrasonic-assisted, affording organic acids-rich extract. This extract was tested against *S. aureus*, *in vitro* and *in vivo*, in rat model contaminated wounds. Strong inhibition activity was recorded in both tests. [270] |
| ***Scolymus maculatus*** |
| Whole plant was separately extracted with water, methanol, ethanol, ethyl acetate, and *n*-hexane, and all extracts were tested against *S. aureus*, *S. typhimurium*, and *C. albicans*. Compared with three commonly used antibiotics, extract had moderate activities, where ethanol and ethyl acetate had strongest inhibitions (MIC). [271] |

## CONCLUSIONS

- Some of the Deca-Plants have excellent antimicrobial activity. Others need to be more studied.
- It is important to investigate the roles of single compounds contained in the D-P plants relating to antimicrobial activity.
- As for antimicrobial activity, the superiority of essential oils over extracts is clear.
- There is a significant need for more research of the antiviral potential of the D-P.
- Accuracy and consistency of scientific reporting are vital.

## REFERENCES


[1] Mohajeri, M.H., Brummer, R.J., Rastall, R.A., Weersma, R.K., Harmsen, H.J., Faas, M., Eggersdorfer, M., The role of the microbiome for human health: from basic science to clinical applications. Eur. J. Nutr. 2018, 57, 1-14. DOI: 10.1007/s00394-018-1703-4

[2] Brier, B., Infectious diseases in ancient Egypt. Infect. Dis. Clin. North Am. 2004, 18, 17-27. DOI: 10.1016/S0891-5520(03)00097-7

[3] Lotfy, W.M., Plague in Egypt: Disease biology, history and contemporary analysis: A minireview. J. Adv. Res. 2015, 6, 549-554. DOI: 10.1016/j.jare.2013.11.002

[4] Spyrou, M.A., Musralina, L., Gnecchi Ruscone, G.A., Kocher, A., Borbone, P.G., Khartanovich, V.I., Buzhilova, A., Djansugurova, L., Bos, K.I., Kühnert, D., Haak, W., Slavin, P., Krause, J., The source of the Black Death in fourteenth-century central Eurasia. Nature. 2022, 606, 718-724. DOI: 10.1038/s41586-022-04800-3

[5] COVID-19 Weekly Epidemiological Update, Edition 158 published 1 September 2023. World Health Organization, 2023. [WHO]

[6] Influenza (Key Facts), October 2023. World Health Organization, 2023. [WHO]

[7] Lane, N., The unseen world: reflections on Leeuwenhoek (1677) 'Concerning little animals'. Phil. Trans. R. Soc. B. 2015, 370, 20140344. DOI: 10.1098/rstb.2014.0344

[8] Artenstein, A.W., The discovery of viruses: advancing science and medicine by challenging dogma. Int. J. Infect. Dis. 2012, 16, e470-e473. DOI: 10.1016/j.ijid.2012.03.005

[9] Ribeiro da Cunha, B., Fonseca, L.P., Calado, C.R., Antibiotic Discovery: Where Have We Come from, Where Do We Go? Antibiotics (Basel). 2019, 8, 45. DOI: 10.3390/antibiotics8020045

[10] Armstrong, G.L., Conn, L.A., Pinner, R.W., Trends in infectious disease mortality in the United States during the 20th century. JAMA. 1999, 281, 61-66. DOI: 10.1001/jama.281.1.61

[11] Sabtu, N., Enoch, D.A., Brown, N.M., Antibiotic resistance: what, why, where, when and how? Br. Med. Bull. 2015, 116, 105-113. DOI: 10.1093/bmb/ldv041

[12] Conly, J., Johnston, B., Where are all the new antibiotics? The new antibiotic paradox. Can. J. Infect. Dis. Med. Microbiol. 2005, 16, 159-160. DOI: 10.1155/2005/892058

[13] Uddin, T.M., Chakraborty, A.J., Khusro, A., Zidan, B.R., Mitra, S., Emran, T.B., Dhama, K., Ripon, M.K., Gajdács, M., Sahibzada, M.U., Hossain, M.J., Koirala, N., Antibiotic resistance in microbes: History, mechanisms, therapeutic strategies and future prospects. J. Infect. Public Health. 2021, 14, 1750-1766. DOI: 10.1016/j.jiph.2021.10.020

[14] Chinemerem Nwobodo, D., Ugwu, M.C., Oliseloke Anie, C., Al-Ouqaili, M.T., Chinedu Ikem, J., Victor Chigozie, U., Saki, M., Antibiotic resistance: The challenges and some emerging strategies for tackling a global menace. J. Clin. Lab. Anal. 2022, 36, e24655. DOI: 10.1002/jcla.24655

[15] Ahmed, S., Ahmed, M.Z., Rafique, S., Almasoudi, S.E., Shah, M., Jalil, N.A., Ojha, S.C., Recent Approaches for Downplaying Antibiotic Resistance: Molecular Mechanisms. Biomed. Res. Int. 2023, 5250040. DOI: 10.1155/2023/5250040

[16] Tamma, P.D., Avdic, E., Li, D.X., Dzintars, K., Cosgrove, S.E., Association of Adverse Events With Antibiotic Use in Hospitalized Patients. JAMA Intern. Med. 2017, 177, 1308-1315. DOI: 10.1001/jamainternmed.2017.1938

[17] Shekhar, S., Petersen, F.C., The Dark Side of Antibiotics: Adverse Effects on the Infant Immune Defense Against Infection. Front. Pediatr. 2020, 8, 544460. DOI: 10.3389/fped.2020.544460

[18] Dinan, K., Dinan, T., Antibiotics and mental health: The good, the bad and the ugly. J. Intern. Med. 2022, 292, 858-869. DOI: 10.1111/joim.13543

[19] Yimenu, D.K., Emam, A., Elemineh, E., Atalay, W., Assessment of Antibiotic Prescribing Patterns at Outpatient Pharmacy Using World Health Organization Prescribing Indicators. J. Prim. Care Community Health. 2019, 10, 2150132719886942. DOI: 10.1177/2150132719886942

[20] Gillies, M., Ranakusuma, A., Hoffmann, T., Thorning, S., McGuire, T., Glasziou, P., Del Mar, C., Common harms from amoxicillin: a systematic review and meta-analysis of randomized placebo-controlled trials for any indication. CMAJ. 2015, 187, E21-E31. DOI: 10.1503/cmaj.140848
[21] Holmes, N.E., Charles, P.G., Safety and efficacy review of doxycycline. Clin. Med. Ther. 2009, 1, 471-482. DOI: 10.4137/CMT.S2035
[22] Klein, E.Y., Van Boeckel, T.P., Martinez, E.M., Pant, S., Gandra, S., Levin, S.A., Goossens, H., Laxminarayan, R., Global increase and geographic convergence in antibiotic consumption between 2000 and 2015. Proc. Natl. Acad. Sci. 2018, 115, E3463-E3470. DOI: 10.1073/pnas.1717295115
[23] Petrovska, B.B., Historical review of medicinal plants' usage. Pharmacogn. Rev. 2012, 6, 1-5. DOI: 10.4103/0973-7847.95849
[24] Dias, D.A., Urban, S., Roessner, U., A historical overview of natural products in drug discovery. Metabolites. 2012, 2, 303-336. DOI: 10.3390/metabo2020303
[25] Bones, U.A., Flach, K.A., Rosa, G.M., da Costa Junior, J.A., Comparative Evaluation Between Empirical and Scientific Knowledge About the Use of Medicinal Plants and Their Compounds. Rev. Gest. Soc. Ambient. 2022, 16, e02961. DOI: 10.24857/rgsa.v16n2-015
[26] Dhama, K., Tiwari, R., Chakraborty, S., Saminathan, M., Kumar, A., Karthik, K., Wani, M.Y., Amarpal, S.S. and Rahal, A., Evidence based antibacterial potentials of medicinal plants and herbs countering bacterial pathogens especially in the era of emerging drug resistance: an integrated update. Int. J. Pharmacol. 2014, 10, 1-43. DOI: 10.3923/ijp.2014.1.43
[27] Gupta, P.D., Birdi, T.J., Development of botanicals to combat antibiotic resistance. J. Ayurveda Integr. Med. 2017, 8, 266-275. DOI: 10.1016/j.jaim.2017.05.004
[28] Khare, T., Anand, U., Dey, A., Assaraf, Y.G., Chen, Z-S., Liu, Z., Kumar, V., Exploring Phytochemicals for Combating Antibiotic Resistance in Microbial Pathogens. Front. Pharmacol. 2021, 12, 720726. DOI: 10.3389/fphar.2021.720726
[29] Abou Auda, M., An ethnobotanical use of plants in the Middle Area, Gaza Strip, Palestine. Adv. Environ. Biol. 2011, 5, 3681-3688. [ResearchGate]
[30] Alam, M.Z., Khan, M.S., Phytomedicine from Middle Eastern countries: An alternative remedy to modern medicine against Candida spp infection. Evid. Based Complement. Alternat. Med. 2021, 6694876. DOI: 10.1155/2021/6694876
[31] Rayan, M., Abu-Farich, B., Basha, W., Rayan, A., Abu-Lafi, S., Correlation between antibacterial activity and free-radical scavenging: In-vitro evaluation of polar/non-polar extracts from 25 plants. Processes. 2020, 8, 117. DOI: 10.3390/pr8010117
[32] Dwikat, M., Jaradat, N., Amer, J., Rahim, A.A., Alqadi, M., Murad, H., Modallal, A., Shalabni, K., Antimicrobial, Anticoagulant and Anticancer Effects of Arum palaestinum Flowers Extracts. Res. Sq. 2021, DOI: 10.21203/rs.3.rs-1101438/v1
[33] Dwikat, M., Amer, J., Jaradat, N., Salhab, A., Rahim, A.A., Qadi, M., Aref, A., Ghanim, M., Murad, H., Modallal, A., Shalabni, K., Arum palaestinum delays hepatocellular carcinoma proliferation through the PI3K-AKT-mTOR signaling pathway and exhibits anticoagulant effects with antimicrobial properties. Front. Pharmacol. 2023, 14, 1180262. DOI: 10.3389/fphar.2023.1180262
[34] Naseef, H., Qadadha, H., Abu Asfour, Y., Sabri, I., Al-Rimawi, F., Abu-Qatouseh, L., Farraj, M., Anticancer, antibacterial, and antifungal activities of Arum palaestinum plant extracts. World J. Pharm. Res. 2017, 6, 31-43. DOI: 10.20959/wjpr201715-10091
[35] Husein, A.I., Ali-Shtayeh, M.S., Jamous, R.M., Abu Zaitoun, S.Y., Jondi, W.J., Zatar, N.A., Antimicrobial activities of six plants used in Traditional Arabic Palestinian Herbal Medicine. Afr. J. Microbiol. Res. 2014, 8, 3501-3507. DOI: 10.5897/AJMR2014.6921
[36] Mustafa, M., Wedian, F., Aldal'in, H.K., Al-Mazaideh, G.M., Mahmoud, S.Y., Farrag, E.S., Gharaibeh, M., Hijawi, T., Al-Rimawi, F., Abbadi, J., Shalayel, M.H., Siddique, N., Salman, H.A., Huneif, M.A., The Efficiency of Some Active Ingredients of Arum palaestinum as Inhibitors to $3CL^{PRO}$ and NSP15 Proteins. Acta Pol. Pharm. 2021, 78, 657–665. DOI: 10.3283/appdr/144970
[37] Al Khateeb, W., Hussein, E., Qouta, L., Alu'datt, M., Al-Shara, B., and Abu-Zaiton, A., In vitro propagation and characterization of phenolic content along with antioxidant and antimicrobial activities of Cichorium pumilum Jacq. Plant Cell Tiss. Organ Cult. 2012, 110, 103-110. DOI: 10.1007/s11240-012-0134-9
[38] Amer, A.M., Antimicrobial Effects of Egyptian Local Chicory, Cichorium endivia subsp. pumilum. Int. J. Microbiol. 2018, 6475072. DOI: 10.1155/2018/6475072
[39] Amin, G.R., Dehmoobed-Sharifabadi, A., Salehi-Surmaghi, M.H., Yasa, N., Aynechi, Y., Emani, M., Shidfar, M.R., Amin, M., Moghadami, M., Kordbacheh, P., Zeini, F., Screening of Iranian plants for antifungal activity: Part 1. DARU J. Pharm. Sci., 2002, 10, 34-37. [Google Scholar]

