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Chamomile Oil

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19.1 Introduction

Chamomile (*Matricaria chamomilla* L.) is one of the important medicinal herbs that is native to southern and eastern Europe. It is also grown in Germany, Hungary, France, Russia, Yugoslavia, and Brazil. It was introduced to India during the Mughal period. Now it is grown in Punjab, Uttar Pradesh, Maharashtra, Jammu, and Kashmir. The plant is found in North Africa, Asia, North and South America, Australia, and New Zealand [1]. Hungary is the main producer of the plant biomass. In Hungary, it grows abundantly in poor soils and is a source of income to poor inhabitants of these areas. Flowers are exported to Germany in bulk for distillation of the oil [2]. In India, the plant had been cultivated in Lucknow for about 200 years, and it was introduced in Punjab about 300 years ago. It was introduced in Jammu in 1957 by Handa et al. [3]. The plant was first introduced in the alkaline soils of Lucknow in 1964–1965 by Chandra et al. [4,5]. There is no demand for blue oil as such at present in India. However, flowers of chamomile are in great demand. Presently, two firms cultivating chamomile exist: M/S Ranbaxy Labs Limited, New Delhi, and M/S German Remedies. The latter is the main grower of chamomile flowers. Chamomile has been used in herbal remedies for thousands of years. It was known in ancient Egypt, Greece, and Rome [6]. This herb has been believed by Anglo-Saxons to be one of the nine sacred herbs given to humans by the Lord [7]. The chamomile drug is included in the pharmacopoeia of 26 countries [8]. It is an ingredient of several traditional, unani, and homeopathy medicinal preparations [9–12]. As a drug, it finds use in flatulence, colic, hysteria, and intermittent fever [13]. The flowers of *M. chamomilla* contain the blue essential oil at 0.2%–1.9% [14,15], which finds a variety of uses. Chamomile is used mainly as an anti-inflammatory and antiseptic medicine, but also as an antispasmodic and mild sudorific [16]. It is used internally mainly as a tisane (infuse 1 tablespoonful of the drug in 1 L of cold water and do not heat) for disturbance of the stomach associated with pain, for sluggish digestion, and for diarrhea and nausea; it is used more rarely and very effectively for inflammation of the urinary tract and for painful menstruation. Externally, the drug in powder form may be applied to wounds slow to heal; for skin eruptions and infections, such as shingles and boils; for haemorrhoids; and for inflammation of the mouth, throat, and eyes [17]. Tabulated products from chamomile flower extracts are marketed in Europe and used for various ailments. Chamomile tea eye washing can induce allergic conjunctivitis. Pollen of *M. chamomilla* contained in these infusions is the allergen responsible for these reactions [18]. Antonelli quoted from writings of several doctors of the sixteenth and seventeenth centuries that chamomile was used in those times in intermittent fevers [19]. Gould et al. have evaluated the hemodynamic effects of chamomile tea in patients with cardiac disease [20]. It was found in general that the patients fell into a deep sleep after taking the beverage. Pasechnik reported that infusion prepared from *M. chamomilla* exercised a marked stimulatory action on the secretary function of the liver [21]. Gayar and Shazli reported toxicity of acetone extract of *M. chamomilla* against larvae of *Culex pipens* L. [22]. The other pharmacological properties include anti-inflammatory, antiseptic, carminative, healing, sedative, and spasmolytic activities [23]. However, *M. chamomilla* has exhibited both positive and negative bactericidal activity with *Mycobacterium tuberculosis*, *Salmonella typhimurium*, and *Staphylococcus aureus*. The international demand for chamomile oil has been steadily growing. As a result, the plant is widely cultivated in Europe and has been introduced in some Asian countries for the production of its essential oil. *M. chamomilla* L., *Anthemis nobilis* L., and *Ormenis multicaulis* Braun Blanquet and Maire, belonging to the family Asteraceae, are a natural and major source of "blue oil" and flavonoids. The oil is used as a mild sedative and for digestion [20,24–29], besides being antibacterial and fungicidal in action [20]. In addition to pharmaceutical uses, the oil is extensively used in perfumery, cosmetics, and aromatherapy, as well as in the food industry [27,30–33]. Gowda et al. studied that the essential oil present in the flower heads contains azulene and is used in perfumery, cosmetic creams, hair preparations, skin lotions, toothpastes, and fine liquors [34]. The dry flowers of chamomile are also in great demand for use in herbal tea and baby massage oil, for promoting the gastric flow of secretion, and for the treatment of cough and cold [35]. The use of herbal tea preparations eliminated colic in 57% of infants [36]. Because of its extensive pharmacological and pharmaceutical properties, the plant possesses great economic value and is in great demand in European countries.