[40] Amin, G.R., Salehi-Surmaghi, M.H., Yasa, N., Aynechi, Y., Dehmoobed-Sharifabadi, A., Emani, M., Shidfar, M.R., Amin, M., Moghadami, M., Kordbacheh, P., Zeini, F., Screening of Iranian plants for antifungal activity: Part 2. DARU J. Pharm. Sci., 2002, 10, 78-89. [ResearchGate]

[41] El-Desouky, T.A., Evaluation of effectiveness aqueous extract for some leaves of wild edible plants in Egypt as anti-fungal and anti-toxigenic. Heliyon. 2021, 7, e06209. DOI: 10.1016/j.heliyon.2021.e06209

[42] Mostafa, R.M., El Desouky, T.A., El Sayed, T.I., El Aziz, A.M., El-Sayed, A.S., Evaluation of Phytochemical Screening and Antifungal Activity for Some Annual Plant Extracts in Egypt. Egypt. Acad. J. Biol. Sci. 2021, 13, 73-87. DOI: 10.21608/eajbsg.2021.179733

[43] Alkowni, R., Jodeh, S., Hussein, F., Jaradat, N., Phytochemical screening and antibacterial activity of Cyclamen persicum Mill tuber extracts. Pak. J. Pharm. Sci. 2018, 31, 187-192. [Google Scholar]

[44] Al-zuabe, M., Ismail, Y., Hasan, D., Alhrout, H., Al-Zeidaneen, S., Albawarshi, Y., Abu-Hamra, E., Antimicrobial Effect of Cyclamen persicum Tuber Extracts Against Bacteria and Candida Species, J. Pure Appl. Microbiol., 2019, 13, 107-116. DOI: 10.22207/JPAM.13.1.11

[45] Ruberto, G., Baratta, M.T., Deans, S.G., Dorman, H.J., Antioxidant and antimicrobial activity of Foeniculum vulgare and Crithmum maritimum essential oils. Planta Med. 2000, 66, 687-693. DOI: 10.1055/s-2000-9773

[46] Kwon, Y.S., Choi, W.G., Kim, W.J., Kim, W.K., Kim, M.J., Kang, W.H., Kim, C.M., Antimicrobial constituents of Foeniculum vulgare. Arch. Pharm. Res. 2002, 25, 154-157. DOI: 10.1007/BF02976556

[47] Lo Cantore, P., Iacobellis, N.S., De Marco, A., Capasso, F., Senatore, F., Antibacterial activity of Coriandrum sativum L. and Foeniculum vulgare Miller Var. vulgare (Miller) essential oils. J. Agric. Food Chem. 2004, 52, 7862-7866. DOI: 10.1021/jf0493122

[48] Park, J.S., Baek, H.H., Bai, D.H., Oh, T.K., Lee, C.H., Antibacterial activity of fennel (Foeniculum vulgare Mill.) seed essential oil against the growth of Streptococcus mutans. Food Sci, Biotechnol. 2004, 13, 581-585. [ResearchGate]

[49] Araque, M., Rojas, L., Usubillaga, A., Antibacterial activity of essential oil of Foeniculum vulgare miller against multiresistant gram-negative bacilli from nosocomial infections. Ciencia. 2007, 15, 366-370. [Google Scholar]

[50] Gulfraz, M., Mehmood, S., Minhas, N., Jabeen, N., Kausar, R., Jabeen, K., Arshad, G., Composition and antimicrobial properties of essential oil of Foeniculum vulgare. Afr. J. Biotechnol. 2008, 7, 4364-4368. [ResearchGate]

[51] Kaur, G.J., Arora, D.S., Antibacterial and phytochemical screening of Anethum graveolens, Foeniculum vulgare and Trachyspermum ammi. BMC Complement. Altern. Med. 2009, 9, 30. DOI: 10.1186/1472-6882-9-30

[52] Anwar, F., Ali, M., Hussain, A.I., Shahid, M., Antioxidant and antimicrobial activities of essential oil and extracts of fennel (Foeniculum vulgare Mill.) seeds from Pakistan. Flavour Frag. J. 2009, 24, 170-176. DOI: 10.1002/ffj.1929

[53] Soylu, S., Soylu, E.M., Evrendilek, G.A., Chemical composition and antibacterial activity of essential oils of bitter fennel (Foeniculum vulgare Mill. var. vulgare) and dill (Anethum graveolens L.) against the growth of food-borne and seed-borne pathogenic bacteria. Ital. J. Food Sci. 2009, 21, 347-355. [ResearchGate]

[54] Miguel, M.G., Cruz, C., Faleiro, L., Simões, M.T., Figueiredo, A.C., Barroso, J.G., Pedro, L.G., Foeniculum vulgare essential oils: chemical composition, antioxidant and antimicrobial activities. Nat. Prod. Commun. 2010, 5, 319-328. PMID: 20334152

[55] Cetin, B., Ozer, H., Cakir, A., Polat, T., Dursun, A., Mete, E., Oztürk, E., Ekinci, M., Antimicrobial activities of essential oil and hexane extract of Florence fennel [Foeniculum vulgare var. azoricum (Mill.) Thell.] against foodborne microorganisms. J. Med. Food. 2010, 13, 196-204. DOI: 10.1089/jmf.2008.0327

[56] Saeedi, M., Ebrahimzadeh, M.A., Morteza-Semnani, K., Âkha, O., Rabiei, K.H., Evaluation of antibacterial effect of ethanolic extract of Foeniculum vulgare Mill. J. Mazandaran Univ. Med. Sci. 2010, 20, 88-91. [ResearchGate]

[57] Zellagui, A., Gherraf, N., Elkhateeb, A., Hegazy, M.E., Mohamed, T.A., Touil, A., Shahat, A.A., Rhouati, S., 2011. Chemical constituents from Algerian Foeniculum vulgare aerial parts and evaluation of antimicrobial activity. J. Chil. Chem. Soc. 2011, 56, 759-763. DOI: 10.4067/S0717-97072011000300008

[58] Shahat, A.A., Ibrahim, A.Y., Hendawy, S.F., Omer, E.A., Hammouda, F.M., Abdel-Rahman, F.H., Saleh, M.A., Chemical composition, antimicrobial and antioxidant activities of essential oils from

organically cultivated fennel cultivars. Molecules. 2011, 16, 1366-1377. DOI: 10.3390/molecules16021366

[59] Kazemi, M., Mousavi, E., Kharestani, H., Chemical compositions and antimicrobial activities of essential oils of Varthemia persica, Foeniculum vulgare and Ferula lycia. Curr. Res. Bacteriol. 2012, 5, 42-52. DOI: 10.3923/crb.2012.42.52

[60] Esquivel-Ferriño, P.C., Favela-Hernández, J.M., Garza-González, E., Waksman, N., Ríos, M.Y., del Rayo Camacho-Corona, M., Antimycobacterial activity of constituents from Foeniculum vulgare var. dulce grown in Mexico. Molecules. 2012, 17, 8471-8482. DOI: 10.3390/molecules17078471

[61] Martins, M.R., Tinoco, M.T., Almeida, A.S., Cruz-Morais, J. Chemical Composition, Antioxidant and Antimicrobial Properties of Three Essential Oils from Portuguese Flora. J. Pharmacog. 2012, 3, 39-44. [ResearchGate]

[62] Dua, A., Garg, G., Mahajan, R., Polyphenols, flavonoids and antimicrobial properties of methanolic extract of fennel (Foeniculum vulgare Miller). Eur. J. Exp. Biol. 2013, 3, 203-208. [ResearchGate]

[63] Roby, M.H., Sarhan, M.A., Selim, K. A., Khalel, K.I., Antioxidant and antimicrobial activities of essential oil and extracts of fennel (Foeniculum vulgare L.) and chamomile (Matricaria chamomilla L.). Ind. Crops Prod. 2013, 44, 437-445. DOI: 10.1016/j.indcrop.2012.10.012

[64] Diao, W.R., Hu, Q.P., Zhang, H., Xu, J.G., Chemical composition, antibacterial activity and mechanism of action of essential oil from seeds of fennel (Foeniculum vulgare Mill.). Food Control. 2014, 35, 109-116. DOI: 10.1016/j.foodcont.2013.06.056

[65] Javadian, F., Mashhadi, M. A., Nasiri, A., Sepehri, Z., Kiani, Z., Shahi, Z., Antimicrobial activity of Foeniculum vulgare Mill essential oil against antibiotic resistance human pathogen. J. Biodivers. Environ. Sci. 2014, 5, 285-290. [Google Scholar]

[66] Mota, A.S., Martins, M.R., Arantes, S., Lopes, V.R., Bettencourt, E., Pombal, S., Gomes, A.C., Silva, L.A., Antimicrobial activity and chemical composition of the essential oils of Portuguese Foeniculum vulgare fruits. Nat. Prod. Commun. 2015, 10, 673-676. PMID: 25973507

[67] Upadhyay, R.K., GC-MS analysis and in vitro antimicrobial susceptibility of Foeniculum vulgare seed essential oil. Am. J. Plant Sci. 2015, 6, 1058-1068. DOI: 10.4236/ajps.2015.67110

[68] Salami, M., Rahimmalek, M., Ehtemam, M.H., Szumny, A., Fabian, S., Matkowski, A., Essential oil Composition, Antimicrobial Activity and Anatomical Characteristics of Foeniculum vulgare Mill. Fruits from Different Regions of Iran, J. Essent. Oil-Bear. Plants. 2016, 19, 1614-1626, DOI: 10.1080/0972060X.2015.1117951

[69] Bano, S., Ahmad, N., Sharma, A.K., Phytochemical investigation and evaluation of anti-microbial and anti-oxidant activity of Foeniculum vulgare (fennel). Int. J. Pharm. Sci. Res. 2016, 7, 310-314. [ResearchGate]

[70] Foroughi, A., Pournaghi, P., Zhaleh, M., Zangeneh, A., Zangeneh, M.M., Moradi, R., Antibacterial activity and phytochemical screening of essential oil of Foeniculum vulgare. Int. J. Pharm. Clin. Res. 2016, 8(11), pp.1505-1509. [ResearchGate]

[71] Erdogan Eliuz, E.A., Ayas, D., Goksen, G., 2016. Antibacterial Actions and Potential Phototoxic Effects of Volatile oils of Foeniculum sp.(fennel), Salvia sp.(sage), Vitis sp.(grape), Lavandula sp.(lavender). Nat. Eng. Sci. 2016, 1, 10-22. [ResearchGate]

[72] Marín, I., Sayas-Barberá, E., Viuda-Martos, M., Navarro, C., Sendra, E., Chemical composition, antioxidant and antimicrobial activity of essential oils from organic fennel, parsley, and lavender from Spain. Foods. 2016, 5, 18. DOI: 10.3390/foods5010018

[73] Chang, S., Mohammadi Nafchi, A., Karim, A.A., Chemical composition, antioxidant activity and antimicrobial properties of three selected varieties of Iranian fennel seeds, J. Essent. Oil Res. 2016, 28, 357-363. DOI: 10.1080/10412905.2016.1146169

[74] Khan, N.T., In vitro Antibacterial Activity of Foeniculum vulgare Seed Extract. Agrotechnology. 2017, 6, 162. DOI: 10.4172/2168-9881.1000162

[75] Agarwal, D., Sharma, L.K., Saxena, S.N., Anti-microbial properties of fennel (Foeniculum vulgare Mill.) seed extract. J. Pharmacog. Phytochem. 2017, 6, 479-482. [Google Scholar]

[76] AbduRahim, S.A., Elamin, B.K., Bashir, A.A., Almagboul, A.Z., In vitro test of antimicrobial activity of Foeniculum Vulgare Mill. (Fennel) essential oil. J. Multidisc. Eng. Sci. Stud. 2017, 3, 1609-1614. [ResearchGate]

[77] Mahdavi, S., Alizad, M., Sajjadi, P., Baleghi, M., A Study of the Antioxidant and Antimicrobial Effects of Ethanolic Extract of Fennel (Foeniculum vulgare Mill) Seeds. J. Babol Univ. Med. Sci. 2017, 19, 32-38. [ResearchGate]

[78] Abd El-Mongy, M., Mohamed, S.E., Mabrouk, M.I., Mohammed, A.M., Hamza, H.A., Role of Foeniculum vulgare oil on the antimicrobial activity of some antibiotics against resistant pathogenic Gram-negative bacteria. J. Biochem. Microbiol. Biotechnol. 2017, 5, 1-6. DOI: 10.54987/jobimb.v5i1.331

[79] Abdel Karim, M., Ayda, A., Khalid, M.S., GC-MS analysis and antimicrobial activity of Saudi Foeniculum vulgare Mill. (Apiaceae) fixed oil. Int. J. Adv. Res. 2017, 5, 1523-1528. [Google Scholar]
[80] Açikgöz, M.A., Kara, S.M., Aruç, C., Ay, E., Morphogenetic, Ontogenetic and Diurnal Variability in Antimicrobial Activity of Bitter Fennel (Foeniculum vulgare Miller var. vulgare) Essential Oil. Indian J. Pharm. Edu. Res. 2017, 51, S190-94. DOI: 10.5530/ijper.51.3s.10
[81] Shahmokhtar, M.K., Armand, S., Phytochemical and Biological Studies of Fennel (Foeniculum vulgare Mill.) from the South West Region of Iran (Yasouj). Nat. Prod. Chem. Res. 2017, 5, 267. DOI: 10.4172/2329-6836.1000267
[82] Batool, R., Salahuddin, H., Mahmood, T., Ismail, M., Study of anticancer and antibacterial activities of Foeniculum vulgare, Justicia adhatoda and Urtica dioica as natural curatives. Cell. Mol. Biol. 2017, 63, 109-114. DOI: 10.14715/cmb/2017.63.9.19
[83] Beyazen, A., Dessalegn, E., Mamo, W., Phytochemical screening, antioxidant and antimicrobial activities of seeds of Foeniculum vulgare (ensilal). World J. Pharm. Sci. 2017, 5, 198-208. [ResearchGate]
[84] Garzoli, S., Božović, M., Baldisserotto, A., Sabatino, M., Cesa, S., Pepi, F., Vicentini, C.B., Manfredini, S., Ragno, R., Essential oil extraction, chemical analysis and anti-Candida activity of Foeniculum vulgare Miller - new approaches. Nat. Prod. Res. 2017, 32, 1254-1259. DOI: 10.1080/14786419.2017.1340291
[85] Pecarski, D., Dragićević-Ćurić, N., Jugović, Z., Chemical composition, antifungal and antibacterial potential of fennel (Foeniculum vulgare) and cumin (Carum carvi) essential oils (Apiaceae). Bulg. J. Crop Sci. 2017, 54(1), pp.66-72. [Google Scholar]
[86] Golestannejad, Z., Gavanji, S., Mohammadi, E., Motamedi, A., Bahrani, M., Rezaei, F., Larki, B., Mojiri, A., Bakhtari, A., Comparison of antibacterial activity of essential oils of Foeniculum vulgare Mill, Mentha arvensis and Mentha piperita against Streptococcus mutans. Adv. Herb. Med. 2018, 4, 3-13. [ResearchGate]
[87] Munir, H., Shahid, M., Subhani, Z., Jabeen, R., Activity-Guided Isolation of a Novel Protein From Foeniculum Vulgare With Antifungal And Antibacterial Activities. Matrix Sci. Pharm. 2018, 2, 01-03. DOI: 10.26480/msp.02.2018.01.03
[88] Seid, M., Dekebo, A., Babu, N., Phytochemical Investigation and Antimicrobial Evaluation of Foeniculum vulgare Leaves Extract Ingredient of Ethiopian Local Liquor. J. Pharm. Nutr. Sci. 2018, 8, 20-28. DOI: 10.6000/1927-5951.2018.08.01.4
[89] Ahmad, B.S., Talou, T., Saad, Z., Hijazi, A., Cerny, M., Kanaan, H., Chokr, A., Merah, O., 2018. Fennel oil and by-products seed characterization and their potential applications. Ind. Crops Prod. 2018, 111, 92-98. DOI: 10.1016/j.indcrop.2017.10.008
[90] Khammassi, M., Loupassaki, S., Tazarki, H., Mezni, F., Slama, A., Tlili, N., Zaouali, Y., Mighri, H., Jamoussi, B., Khaldi, A., Variation in essential oil composition and biological activities of Foeniculum vulgare Mill. populations growing widely in Tunisia. J. Food Biochem. 2018, 42, e12532. DOI: 10.1111/jfbc.12532
[91] Javad, S., Tahir, A., Ghaffar, N., Ilyas, S., Akhtar, I., Augmentation of anti-bacterial efficacy of Augmentin- an antibiotic by Foeniculum vulgare extract. Pure Appl. Biol. 2019, 8,1818-1823. DOI: 10.19045/bspab.2019.80125
[92] Ghasemian, A., Al-Marzoqi, A.H., Mostafavi, S.K., Alghanimi, Y.K., Teimouri, M., Chemical Composition and Antimicrobial and Cytotoxic Activities of Foeniculum vulgare Mill Essential Oils. J. Gastrointest. Cancer. 2020, 51, 260-266. DOI: 10.1007/s12029-019-00241-w
[93] Barrahi, M., Esmail, A., Elhartiti, H., Chahboun, N., Benali, A., Amiyare, R., Lakhrissi, B., Rhaiem, N., Zarrouk, A., M. Ouhssine, M., Chemical composition and evaluation of antibacterial activity of fennel (Foeniculum vulgare Mill) seed essential oil against some pathogenic bacterial strains. Caspian J. Environ. Sci. 2020, 18, 295-307. DOI: 10.22124/cjes.2020.4276
[94] Omidi Nasab, M., Aeini, M., Composition and antibacterial activity of the chemical essential oil of Foeniculum vulgare and Eucalyptus to control some important plant pathogenic bacteria. J. Microb. World. 2020, 12, 393-399. [ResearchGate]
[95] Ekhtelat, M., Birghani, S.A., Namjoyan, F., Ameri, A., The antibacterial activity of barberry root and fennel seed extracts individually and in combination with nisin and sodium diacetate against Escherichia coli O157: H7. Jundishapur J. Nat. Pharm. Prod. 2020, 15, e55078. DOI: 10.5812/jjnpp.55078
[96] Abdullah, B.H., Abbas, I.S., Jasiem, T.M., Phytochemical study and evaluation of Iraqi fennel seed oil as antibacterial of urinary tract infection. Indian J. Forensic Med. Toxicol. 2020, 14, 842-846. [ResearchGate]