19.2 Botany of the Plant

True chamomile is an annual plant with thin spindle-shaped roots only, penetrating flatly into the soil. The branched stem is erect and heavily ramified, and grows to a height of 10–80 cm. The long and narrow leaves are bi- to tripinnate. The flower heads are placed separately; they have a diameter of 10–30 mm and are pedunculate and heterogamous. The golden-yellow tubular florets with five teeth are 1.5–2.5 mm long, always ending in a glandulous tube. The 11–27 white plant flowers are 6–11 mm long, 3.5 mm wide, and arranged concentrically. The receptacle is 6–8 mm wide, flat in the beginning and conical, cone shaped later, hollow—the latter being a very important distinctive characteristic of

Matricaria, and without paleae. The fruit is a yellowish-brown achene. The true chamomile is very often confused with plants of the genera *Anthemis*. Special attention has to be paid to avoid confusion with *Anthemis cotula* L., a poisonous plant with a revolting smell. In contrast to true chamomile, *A. cotula*, similar to *Anthemis arvensis* L. and *Anthemis austriaca* Jacq., has setiform, prickly pointed paleae, and a filled receptacle. The latter species are nearly odorless [37]. Although the systematic status is quite clear nowadays, there are a number of inaccuracies concerning the names. Apart from misdeterminations and confusion, the synonymous use of the names *Anthemis*, *Chamomilla*, and *Matricaria* leads to uncertainty with regard to the botanical identification. Moreover, the nomenclature is complicated by the fact that Linnaeus made mistakes in the first edition of his *Species Plantarum* that he corrected later on. The best-known botanical name for true chamomile is *Matricaria recutita* (syn. *M. chamomilla* and *Chamomilla recutita* (L.) Rauschert), belonging to the genus *Chamomilla* and family Asteraceae [37]. *M. chamomilla* is a diploid species ($2n = 18$), allogamous in nature, exhibiting wide segregation as a commercial crop. Chamomile, a well-known old-time drug, is known by an array of names, such as baboonig, babuna, babuna camornile, babunj, German chamomile, Hungarian chamomile, Roman chamomile, English chamomile, camomilla, flos chamomile, single chamomile, sweet false chamomile, pinheads, and scented mayweed, suggesting its widespread use [38,39]. The three plants, namely, *A. nobilis* Linn, *Corchorus depressus* Linn, and *M. chamomilla* Linn, are reported under one unani name, *babuna*, at different places in the literature. This created a lot of confusion and misuse of the drug as an adulterant and so forth. Ghauri et al. conducted a detailed taxonomic and anatomical study and concluded that babuna belongs to the family Compositae (Asteraceae) and the correct scientific name of babuna is *M. chamomilla* L. [40].

19.3 Methods of Extraction of Chamomile Oil

Extraction of essential oils was performed using hydrodistillation of dried samples of flower heads using a Clevenger-type apparatus over 3 h. The oils were dried over sodium sulfate. Early efforts at extraction used alcohol and a fermentation process. New methods of essential oil extraction are entering the mainstream of aromatherapy, offering new choices in oils never before available. With the new labels of supercritical CO_2, along with the traditional steam and hydrodistillations, “absolutes,” and cold pressing, a little education for the aromatherapy enthusiast can go a long way in essential oil selection. Is one process better than another? Does one produce a nicer-smelling oil, or one with greater aromatherapeutic value? It turns out that essential oil production, like winemaking, is an art form, as well as a science. The way in which oils are extracted from plants is important because some processes use solvents that can destroy the therapeutic properties. Some plants, particularly flowers, do not lend themselves to steam distilling. They are too delicate, or their fragrance and therapeutic essences cannot be completely released by water alone. These oils will be produced as absolutes—and while not technically considered essential oils, they can still be of therapeutic value. Jasmine oil and rose oil, in particular, are delicate flowers whose oils are often found in absolute form. The value of the newer processing methods depends greatly on the experience of the distiller, as well as the intended application of the final product. Each method is important, and has its place in the making of aromatherapy-grade essential oils. Some of the few methods for extractions of essential oils are given below:

- *Maceration*: Maceration actually creates more of an "infused oil" than an essential oil. The plant matter is soaked in vegetable oil, heated, and strained, at which point it can be used for massage.
- *Cold pressing*: Cold pressing is used to extract the essential oils from citrus rinds such as orange, lemon, grapefruit, and bergamot. This method involves the simple pressing of the rind at about 120°F to extract the oil. The rinds are separated from the fruit, are ground or chopped, and are then pressed. The result is a watery mixture of essential oil and liquid that will separate given time. Little, if any, alteration from the oil's original state occurs—these citrus oils retain their bright, fresh, uplifting aromas, like that of smelling a wonderfully ripe fruit. It is important to note that oils extracted using this method have a relatively short shelf life, so make or purchase only what you will be using within the next 6 months.
- *Solvent extraction*: A hydrocarbon solvent is added to the plant material to help dissolve the essential oil. When the solution is filtered and concentrated by distillation, a substance containing resin (resinoid) or a combination of wax and essential oil (known as concrete) remains. From the concentrate, pure alcohol is used to extract the oil. When the alcohol evaporates, the oil is left behind. This is not considered the best method for extraction, as the solvents can leave a small amount of residue behind, which could cause allergies and effect the immune system.
- *Enfleurage*: This is an intensive and traditional way of extracting oil from flowers. The process involves layering fat over the flower petals. After the fat has absorbed the essential oils, alcohol is used to separate and extract the oils from the fat. The alcohol is then evaporated and the essential oil collected.
- *Hydrodistillation*: Some processes become obsolete to carry out extraction, like hydrodistillation, which is often used in primitive countries. The risk is that the still can run dry, or be overheated, burning the aromatics and resulting in an essential oil with a burnt smell. Hydrodistillation seems to work best for powders (i.e., spice powders and ground wood) and very tough materials, like roots, wood, or nuts.
- *Supercritical fluid extraction*: This modern technique involves the use of carbon dioxide as the "solvent" that carries the essential oil away from the raw plant material. Carbon escapes in its gaseous form, leaving the essential oil behind.
- *Turbo distillation extraction*: Turbo distillation is suitable for hard-to-extract or coarse plant material, such as bark, roots, and seeds. In this process, the plants soak in water and steam is circulated through this plant and water mixture. Throughout the entire process, the same water is continually recycled through the plant material. This method allows faster extraction of essential oils from hard-to-extract plant materials.
- *Steam distillation*: Most commonly, the essence is extracted from the plant using a technique called distillation. One type of distillation places the plants or flowers on a screen. Steam is passed through the area and becomes "charged" with the essence. The steam then passes through an area where it cools and condenses. This mixture of water and essential oil is separated and bottled. Since plants contain such a small amount of this precious oil, several hundred pounds may be needed to produce a single ounce.

19.4 Methods of Analysis of Chamomile Oil

Gas chromatography (GC) is one of the best techniques to identify the constituents of an essential oil. When properly used, it can easily detect and identify major components of essential oils, and give some indications of the quality and authenticity of the oil. The technique does have limitations, however. Many minor components of essential oils (<0.01%) do not register on GC detector systems. The separation of essential oil components is usually carried out by GC with fused-silica capillary columns. The properties and conditions of columns used are variable, depending on the polarity of the components to be separated. It is advantageous to use a more selective phase for a given separation, as the overlapping of peaks in the final chromatogram is often a significant drawback of chromatographic techniques in natural samples. The discovery of chiral phases (mostly based on cyclodextrin derivatives) allows the resolution of enantiomers of volatile components. These phases can give different elution sequences for a polarity range and provide a distinct advantage in identification because of large changes in solute relative retention times. The information obtained from high-resolution GC analysis of the volatile fraction of essential oils must be sufficient to determine whether the product is genuine. If the product is adulterated, the kind and level of adulteration must be detected. Therefore, a selective and accurate separation is absolutely necessary in the case of industrial analysis. On the other hand, GC sometimes permits the separation and further identification of some components of the nonvolatile residue as well.

19.5 Composition of Chamomile Oil

Different cultivars have different amounts of active components. However, their chemical composition is affected by the local ecological conditions and the cultivation method [41]. A study of the main sesquiterpenes of chamomile essential oil revealed the major components to be chamazulene (19.9%), α-bisabolol (20.9%), A and B α-bisabolol oxides (21.6% and 1.2%, respectively), and β-farnesene (3.1%). Among the minor components was spathulenol [42]. An Iranian experiment studied four cultivars of German chamomile, Bodegold (tetraploid), Germania (diploid), Bona (diploid), and Goral (tetraploid). The results showed that the plant heights of Goral and Bodegold were significantly higher than those of Germania and Bona. Goral produced the highest anthodia yield. The lowest dry anthodia yield was produced by Bona. The highest essential oil content (0.627% w/w) was extracted from Bona in the first harvest, but Germania produced the lowest essential oil content (0.627% w/w) at the third harvest. The chamazulene content of the cultivars ranged between 9.6% and 14% [43]. The essential oils of *M. recutita* L. cultivated in Estonia were isolated, and 37 components were identified. The main components were α-bisabolol oxide A (20%–33%) and B (12%–85%), bisabolone oxide A (14%–75%), (E)-farnesene (13%–45%), α-bisabolol (14%–85%), chamazulene (7%–55%), and en-yn-dicycloether (22%–175%) [44]. A recent investigation in Estonia indicated that the main constituents of the essential oils were as follows: α-bisabolol oxide A (39.4%), bisabolone oxide A (13.9%), (Z)-en-yne-dicycloether (11.5%), α-bisabolol oxide B (9.9%), α-bisabolol (5.6%), and chamazulene (4.7%) [45]. A study regarding the responses of young plants of diploid and tetraploid *M. chamomilla* cultivars to abiotic stress (within an interval from 6 h before to 54 h after spraying the leaf rosettes with aqueous $CuCl_2$ solution) revealed that the content of herniarin in the treated plants rose approximately three times. The highest amounts of umbelliferone in stressed plants exceeded 9 times and 20 times those observed in control plants of the tetraploid and diploid cultivars, respectively. Due to stress, the concentration of en-yn-dicycloether in leaves decreased by more than 40% [46]. An Iranian study in Isfahan indicated essential oil components of German chamomile isolated by hydrodistillation of the aerial parts of the plant. Sixty-three components were characterized, representing 86.21% of the total oil components detected; α-bisabolol oxides A (25.01%) and B (9.43%), spathulenol (8.49%), *cis*-en-yn-dicycloether (7.42%), and α-24-bisabolene oxide A (7.17%) were the major constituents of the oil. Chamazulene represented 3.28%, and α-bisabolol 6.01% [47].