[97] Hemmanur, S., Nasim, I., Evaluation of Antimicrobial Efficacy of Foeniculum vulgare Essential Oil – An in vitro Study. Plant Cell Biotechnol. Mol. Biol. 2020, 21, 83-89. [Google Scholar]
[98] Abdul, A., Qonitah, F., Antibacterial Activity of Fennel Leaves Ethanol Extract (Foeniculum vulgare Mill) Against Pseudomonas Aeruginosa. J. Farm. Sains Praktis. 2021, 7, 154-162. [Google Scholar]
[99] Borotová, P., Galovičová, L., Valková, V., Ďúranová, H., Vuković, N., Vukić, M., Babošová, M., Kačániová, M., Biological activity of essential oil from. Acta Hort. Regiotec. 2021, 24, 148-152. DOI: 10.2478/ahr-2021-0037
[100] Korinek, M., Handoussa, H., Tsai, Y-H., Chen, Y-Y., Chen, M-H., Chiou, Z-W., Fang, Y., Chang, F-R., Yen, C-H., Hsieh, C-F., Chen, B-H., El-Shazly, M., Hwang, T-L., Anti-Inflammatory and Antimicrobial Volatile Oils: Fennel and Cumin Inhibit Neutrophilic Inflammation via Regulating Calcium and MAPKs. Front. Pharmacol. 2021, 12, 674095. DOI: 10.3389/fphar.2021.674095
[101] Hassan, S.F., Al-Yasari, I.H., Effect of alcoholic extract of medicinal plants Nigella sativa and Foeniculum vulgare in the growth of Staphylococcus aureus. J. Gen. Environ. Resourc. Conserv. 2021, 9, 202-206. [Google Scholar]
[102] Ram, L., Jain, D., Sharma, N., Kumar, M., Siyag, S.S., Kumar Gurjar, M., Comparative Evaluation of Antibacterial Activity of Turmeric (Curcuma longa) and Fennel (Foeniculum vulgare) Extracts. Int. J. Curr. Microbiol. App. Sci. 2021, 10, 2256-5561. DOI: 10.20546/ijcmas.2021.1001.260
[103] Atanasova-Pančevska, N., Kungulovski, D., Najdoska-Bogdanov, M., Bogdanov, J., Stefova, M., Comparative study of essential oils from fennel fruits and anise fruits: Chemical composition and in vitro antimicrobial activity. Maced. J. Chem. Chem. Eng. 2021, 40, 241-252. DOI: 10.20450/mjcce.2021.2418
[104] Alsalman, A., Aboalhaija, N., Talib, W., Abaza, I., Afifi, F., Evaluation of the Single and Combined Antibacterial Efficiency of the Leaf Essential Oils of Four Common Culinary herbs: Dill, Celery, Coriander and Fennel Grown in Jordan, J. Essent. Oil-Bear. Plants. 2021, 24, 317-328. DOI: 10.1080/0972060X.2021.1925595
[105] Di Napoli, M., Castagliuolo, G., Badalamenti, N., Maresca, V., Basile, A., Bruno, M., Varcamonti, M., Zanfardino, A., Antimicrobial, Antibiofilm, and Antioxidant Properties of Essential Oil of Foeniculum vulgare Mill. Leaves. Plants. 2022, 11, 3573. DOI: 10.3390/plants11243573
[106] Qaralleh, H., Khleifat, K., Al-Limoun, M., Al-Tarawneh, A., Khleifat, W., Almajali, I., Buqain, R., Shadid, K.A., Alsowayeh, N., Antibacterial activity of airborne fungal mediated nanoparticles in combination with Foeniculum vulgare essential oil. J. Herbmed. Pharmacol. 2022, 11, 419-427. DOI: 10.34172/jhp.2022.48
[107] Wany, A., Pandey, P., Raja, W., Evaluation of Phytochemical Screening and Antibacterial Activity of Foeniculum vulgare Seed Extract using Disk Diffusion Method J. Adv. Bio-pharm. Pharm. 2022, 4, 7-12. DOI: 10.46610/JABP.2022.v04i02.002
[108] Naaz, S., Ahmad, N., Qureshi, M.I., Hashmi, N., Akhtar, M.S., Khan, M.M., Antimicrobial and antioxidant activities of fennel oil. Bioinformation. 2022, 18, 795-800. DOI: 10.6026/97320630018795
[109] Erdoğan Eliuz, E.A., Antimicrobial performance of methanol extract of Foeniculum vulgare Mill. as a sanitizer agent. Indian J. Exp. Biol. 2023, 61, 124-130. DOI: 10.56042/ijeb.v61i02.39139
[110] Falana, M.B., Nurudeen, Q.O., Phytochemical components, antioxidant and antimicrobial properties of fermented seeds of Foeniculum vulgare. ABUAD Int. J. Nat. Appl. Sci. 2023, 3, 36-41. DOI: 10.53982/aijnas.2023.0302.05-j
[111] Coimbra, A., Miguel, S., Ribeiro, M., Coutinho, P., Silva, L.A., Ferreira, S., Duarte, A.P., Chemical composition, antioxidant, and antimicrobial activities of six commercial essential oils. Lett. Appl. Microbiol. 2023, 76, ovac042. DOI: 10.1093/lambio/ovac042
[112] Shabnam, J., Sobia, M., Ibatsam, K., Rauf, A., Saleem, M.H., Comparative antimicrobial activity of clove and fennel essential oils against food borne pathogenic fungi and food spoilage bacteria. Afr. J. Biotechnol. 2012, 11, 16065-16070. DOI: 10.5897/AJB11.3058
[113] Bozkurt, I.A., Soylu, S., Kara, M., Soylu, E.M., Chemical Composition and Antibacterial Activity of Essential Oils Isolated from Medicinal Plants against Gall Forming Plant Pathogenic Bacterial Disease Agents. KSU J. Agric. Nat. 2020, 1474-1482. DOI: 10.18016/ksutarimdoga.vi.723544
[114] Soylu, S., Yigitbas, H., Soylu, E.M., Kurt, S., Antifungal effects of essential oils from oregano and fennel on Sclerotinia sclerotiorum. J. Appl. Microbiol. 2007, 103, 1021–1030. DOI: 10.1111/j.1365-2672.2007.03310.x
[115] Olgun, Ç., Özkan, O.E., Güney, B., Pattabanoglu, E.S., Güney, K., Gür, M., Chemical Composition and Antimicrobial Activity in Cold Press Oil of Fennel, Anise, White and Black Mustard Seeds. Indian J. Pharm. Edu. Res. 2017, 51, S200-04. DOI: 10.5530/ijper.51.3s.12

[116] Suleiman, W.B., El-Husseiny Helal, E., Chemical constituents and potential pleiotropic activities of Foeniculum vulgare (Fennel) ethanolic extract; in vitro approach. Egypt. J. Chem. 2022, 65, 617-626. DOI: 10.21608/EJCHEM.2021.107991.4938
[117] Zeng, H., Chen, X., Liang, J., In vitro antifungal activity and mechanism of essential oil from fennel (Foeniculum vulgare L.) on dermatophyte species. J. Med. Microbiol. 2015, 64, 93–103. DOI: 10.1099/jmm.0.077768-0
[118] Khammassi, M., Habiba, K., Mighri, H., Mouna, S., Oumayma, K., Seçer, E., Ismail, A., Jamoussi, B., Yassine, M., Phytochemical Screening of Essential Oils and Methanol Extract Constituents of Wild Foeniculum vulgare Mill.: a Potential Natural Source for Bioactive Molecules. Chem. Afr. 2023. DOI: 10.1007/s42250-022-00571-6
[119] Shukla, H.S., Dubey, P., Chaturvedi, R.V., Antiviral properties of essential oils of Foeniculum vulgare and Pimpinella anisum L. Agronomie. 1989, 9, 277-279. [Google Scholar]
[120] Maurya, S., Marimuthu, P., Singh, A., Rao, G.P., Singh, G., Antiviral Activity of Essential Oils and Acetone Extracts of Medicinal Plants Against Papaya Ring Spot Virus. J. Essent. Oil-Bear. Plants. 2005, 8, 233-238. DOI: 10.1080/0972060X.2005.10643452
[121] Orhan, I.E., Özcelik, B., Kartal, M., Kan, Y., Antimicrobial and antiviral effects of essential oils from selected Umbelliferae and Labiatae plants and individual essential oil components. Turk. J. Biol. 2012, 36, 239-246. DOI: 10.3906/biy-0912-30
[122] Tharanath, V., Peddanna, K., Kotaiah, Y., Venkataramana, D., Flavonoids isolated from Foeniculum vulgare (Fennel) have virostatic efficiency against bluetongue virus. Int. J. Pharm. Sci. Rev. Res. 2013, 23, 237-242. [ResearchGate]
[123] Dorra, N.H., Elbarrawy, M., Sallam, S.M., Mahmoud, R.S., Evaluation of antiviral and antioxidant activity of selected herbal extracts. J. High Inst. Public Health. 2019, 49, 36-40. DOI: 10.21608/jhiph.2019.29464
[124] Ibrahim, N., Moussa, A.Y., A comparative volatilomic characterization of Florence fennel from different locations: antiviral prospects. Food Funct. 2021, 12, 1498–1515. DOI: 10.1039/d0fo02897e
[125] Mahmood, A.M., Sallo, A.K., Hasan, M.A., Chemical components and antibacterial activity of Gundelia tournefortii (L.) Compositae/Asteraceae (Iraq, Kurdistan Region, Sulaymaniyah, Penjwin area, "Kokhalan"). J. Indian Chem. Soc. 2014, 91, 2107-2111. [ResearchGate]
[126] Ayoubi, B., Baradari, P., July. Antibacterial Activity of Gundelia tournefortii Compounds against Salmonella choleraesuis. Biol. Forum. 2015, 7, 1076-1081. [Google Scholar]
[127] Ayoubi, B., Darvishi, S., Mirahmadi, F., Antibacterial properties of Kurdistan Gundelia tournefortii ethanolic extract against Staphylococcus aureus and Escherichia coli. J. Food Hyg. 2016, 6, 73-83. [ResearchGate]
[128] Dastan, D., Yousefzadi, M., Volatile oil constituent and biological activity of Gundelia tournefortii L. from Iran. J. Rep. Pharma. Sci. 2016. 5, 18-24. DOI: 10.4103/2322-1232.222589
[129] Özaltun, B., Dastan, T., Evaluation of antimicrobial activities and in vitro cytotoxic activities of Gundelia tournefortii L. Plant extracts. SDÜ Med. J. 2019, 26, 436-442. DOI: 10.17343/sdutfd.534049
[130] Saraç, H., Demirbaş, A., Daştan, S.D., Ataş, M., Çevik, Ö., Eruygur, N., Evaluation of nutrients and biological activities of Kenger (Gundellia tournefortii L.) seeds cultivated in Sivas province. Turk. J. Agric. Food Sci. Technol. 2019, 7, 52-58. DOI: 10.24925/turjaf.v7isp2.52-58.3126
[131] Ceylan, S., Cetin, S., Camadan, Y., Saral, O., Ozsen, O., Tutus, A., Antibacterial and antioxidant activities of traditional medicinal plants from the Erzurum region of Turkey. Irish J. Med. Sci. 2019, 188, 1303-1309. DOI: 10.1007/s11845-019-01993-x
[132] Darwish, R.M., Aburjai, T.A, Effect of ethnomedicinal plants used in folklore medicine in Jordan as antibiotic resistant inhibitors on Escherichia coli. BMC Complement. Alternat. Med. 2010, 10, 9. DOI: 10.1186/1472-6882-10-9
[133] Alma, M.H., Mavi, A., Yildirim, A., Digrak, M., Hirata, T., Screening chemical composition and in vitro antioxidant and antimicrobial activities of the essential oils from Origanum syriacum L. growing in Turkey. Biol. Pharm. Bull. 2003, 26, 1725-1729. DOI: 10.1248/bpb.26.1725
[134] 134)Al-Bandak, G., Tsironi, T., Taoukis, P., Oreopoulou, V., Antimicrobial and antioxidant activity of Majorana syriaca in Yellowfin tuna. Int. J. Food Sci. Technol. 2009, 44, 373-379. DOI: 10.1111/j.1365-2621.2008.01775.x
[135] Lakis, Z., Mihele, D., Nicorescu, I., Vulturescu, V., Udeanu, D.I., The antimicrobial activity of Thymus vulgaris and Origanum syriacum essential oils on Staphylococcus aureus, Streptococcus pneumoniae and Candida albicans. Farmacia, 2012, 60, 857-865. [ResearchGate]

[136] Ibrahim, L., Karaky, M., Ayoub, P., El Ajouz, N., Ibrahim, S., Chemical composition and antimicrobial activities of essential oil and its components from Lebanese Origanum syriacum L., J. Essent. Oil Res. 2012, 24, 339-345. DOI: 10.1080/10412905.2012.692900
[137] Al-Mariri, A., Safi, M., In Vitro Antibacterial Activity of Several Plant Extracts and Oils against Some Gram-Negative Bacteria. Iran. J. Med. Sci. 2014, 39, 36-43. [ResearchGate]
[138] Al-fawwaz, A.T., Alsohaili, S.A., Antimicrobial Activity of Varthemia iphinoides and Majorana syriaca Essential Oils from Jordan and Their Potential Use as Natural Food Preservatives. J. Nat. Sci. Res. 2015, 5, 155-161. [ResearchGate]
[139] El Gendy, A.N., Leonardi, M., Mugnaini, L., Bertelloni, F., Ebani, V.V., Nardoni, S., Mancianti, F., Hendawy, S., Omer, E., Pistelli, L., Chemical composition and antimicrobial activity of essential oil of wild and cultivated Origanum syriacum plants grown in Sinai, Egypt. Ind. Crops Prod. 2015, 67, 201-207. DOI: 10.1016/j.indcrop.2015.01.038
[140] Assaf, A.M., Amro, B.I., Mashallah, S., Haddadin, R.N., Antimicrobial and anti-inflammatory potential therapy for opportunistic microorganisms. J. Infect. Dev. Ctries. 2016, 10, 494-505. DOI: 10.3855/jidc.7610
[141] Ayman, A.M., Odeh, A., Alobeid, B., Boukai, H., In vitro antibacterial activity of Origanum syriacum L. essential oils against gram-negative bacteria. Avicenna J. Clin. Microbiol. Infect. 2019, 6, 26-30. DOI: 10.34172/ajcmi.2019.06
[142] Shehadeh, M., Jaradat, N., Al-Masri, M., Zaid, A.N., Hussein, F., Khasati, A., Suaifan, G., Darwish, R., Rapid, cost-effective and organic solvent-free production of biologically active essential oil from Mediterranean wild Origanum syriacum. Saudi Pharm. J. 2019, 27, 612-618. DOI: 10.1016/j.jsps.2019.03.001
[143] Zinab, A., Issa, A., Antimicrobial activity of Myrtus communis L. and Origanum syriacum L. against some of human pathogenic bacteria. Tishreen Univ. J. Biol. Sci. Ser. 2020, 42. 11-24. [Journal Website]
[144] Shamseddine, L., Chidiac, J.J., Composition's effect of Origanum Syriacum essential oils in the antimicrobial activities for the treatment of denture stomatitis. Odontology. 2021, 109, 327-335. DOI: 10.1007/s10266-020-00547-3
[145] Abd El-Motaleb, M., Abd El-Hameid, A.R., Helmy, W.A., Ewais, E.A., Abdel-Hady, M.S., Essential oil content and composition of endemic Origanum syriacum ssp. sinaicum and it's antimicrobial activity. Middle East J. Appl. Sci. 2021, 11, 589-594. DOI: 10.36632/mejas/2021.11.2.46
[146] Al-Hijazeen, M., Anti-bacterial effect of Rosmarinus officinalis Linn. extract and Origanum syriacum L. essential oil on survival and growth of total aerobic bacteria and Staphylococcus aureus using cooked chicken meat. Food Sci. Technol. 2022, 42, e60720. DOI: 10.1590/fst.60720
[147] Daouk, R.K., Dagher, S.M., Sattout, E.J., Antifungal Activity of the Essential Oil of Origanum syriacum L. J. Food Prot. 1995, 58, 1147-1149. DOI: 10.4315/0362-028X-58.10.1147
[148] Qadi, M., Jaradat, N., Al-Maharik, N., Hawash, M., Abdalrazeq, M., Fuqha, A., Jabareen, D., Atamni, N., Zarour, A., Anticandidal effects and chemical compositions of volatile oils extracted from Origanum syriacum, Clinopodium serpyllifolium subsp. fruticosum and Thymbra capitata from Palestine. Chem. Biol. Technol. Agric. 2023, 10, 87. DOI: 10.1186/s40538-023-00459-8
[149] Shimoni, M., Putievsky, E., Ravid, U., Reuveni, R., Antifungal activity of volatile fractions of essential oils from four aromatic wild plants in israel. J. Chem. Ecol. 1993, 19, 1129-1133. DOI: 10.1007/BF00987374
[150] Khoury, M., Stien, D., Eparvier, V., Ouaini, N. and El Beyrouthy, M., 2016. Report on the medicinal use of eleven Lamiaceae species in Lebanon and rationalization of their antimicrobial potential by examination of the chemical composition and antimicrobial activity of their essential oils. Evid. Based Complement. Alternat. Med. 2016, 2547169. DOI: 10.1155/2016/2547169
[151] Cheng, C.L., Wang, Z.Y., Bacteriostasic activity of anthocyanin of Malva sylvestris. J. For. Res. 2006, 17, 83-85. DOI: 10.1007/s11676-006-0020-6
[152] Razavi, S.M., Zarrini, G., Molavi, G., Ghasemi, G., Bioactivity of Malva sylvestris L., a medicinal plant from Iran. Iran. J. Basic Med. Sci. 2011, 14, p.574-579. [ResearchGate]
[153] Eini, M., shayegh, J., Moharrami, F., Comparison of antibacterial effect of Malva sylvestris L. (aerial and root organs) by MIC. J. Shahid Sadoughi Univ. Med. Sci. 2014, 21, 816-822. [Google Scholar]
[154] Benso, B., Rosalen, P.L., Alencar, S.M., Murata, R.M., Malva sylvestris Inhibits Inflammatory Response in Oral Human Cells. An In Vitro Infection Model. PLoS ONE, 2015, 10, e0140331. DOI: 10.1371/journal.pone.0140331
[155] Cecotti, R., Bergomi, P., Carpana, E., Tava, A., Chemical characterization of the volatiles of leaves and flowers from cultivated Malva sylvestris var. mauritiana and their antimicrobial activity against the

aetiological agents of the European and American foulbrood of honeybees (Apis mellifera). Nat. Prod. Commun. 2016, 11, 1527-1530. DOI: 10.1177/1934578X1601101026

[156] Azadpour, M., Azadpour, N., Bahmani, M., Hassanzadazar, H., Rafieian-Kopaei, M., Naghdi, N., Antimicrobial effect of Ginger (Zingiber officinale) and mallow (Malva sylvestris) hydroalcholic extracts on four pathogen bacteria. Der Pharm. Lett. 2016, 8, 181-187. [ResearchGate]

[157] Vahabi, S., Hakemi-Vala, M., Gholami, S., In vitro Antibacterial Effect of Hydroalcoholic Extract of Lawsonia inermis, Malva sylvestris, and Boswellia serrata on Aggregatibacter actinomycetemcomitans. Adv. Biomed. Res. 2019, 8, 22. DOI: 10.4103/abr.abr_205_18

[158] Dowek, S., Fallah, S., Basheer-Salimia, R., Jazzar, M., Qawasmeh, A., Antibacterial, antioxidant and phytochemical screening of Palestinian mallow, Malva sylvestris L. Int. J. Pharm. Pharm. Sci. 2020, 12, 12-16. DOI: 10.22159/ijpps.2020v12i10.39053

[159] Eghbal, H., Mohammadi, A., Mohammad Nejad Khiavi, N., Jahani, N., Evaluation of Antibacterial Properties of Essential Oil of Malva Sylvestris Collected from Meshkinshahr on Common Bacteria of Oral Infection and Comparison with Chlorhexidine Mouthwash. J. Adv. Biomed. Sci. 2020, 10, 2872-2882. [Google Scholar]

[160] Sadat, S.S., Azari, A.A., Mazandarani, M., Evaluation of the Antibacterial Activity of Ethanolic Extract of Matricaria chamomilla, Malva sylvestris, and Capsella bursa-pastoris against Methicillin-Resistant Staphylococcus aureus. Iran. J. Med. Microbiol. Infect. Dis. 2020, 8, 127-131. DOI: 10.29252/JoMMID.8.4.127

[161] Pimenta, R.S., Antimicrobial effect analysis of Verbena officinalis, Malva sylvestris and Ageratum conyzoides on Gardnerella vaginalis and Candida spp. isolated from vaginal secretion in Palmas, TO, Brazil. 2020, 9, 1-11. [ResearchGate]

[162] Turan, K., Akcan, M., Kalfa, O.M., Preparation, Characterization and Antibacterial Activity of Malva Sylvestris L. Seed Extract Containing Novel Electrospun PVA Nanofibers. Gazi Univ. J. Sci. 2021, 34, 987-998. DOI: 10.35378/gujs.794638

[163] Nozohour, Y., Jalilzadeh, G., Antibacterial Activities of Ethanolic Extract of Malva sylvestris L. Against Salmonella enterica and Escherichia coli Isolated from Diarrheic Lambs. Iran. J. Med. Microbiol. 2021, 15,121-129. DOI: 10.30699/ijmm.15.1.121

[164] Fathi, M., Ghane, M., Pishkar, L., Phytochemical composition, antibacterial, and antibiofilm activity of Malva sylvestris against human pathogenic bacteria. Jundishapur J. Nat. Pharma. Prod. 2022, 17, e114164. DOI: 10.5812/jjnpp.114164.

[165] Shadid, K.A., Shakya, A.K., Naik, R.R., Jaradat, N., Farah, H.S., Shalan, N., Khalaf, N.A., Oriquat, G.A., Phenolic content and antioxidant and antimicrobial activities of Malva sylvestris L., Malva oxyloba Boiss., Malva parviflora L., and Malva aegyptia L. leaves extract. J. Chem. 2021, 8867400. DOI: 10.1155/2021/8867400

[166] Ardakani, H., Khosravani, S.A., Mansourian, A., Jahedi, S., Sharifi, A., Antimicrobial Effects of Hydroalcoholic Extract of Malva sylvestris as a Food Preservative. Armaghane Danesh. 2021, 26, 563-576. DOI: 10.52547/armaghanj.26.4.563

[167] Kaziyama, V.M., Fernandes, M.J., Simoni, I.C., Antiviral activity of commercially available medicinal plants on suid and bovine herpesviruses. Rev. Bras. Plantas Med. 2012, 14, 522-528. DOI: 10.1590/S1516-05722012000300015

[168] Benso, B., Rosalen, P.L., Pasetto, S., Marquezin, M.C., Freitas–Blanco, V., Murata, R.M., 2021. Malva sylvestris derivatives as inhibitors of HIV-1 BaL infection. Nat. Prod. Res. 2021, 35, 1064-1069. DOI: 10.1080/14786419.2019.1619720

[169] Mazaheri, M., Babaeian, M., Ekhveh, M., Vakili, Z., Vakili, Z., Efficacy of herbal tea preparation including mallow flower, chicory seeds, sweet violet, melilotus officinalis, and bindii for improving respiratory symptoms in patients with covid-19; a randomized controlled clinical trial. Immunopathol. Persa. 2022, e31352. DOI: 10.34172/ipp.2022.31352

[170] Gulluce, M., Sokmen, M., Sahin, F., Sokmen, A., Adiguzel, A., Ozer, H., Biological activities of the essential oil and methanolic extract of Micromeria fruticosa (L) Druce ssp serpyllifolia (Bieb) PH Davis plants from the eastern Anatolia region of Turkey. J. Sci. Food Agric. 2004, 84, 735-741. DOI: 10.1002/jsfa.1728

[171] Al-Hamwi, M., Aboul-Ela, M., El-Lakany, A., El-Achi, N., Ghanem, N., El Hamaoui, B., Bakkour, Y., El-Omar, F., Chemical composition, antimicrobial and antioxidant activities of the ethanolic extract of Micromeria fruticosa growing in Lebanon. Int J Chem Sci. 2015, 13, 325-335. [ResearchGate]

[172] Salameh, N., Shraim, N., Jaradat, N., El Masri, M., Adwan, L., K'aibni, S., Alkowni, R., Radwan, A., AbuAlhasan, M., Screening of antioxidant and antimicrobial activity of Micromeria fruticosa serpyllifolia volatile oils: A comparative study of plants collected from different regions of west bank, Palestine. BioMed Res. Int. 2020, 4851879. DOI: 10.1155/2020/4851879

[173] Sadeq, O., Mechchate, H., Es-safi, I., Bouhrim, M., Jawhari, F-Z., Ouassou, H., Kharchoufa, L., Alzain, N.M., M. Alzamel, N.M., Alkamaly, O.M., Bouyahya, A., Benoutam, A., Imtara, H., Phytochemical Screening, Antioxidant and Antibacterial Activities of Pollen Extracts from Micromeria fruticosa, Achillea fragrantissima, and Phoenix dactylifera. Plants. 2021, 10, 676. DOI: 10.3390/plants10040676

[174] Al-Shboul, T.M., Najadat, I.M., Hussein, E.I., Al Khateeb, W.M., Phytochemical Analysis and Biological Activity of Micromeria fruticosa (L.) Collected from Northern Jordan. Jordan J. Biol. Sci. 2022, 15, 833-839. DOI: 10.54319/jjbs/150512

[175] Al-Nuri, M., Abu-Reidah, I.M., Alhajeh, A.A., Omar, G., Adwan, G., Warad, I., GC–MS-Based Metabolites Profiling, In Vitro Antioxidant, Anticancer, and Antimicrobial Properties of Different Solvent Extracts from the Botanical Parts of Micromeria fruticosa (Lamiaceae). Processes. 2022. 10, 1016. DOI: 10.3390/pr10051016

[176] Yıldırım, A., Mavi, A., Oktay, M., Kara, A.A., Algur, Ö.F., Bilaloğlu, V., Comparison of antioxidant and antimicrobial activities of Tilia (Tilia argentea Desf ex DC), sage (Salvia triloba L.), and Black tea (Camellia sinensis) extracts. J. Agric. Food Chem. 2000, 48, 5030-5034. DOI: 10.1021/jf000590k

[177] Delamare, A.P., Moschen-Pistorello, I.T., Artico, L., Atti-Serafini, L., Echeverrigaray, S., Antibacterial activity of the essential oils of Salvia officinalis L. and Salvia triloba L. cultivated in South Brazil. Food Chem. 2007, 100, 603-608. DOI: 10.1016/j.foodchem.2005.09.078

[178] Pierozan, M.K., Pauletti, G.F., Rota, L., Santos, A.C., Lerin, L.A., Di Luccio, M., Mossi, A.J., Atti-Serafini, L., Cansian, R.L., Oliveira, J.V., 2009. Chemical characterization and antimicrobial activity of essential oils of Salvia L. species. Food Sci. Technol. 2009, 29, 764-770. DOI: 10.1590/S0101-20612009000400010

[179] Gonaid, M.H., Habib, I.H., Al-Arefy, H., Ul-Islam, M., Comparative chemical and biological studies of Salvia fruticosa, Ocimum basillicum and Pelargonium graveolans cultivated in Al-Jabal Al-Akhdar. J. Nat. Prod. Plant Resour. 2012, 2, 705-710. [ResearchGate]

[180] Giweli, A.A., Džamić, A.M., Soković, M., Ristić, M.S., Janaćković, P., Marin, P.D., The chemical composition, antimicrobial and antioxidant activities of the essential oil of Salvia fruticosa growing wild in Libya. Arch. Biol. Sci. 2013, 65, 321-329. DOI: 10.2298/ABS1301321G

[181] Alzoubi, H.M., Ibrahim, A.I., Alsbou, M.S., Aqel, A.A., Inhibitory effect of Mediterranean sage and rosemary on clinical and community isolates of methicillin-resistant Staphylococcus aureus. Jordan J. Biol. Sci. 2014, 7, 161-164. DOI: 10.12816/0008233

[182] Kulaksız, B., Er, S., Üstündağ Okur, N., Saltan İşcan, G., Investigation of antimicrobial activities of some herbs containing essential oils and their mouthwash formulations. Turk. J. Pharm. Sci. 2018, 15, 370-375. DOI: 10.4274/tjps.37132

[183] Nasreddine, S., Mcheik, A., Khalil, M., El-Rashed, Z., Daher, A., Khalife, H., The antioxidant, antibacterial, antihemolytic and epithelial ovarian cancer antiproliferative activities of the lebanese plant Salvia libanotica. Asian J. Sci. Technol. 2018, 9, 8695-8703. [Journal Website]

[184] Soomro, S., Sanghi, S.U., Mashooq, A.A., In Vitro Biological Activity of Ethanolic Extract of Maramiyah (Salvia Libanotica) and Its Combination with Essential Oil. Int. J. Pharm. Phytopharmacol. Res. 2019, 9, 32-37. [ResearchGate]

[185] Karadağ, A.E., İpekçi, E., Yağcılar, A.P., Demirbolat, İ., Kartal, M., Siafaka, P.I., Üstündağ Okur, N., Antibacterial evaluation of Elettaria cardamomum (L.) Maton, Lavandula angustifolia Mill. and Salvia fruticosa Mill. essential oil combinations in mouthwash preparations. Nat. Volatiles Essent. Oils. 2020, 7, 9-17, DOI: 10.37929/nveo.685474

[186] Jaradat, N., Abdallah, S., Al-Maharik, N., Altamimi, M., Hawash, M., Qneibi, M., Abu Khair, A., Zetawi, A., Jabarin, L., Constituents, Antibacterial Adhesion, Cytotoxic and in vitro Metastasis Blocking Properties of Salvia fruticosa Essential Oils from Three Palestinian Localities. Chem. Biodivers. 2022, 19, e202100872. DOI: 10.1002/cbdv.202100872

[187] Pelin Bahadirli, N., Comparison of Chemical Composition and Antimicrobial Activity of Salviafruticosa Mill. and S.aramiensis Rech. Fill. (Lamiaceae), J. Essent. Oil-Bear. Plants. 2022, 25, 716-727. DOI: 10.1080/0972060X.2022.211038

[188] Stojanović, D., Marčetić, M., Ušjak, D., Milenković, M., Composition and antimicrobial activity of essential oils of Salvia fruticosa and Salvia ringens (Lamiaceae). Vojnosanit. Pregl. 2022, 79, 62-68. DOI: 10.2298/VSP200508083S

[189] Abdelshafeek, K.A., Rahmatalla, A.B., Muftah, A.H., Alderhami, S.A., GC/MS analysis of the oils and lipid constituents and evaluation of different extracts from Salvia fruticosa Mill. seed. Egypt. J. Chem. 2022, 65, 63-771. DOI: 10.21608/EJCHEM.2022.132670.5863

[190] Dawra, M., Bouajila, J., El Beyrouthy, M., Abi Rizk, A., Taillandier, P., Nehme, N., El Rayess, Y., Chemical Characterization and Antioxidant, Antibacterial, Antiacetylcholinesterase and

Antiproliferation Properties of Salvia fruticosa Miller Extracts. Molecules. 2023, 28, 2429. DOI: 10.3390/molecules28062429

[191] Bozyel, M.E., Canli, K., Benek, A., Simsek, O., Akata, I., Altuner, E.M., Biochemical Composition, and In Vitro Antimicrobial and Antioxidant Activities of Salvia fruticosa, An Ethnomedicinal Plant. Appl. Ecol. Environ. Res. 2023, 21, 3243-3256. DOI: 10.15666/aeer/2104_32433256

[192] Duletić-Laušević, S., Aradski, A.A., Šavikin, K., Knežević, A., Milutinović, M., Stević, T., Vukojević, J., Marković, S., Marin, P.D., Composition and biological activities of Libyan Salvia fruticosa Mill. and S. lanigera Poir. extracts. S. Afr. J. Bot. 2018, 117, 101-109. DOI: 10.1016/j.sajb.2018.05.013

[193] Adam, K., Sivropoulou, A., Kokkini, S., Lanaras, T., Arsenakis, M., Antifungal activities of Origanum vulgare subsp. hirtum, Mentha spicata, Lavandula angustifolia, and Salvia fruticosa essential oils against human pathogenic fungi. J. Agric. Food Chem. 1998, 46, 1739-1745. DOI: 10.1021/jf9708296

[194] Pitarokili, D., Tzakou, O., Loukis, A., Harvala, C., Volatile metabolites from Salvia fruticosa as antifungal agents in soilborne pathogens. J. Agric. Food chem. 2003, 51, 3294-3301. DOI: 10.1021/jf0211534

[195] Sivropoulou, A., Nikolaou, C., Papanikolaou, E., Kokkini, S., Lanaras, T., Arsenakis, M., Antimicrobial, cytotoxic, and antiviral activities of Salvia fructicosa essential oil. J. Agric. Food Chem. 1997, 45, 3197-3201. DOI: 10.1021/jf970031m

[196] Tseliou, M., Pirintsos, S.A., Lionis, C., Castanas, E., Sourvinos, G., Antiviral effect of an essential oil combination derived from three aromatic plants (Coridothymus capitatus (L.) Rchb. f., Origanum dictamnus L. and Salvia fruticosa Mill.) against viruses causing infections of the upper respiratory tract. J. Herb. Med. 2019, 17, 100288. DOI: 10.1016/j.hermed.2019.100288

[197] Tesaki, S., Tanabe, S., Ono, H., Fukushi, E., Kawabata, J., Watanabe, M., 4-Hydroxy-3-nitrophenylacetic and Sinapic Acids as Antibacterial Compounds from Mustard Seeds. Biosci. Biotechnol. Biochem. 1998, 62, 998-1000. DOI: 10.1271/bbb.62.998

[198] Li, J.J., Zehentbauer, G.N., Bunke, P.R., Zent, J.B., Ekanayake, A., Kester, J.J., March. IsoGard™: a natural anti-microbial agent derived from white mustard seed. Acta Hortic. 2006, 709, 101-108. DOI: 10.17660/ActaHortic.2006.709.11

[199] Kim, H.W., Lee, C.H., Kim, M-G., Lee, H-S., Antibacterial Activities of Phenethyl Isothiocyanate and Its Derivatives against Human Oral Pathogens. J. Korean Soc. Appl. Biol. Chem. 2009, 52, 555-559. DOI: 10.3839/jksabc.2009.093

[200] Al-Qudah, M.A., Al-Jaber, H.I, Muhaidat, R., Hussein, E.I., Abdel-Hamid 1, A.A., Al-Smadi, M.L., Abaza, I.F., Afifi, F.U., Abu-Orabi, S.T., Chemical Composition and Antimicrobial Activity of the Essential Oil from Sinapis alba L. and Sinapis arvensis L. (Brassicaceae) growing wild in Jordan. Res. J. Pharm. Biol. Chem. Sci. 2011, 2, 1136-1144. [ResearchGate]

[201] Mbega, E.R., Mortensen, C.N., Mabagala, R.B., Wulff, E.G., The effect of plant extracts as seed treatments to control bacterial leaf spot of tomato in Tanzania. J. Gen. Plant Pathol. 2012, 78, 277-286. DOI 10.1007/s10327-012-0380-z

[202] Sujatha, R., Mariajancyrani, J., Chandramohan, G., Preliminary phytochemical investigation and antimicrobial activity of Sinapis alba. Sch. J. App. Med. Sci. 2013, 1, 138-141. DOI: 10.36347/sjams.2013.v01i03.001

[203] Peng, C., Zhao, S.Q., Zhang, J., Huang, G.Y., Chen, L.Y., Zhao, F.Y., Chemical composition, antimicrobial property and microencapsulation of Mustard (Sinapis alba) seed essential oil by complex coacervation. Food Chem. 2014, 165, 560-568. DOI: 10.1016/j.foodchem.2014.05.126

[204] Aliakbarlu, J., Mohammadi, S., Khalili, S., A study on antioxidant potency and antibacterial activity of water extracts of some spices widely consumed in I ranian diet. J. Food Biochem. 2014, 38, 159-166. DOI: 10.1111/jfbc.12034

[205] Singh, S., Das, S.S., Singh, G., Perroti, M., Schuff, C., Catalán, C.A., Comparison of chemical composition, antioxidant and antimicrobial potentials of essential oils and oleoresins obtained from seeds of Brassica juncea and Sinapis Alba. MOJ Food Process Technol. 2017, 4, 113-120. DOI: 10.15406/mojfpt.2017.04.00100

[206] Boscaro, V., Boffa, L., Binello, A., Amisano, G., Fornasero, S., Cravotto, G., Gallicchio, M., Antiproliferative, proapoptotic, antioxidant and antimicrobial effects of Sinapis nigra L. and Sinapis alba L. extracts. Molecules. 2018. 23, 3004. DOI: 10.3390/molecules23113004

[207] Tambur, Z., Cenić, Milošević D., Mileusnić, I., Doder, R., Marjanović, M., Miljković, Selimović, B., Kulišić, Z., Opačić, D., Inhibitory effects of different medicinal plants on Candida albicans growth. Med. Weter. 2018, 74, 473-476. DOI: 10.21521/mw.5995

[208] Camacho, C., Arias-Palacios, J., Rodríguez, A., Assessment of the antibacterial capacity of extracts of Sinapis alba L. by the method of plates and wells. PharmacologyOnline. 2019, 2, 329-335. [ResearchGate]
[209] Weldu, H., Mehari, A., Alem, L., Evaluation of antimicrobial activities of Sinapis alba and Brassica nigra leaves against selected microorganisms. Pharm. Biosci. J. 2019, 7, 01-06. DOI: 10.20510/ukjpb/7/i2/182377
[210] Porter, J.A., Monu, E.A., Evaluating the antimicrobial efficacy of white mustard essential oil alone and in combination with thymol and carvacrol against Salmonella. J. Food Prot. 2019, 82, 2038-2043. DOI: 10.4315/0362-028X.JFP-19-029
[211] Persaud, C., Daniel, R., Hemraj, D., Phytochemical composition and antimicrobial activities of three selected spices seed extracts against food spoilage microorganisms. Bioteknologi, 2019, 16, 41-47. DOI: 10.13057/biofar/c160201
[212] Porter, J.A., Morey, A., Monu, E.A., Antimicrobial efficacy of white mustard essential oil and carvacrol against Salmonella in refrigerated ground chicken. Poult. Sci. 2020, 99, 5091-5095. DOI: 10.1016/j.psj.2020.06.027
[213] Khatib, R., Al-Makky, K., Anti-oxidant and Anti-bacterial Activities of Sinapis alba L. (Leaves, Flowers and Fruits) Grown in Syria. Bull. Pharm. Sci. Assiut. 2021, 44, 339-346. DOI: 10.21608/bfsa.2021.75550.1102
[214] Bajpai, D., Malaiappan, S., Rajeshkumar, S., (September 13, Evaluation of Anti-inflammatory and Antimicrobial Properties of Mustard Seed Extract-Based Hydrogel: An In Vitro Study. Cureus. 2023, 15, e45146. DOI: 10.7759/cureus.45146
[215] Barakat, A.B., Shoman, S.A., Dina, N., Alfarouk, O.R., Antiviral activity and mode of action of Dianthus caryophyllus L. and Lupinus termes L. seed extracts against in vitro herpes simplex and hepatitis A viruses infection. J. Microbiol. Antimicrob. 2010, 2, 23-29. DOI: 10.5897/JMA.9000011
[216] Salam, M.A., Al-Amin, M.Y.; Salam, M.T., Pawar, J.S., Akhter, N., Rabaan, A.A., Alqumber, M.A., Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. Healthcare. 2023, 11, 1946. DOI: 10.3390/healthcare11131946
[217] Premanandh, J., Samara, B.S., Mazen, A.N., Race Against Antimicrobial Resistance Requires Coordinated Action – An Overview. Front. Microbiol. 2016, 6, 1536. DOI: 10.3389/fmicb.2015.01536
[218] Shallcross, L.J., Davies, D.S., Antibiotic overuse: a key driver of antimicrobial resistance. Br. J. Gen. Pract. 2014, 64, 604-605. DOI: 10.3399/bjgp14X682561
[219] Sharma, M., Kumar, K., Dubey, K.K., Disposal of unused antibiotics as household waste: A social driver of antimicrobial resistance. Environ. Qual. Manage. 2021, 30, 127-140. DOI: 10.1002/tqem.21744
[220] Paul, S.D., Gandhi, S., Fate of Improper Drug Disposal and its Impact on Health. Int. J. Pharm. Sci. Rev. Res. 2020, 64, 188-193. DOI: 10.47583/ijpsrr.2020.v64i01.034
[221] Polianciuc, S.I., Gurzău, A.E., Kiss, B., Ştefan, M.G., Loghin, F., Antibiotics in the environment: causes and consequences. Med. Pharm. Rep. 2020, 93, 231-240. DOI: 10.15386/mpr-1742
[222] Huang, A., Yan, M., Lin, J., Xu, L., Gong, H., Gong, H., A Review of Processes for Removing Antibiotics from Breeding Wastewater. Int. J. Environ. Res. Public Health. 2021, 18, 4909. DOI: 10.3390/ijerph18094909
[223] de Ilurdoz, M.S., Sadhwani, J.J., Reboso, J.V., Antibiotic removal processes from water & wastewater for the protection of the aquatic environment-a review. J. Water Proc. Eng. 2022, 45, 102474. DOI: 10.1016/j.jwpe.2021.102474
[224] Shi, H., Wang, H., Zhang, E., Qu, X., Li, J., Zhao, S., Gao, H., Chen, Z., Boosted Photocatalytic Performance for Antibiotics Removal with Ag/PW12/TiO2 Composite: Degradation Pathways and Toxicity Assessment. Molecules. 2023, 28, 6831. DOI: 10.3390/molecules28196831
[225] Abu-Qatouseh, L., Mallah, E., Mansour, K., Evaluation of anti-Propionibacterium acnes and anti-inflammatory effects of polyphenolic extracts of medicinal herbs in Jordan. Biomed. Pharmacol. J. 2019. 12, 211-217. DOI: 10.13005/bpj/1629
[226] Veiko, A.G., Olchowik-Grabarek, E., Sekowski, S., Roszkowska, A., Lapshina, E.A., Dobrzynska, I., Zamaraeva, M., Zavodnik, I.B., Antimicrobial Activity of Quercetin, Naringenin and Catechin: Flavonoids Inhibit Staphylococcus aureus-Induced Hemolysis and Modify Membranes of Bacteria and Erythrocytes. Molecules. 2023, 28, 1252. DOI: 10.3390/molecules28031252
[227] Dezsi, Ş., Bădărău, A.S., Bischin, C., Vodnar, D.C., Silaghi-Dumitrescu, R., Gheldiu, A.M., Mocan, A., Vlase, L., Antimicrobial and antioxidant activities and phenolic profile of Eucalyptus globulus Labill. and Corymbia ficifolia (F. Muell.) K.D. Hill & L.A.S. Johnson leaves. Molecules. 2015, 20, 4720-4234. DOI: 10.3390/molecules20034720

[228] Pereira, V., Dias, C., Vasconcelos, M.C., Rosa, E., Saavedra, M.J., Antibacterial activity and synergistic effects between Eucalyptus globulus leaf residues (essential oils and extracts) and antibiotics against several isolates of respiratory tract infections (Pseudomonas aeruginosa). Ind. Crops Prod. 2014, 52, 1-7. DOI: 10.1016/j.indcrop.2013.09.032
[229] Morris, C.E., Monier, J., Jacques, M., Methods for observing microbial biofilms directly on leaf surfaces and recovering them for isolation of culturable microorganisms. Appl. Environ. Microbiol. 1997, 63, 1570-1576. DOI: 10.1128/aem.63.4.1570-1576.1997
[230] Boureau, T., Jacques, M.A., Berruyer, R., Dessaux, Y., Dominguez, H., Morris, C.E., Comparison of the phenotypes and genotypes of biofilm and solitary epiphytic bacterial populations on broad-leaved endive. Microb. Ecol. 2004, 47, 87-95. DOI: 10.1007/s00248-002-0106-4
[231] Susanti, D., Haris, M.S., Taher, M., Khotib, J., Natural products-based metallic nanoparticles as antimicrobial agents. Front. Pharmacol. 2022, 13, 895616. DOI: 10.3389/fphar.2022.895616
[232] El-Desouky, T.A., El Sayed, T.I., Abd El Aziz, A.M., Mostafa, R.M., El-Sayed, A.S., Control for Mycotoxigenic Fungi by Nanosilver Synthesised by Wild Plants Extracts. J. Bioprocess. Biotech. 2022, 12, 496. DOI: 10.37421/2155-9821.2022.12.496
[233] Sulthana, R.N., Rajanikanth, A., Green Synthesis of Silver Nanoparticles Using Seed Extract of Foeniculum vulgare and their Antibacterial Activity. Int. J. Curr. Res. Biosci. Plant Biol. 2018, 5, 77-83. DOI: 10.20546/ijcrbp.2018.507.010
[234] Salari, P., Moghaddam, M.G., Bahreini, M., Sharifmoghadam, M.R., Green synthesis of ZnO nanoparticles from Foeniculum vulgare Mill. seed extract and its antibacterial effects on foodborne bacteria. J. Med. Plants. 2023, 22, 14-26. DOI: 10.61186/jmp.22.86.14
[235] Allafchian, A.R., Farhang, H.R., Jalali, S.A., Vahabi, M.R., Gundelia tournefortii L.: a natural source for the green synthesis of silver nanoparticles. IET Nanobiotechnol. 2017, 11, 815–820. DOI: 10.1049/iet-nbt.2017.0062
[236] Baran, M.F., Koç, A., Uzan, S., Synthesis, characterization and antimicrobial applications of silver nanoparticles (AgNPs) with Kenger (Gundelia tournefortii) leaf. EJONS Int. J. Math. Eng. Nat. Sci. 2018, 5, 44-52. [Google Scholar]
[237] Han, S., Ahmeda, A., Jalalvand, A.R., Lu, W., Zangeneh, M.M., Zangeneh, A., Application of silver nanoparticles containing Gundelia tournefortii L. leaf aqueous extract in the treatment of microbial diseases and cutaneous wound healing. Appl. Organometal. Chem. 2020, 36, e5491. DOI: 10.1002/aoc.5491
[238] Zhaleh, M., Zangeneh, A., Goorani, S., Seydi, N., Zangeneh, M.M., Tahvilian, R., Elham Pirabbasi, E., In vitro and in vivo evaluation of cytotoxicity, antioxidant, antibacterial, antifungal, and cutaneous wound healing properties of gold nanoparticles produced via a green chemistry synthesis using Gundelia tournefortii L. as a capping and reducing agent. Appl. Organometal. Chem. 2019, 33, e5015. DOI: 10.1002/aoc.5015
[239] Keskin, C., Baran, A., Baran, M.F., Hatipoğlu, A., Adican, M.T., Atalar, M.N., Huseynova, I., Khalilov, R., Ahmadian, E., Yavuz, Ö. and Kandemir, S.İ., Eftekhari, A., Green synthesis, characterization of gold nanomaterials using Gundelia tournefortii leaf extract, and determination of their nanomedicinal (antibacterial, antifungal, and cytotoxic) potential. J. Nanomater. 2022, 7211066. DOI: 10.1155/2022/7211066
[240] Mehdizadeh, S., Ghasemi, N., Ramezani, M., Mahanpoor, K., Biosynthesis of Silver Nanoparticles Using Malva Sylvestris Flower Extract and Its Antibacterial and Catalytic Activity, Chem. Methodol., 2021, 5, 356-366. DOI: 10.22034/chemm.2021.132490
[241] Sadeghi-Kiakhani, M., Tehrani-Bagha, A.R., Miri, F.S., Hashemi, E., Safi, M., Eco-Friendly Procedure for Rendering the Antibacterial and Antioxidant of Cotton Fabrics via Phyto-Synthesized AgNPs With Malva sylvestris (MS) Natural Colorant. Front. Bioeng. Biotechnol. 2022, 9, 814374. DOI: 10.3389/fbioe.2021.814374
[242] Mousavi, S.M., Hashemi, S.A., Zarei, M., Bahrani, S., Savardashtaki, A., Esmaeili, H., Lai, C.W., Mazraedoost, S., Abassi, M., Ramavandi, B., Data on cytotoxic and antibacterial activity of synthesized $Fe_3O_4$ nanoparticles using Malva sylvestris. Data Brief. 2019, 28, 104929. DOI: 10.1016/j.dib.2019.104929
[243] Kubo, I., Fujita, K., Kubo, A., Nihei, K., Ogura, T., Antibacterial Activity of Coriander Volatile Compounds againstSalmonella choleraesuis. J. Agric. Food Chem. 2004, 52, 3329–3332. DOI:10.1021/jf0354186
[244] Abdelbaky, A.S., Mohamed, A.M., Abd El-Mageed, T.A., Rady, M.M., Alshehri, F., El-Saadony, M.T., Abu Qamar, S.F., El-Tarabily, K.A., Al-Elwany, O.A., Bio-organic fertilizers promote yield, chemical composition, and antioxidant and antimicrobial activities of essential oil in fennel (Foeniculum vulgare) seeds. Sci. Rep. 2023, 13, 13935. DOI: 10.1038/s41598-023-40579-7

[245] Abdellaoui, M., Derouich, M., El-Rhaffari, L., Essential oil and chemical composition of wild and cultivated fennel (Foeniculum vulgare Mill.): a comparative study. S. Afr. J. Bot. 2020, 135, 93-100. DOI: 10.1016/j.sajb.2020.09.004
[246] Zein, S., Awada, S., Rachidi, S., Hajj, A., Krivoruschko, E., Kanaan, H., Chemical analysis of essential oil from Lebanese wild and cultivated Origanum syriacum L. (Lamiaceae) before and after flowering. J. Med. Plants Res. 2011, 5, 379-387. [ResearchGate]
[247] Abu-Lafi, S., Odeh, I., Dewik, H., Qabajah, M., Dembitsky, V.M., Hanuš, L.O., Diverse Terpenoids and Phenolic Compounds Extracted from Leaves of Majorana syriaca Growing Wild in Palestine, J. Herb. Spices Med. Plants. 2009, 15, 272-280. DOI: 10.1080/10496470903378987
[248] Abu-Lafi, S., Odeh, I., Dewik, H., Qabajah, M., Hanus, L.O., Dembitsky, V.M., Thymol and carvacrol production from leaves of wild Palestinian Majorana syriaca. Bioresour. Technol. 2008, 99, 3914-3918. DOI: 10.1016/j.biortech.2007.07.042
[249] Dincer, C., Topuz, A., Sahin-Nadeem, H., Ozdemir, K.S., Cam, I.B., Tontul, I., Gokturk, R.S., Ay, S.T., A comparative study on phenolic composition, antioxidant activity and essential oil content of wild and cultivated sage (Salvia fruticosa Miller) as influenced by storage. Ind. Crops Prod. 2012, 39, 170-176. DOI: 10.1016/j.indcrop.2012.02.032
[250] Alqarni, M.H., Salkini, A.A., Abujheisha, K.Y., Daghar, M.F., Al-khuraif, F.A., Abdel-Kader, M.S., Qualitative, quantitative and antimicrobial activity variations of the essential oils isolated from Thymus vulgaris and Micromeria fruticosa samples subjected to different drying conditions. Arab. J. Sci. Eng. 2022, 47, 6861-6867. DOI: 10.1007/s13369-021-06469-8
[251] Yousefi, M., Mizani, M., Rasouli, S., Sharifan, A., Bameni Moghadam, M., Optimization of deheating process of yellow mustard (Sinapis alba) by response surface methodology and desirability function. Int. J. Biosci. 2014, 5, 147-155. DOI: 10.12692/ijb/5.9.147-155
[252] Hosseinvand, A., Sorkhinejad, A., Evaluation of Mustard Powder as Natural Ingredient to reduce Antimicrobial levels and Physichochemical properties in Beef. Madridge J. Food Technol. 2019, 4, 170-175. DOI: 10.18689/mjft-1000126
[253] Shofran, B.G., Purrington, S.T., Breidt, F., Fleming, H.P., Antimicrobial properties of sinigrin and its hydrolysis products. J. Food Sci. 1998, 63, 621-624. DOI: 10.1111/j.1365-2621.1998.tb15798.x
[254] Popova, I.E., Morra, M.J., Simultaneous quantification of sinigrin, sinalbin, and anionic glucosinolate hydrolysis products in Brassica juncea and Sinapis alba seed extracts using ion chromatography. J. Agric. Food Chem. 2014, 62, 10687-10693. DOI: 10.1021/jf503755m
[255] Timmerer, U., Lehmann, L., Schnug, E., Bloem, E., Toxic Effects of Single Antibiotics and Antibiotics in Combination on Germination and Growth of Sinapis alba L. Plants (Basel). 2020, 9, 107. DOI: 10.3390/plants9010107
[256] Lietzow, J., Biologically Active Compounds in Mustard Seeds: A Toxicological Perspective. Foods. 2021, 10, 2089. DOI: 10.3390/foods10092089
[257] Zoller, O., Brüschweiler, B.J., Magnin, R., Reinhard, H., Rhyn, P., Rupp, H., Zeltner, S., Felleisen, R., Natural occurrence of bisphenol F in mustard. Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 2016, 33, 137-146. DOI: 10.1080/19440049.2015.1110623
[258] Kaspate, D., Saldanha, T., Narkhede, S., Karmarkar, B., Shah, K., Acute oral toxicity of Sinapis alba in swiss albino mice. Asian J. Pharm. Clin. Res. 2015, 8, 182-184. [ResearchGate]
[259] Leite-Andrade, M.C., de Araújo Neto, L.N., Buonafina-Paz, M.D., de Assis Graciano dos Santos, F., da Silva Alves, A.I., de Castro, M.C.A.B., Mori, E., de Lacerda, B.C., Araújo, I.M., Coutinho, H.D., Kowalska, G., Kowalski, R., Baj, B., Pereira Neves, R., Antifungal Effect and Inhibition of the Virulence Mechanism of D-Limonene against Candida parapsilosis. Molecules. 2022, 27, 8884. DOI: /10.3390/molecules27248884
[260] Han, Y., Sun, Z., Chen, W., Antimicrobial Susceptibility and Antibacterial Mechanism of Limonene against Listeria monocytogenes. Molecules. 2019, 25, 33. DOI: 10.3390/molecules25010033
[261] Lee, Y-g., Lee, J., Chun, P., Real-world Adverse Events Associated with Fluconazole and Itraconazole: Analysis of Nationwide Data Using a Spontaneous Reporting System Database. Korean J. Clin. Pharm. 2022, 32, 204-214. DOI: 10.24304/kjcp.2022.32.3.204
[262] Escribano, P., Guinea, J., Fluconazole-resistant Candida parapsilosis: A new emerging threat in the fungi arena. Front. Fungal Biol. 2022, 3, 1010782. DOI: 10.3389/ffunb.2022.1010782
[263] Selby, N.M., Shaw, S., Woodier, N., Fluck, R.J., Kolhe, N.V., Gentamicin-associated acute kidney injury. QJM. 2009, 102, 873-880. DOI: 10.1093/qjmed/hcp143
[264] Hanes, R.M., Huang, Z., Investigation of Antimicrobial Resistance Genes in Listeria monocytogenes from 2010 through to 2021. Int. J. Environ. Res. Public Health. 2022, 19, 5506. DOI: 10.3390/ijerph19095506

[265] Díaz, K., Espinoza, L., Madrid, A., Pizarro, L., Chamy, R., Isolation and Identification of Compounds from Bioactive Extracts of Taraxacum officinale Weber ex F. H. Wigg. (Dandelion) as a Potential Source of Antibacterial Agents. Evid. Based Complement. Alternat. Med. 2018, 2018:2706417. DOI: 10.1155/2018/2706417

[266] Javed, T., Ashfaq, U.A., Riaz, S., Rehman, S., Riazuddin, S., In-vitro antiviral activity of Solanum nigrum against Hepatitis C Virus. Virol. J. 2011, 8, 26. DOI: 10.1186/1743-422X-8-26

[267] Gavanji, S., Bakhtari, A., Baghshahi, H., Chamgordani, Z.H., Sadeghi, A., Antibacterial Effect of Allium ampeloprasum and Allium porrum Extracts on Staphylococcus aureus and Pseudomonas aeruginosa. J. Pharmacopuncture. 2023, 26, 53-59. DOI: 10.3831/KPI.2023.26.1.53

[268] AlMousa, L.A., AlFaris, N.A., Alshammari, G.M., ALTamimi, J.Z., Alsyadi, M.M., Alagal, R.I., Yahya, M.A., Antioxidant and antimicrobial potential of two extracts from Capparis spinosa L. and Rumex nervosus and molecular docking investigation of selected major compounds. Saudi J. Biol. Sci. 2022, 29, 103346. DOI: 10.1016/j.sjbs.2022.103346

[269] Rizwana, H., Alwhibi, M.S., Soliman, D.A., Research article antimicrobial activity and chemical composition of flowers of Matricaria aurea a native herb of Saudi Arabia. Int. J. Pharmacol. 2016, 12, 576-586. DOI: 10.3923/ijp.2016.576.586

[270] Liu, G., Liu, A., Yang, C., Zhou, C., Zhou, Q., Li, H., Yang, H., Mo, J., Zhang, Z., Li, G., Si, H., Ou, C., Portulaca oleracea L. organic acid extract inhibits persistent methicillin-resistant Staphylococcus aureus in vitro and in vivo. Front. Microbiol. 2023, 13, 1076154. DOI: 10.3389/fmicb.2022.1076154

[271] Abu-Lafi, S., Rayan, M., Masalha, M., Abu-Farich, B., Al-Jaas, H., Abu-Lafi, M., Rayan, A., Phytochemical Composition and Biological Activities of Wild Scolymus maculatus L. Medicines (Basel). 2019, 6, 53. DOI: 10.3390/medicines6020053