19.6 Physical and Chemical Properties of Oil

The chemical and physical properties of *Chamomilla recutita* (*matricaria*) flower oil are included in Table 19.1. Information on the other 10 ingredients was not found, nor was unpublished information provided.

19.7 General Use of Chamomile Oil

Traditionally, chamomile has been used for centuries as an anti-inflammatory, antioxidant, mild astringent, and healing medicine [50]. As a traditional medicine, it is used to treat wounds, ulcers, eczema, gout, skin irritations, bruises, burns, canker sores, neuralgia, sciatica, rheumatic pain, hemorrhoids, mastitis, and other ailments [51,52]. Externally, chamomile has been used to treat diaper rash; cracked nipples; chicken pox; ear and eye infections; disorders of the eyes, including blocked tear ducts; conjunctivitis; nasal inflammation; and poison ivy [53,54]. Chamomile is widely used to treat inflammations of the skin and mucous membranes, and for various bacterial infections of the skin, oral cavity

TABLE 19.1

Chemical and Physical Properties of Chamomile

Properties	*Chamomilla recutita* (*matricaria*) Oil
Form	Deep blue or blue-green liquid with strong, characteristic odor
Specific gravity	Between 0.910 and 0.950
Refractive index solubility	Soluble in most fixed oils and in propylene glycol; insoluble in glycerine and in mineral oil
Acid value	Between 5 and 50 mg of KOH/g of oil
Ester value	Between 65 and 155 mg of KOH/g of oil
Saponification number	≈43
UV absorption maximum	285 nm

Source: Pauli, A., *Int. J. Essent. Oil*, 2(2), 60–68, 2008; U.S. Pharmacopeial Convention, *Food Chemicals Codex*, 6th ed., U.S. Pharmacopeial Convention, Rockville, MD, 2009.

and gums, and respiratory tract. Chamomile in the form of an aqueous extract has been frequently used as a mild sedative to calm nerves and reduce anxiety, and to treat hysteria, nightmares, insomnia, and other sleep problems [55]. Chamomile has been valued as a digestive relaxant and has been used to treat various gastrointestinal disturbances, including flatulence, indigestion, diarrhea, anorexia, motion sickness, nausea, and vomiting [56,57]. Chamomile has also been used to treat colic, croup, and fevers in children [58]. It has been used as an emmenagogue and a uterine tonic in women. It is also effective in arthritis, back pain, bedsores, and stomach cramps.

19.8 Use as a Pesticide

Chamomile oil is volatile, which means it has the ability to vaporize at room temperature. One of the methods to determine the suitability of the chamomile drug is to determine the amount of essential oil or volatile oil content in it. To determine the total volatile component in the chamomile flowers, the flowers are steam distilled in a Clevenger-type apparatus. The volume of the oil distilled per 100 g of flowers is expressed in percentage. This percentage indicates the total volatile oil content. The lousicidal and repellent effects of five essential oils, camphor (*Cinnamomum camphora*), onion (*Allium cepa*), peppermint (*Mentha piperita*), chamomile (*M. chamomilla*), and rosemary (*Rosmarinus officinalis*) oils, were investigated for the first time against the buffalo louse, *Haematopinus tuberculatus*, and flies infesting water buffaloes in Qalyubia Governorate, Egypt [59]. For *in vitro* studies, filter paper contact bioassays were used to test the oils and their lethal activities were compared with that of *d*-phenothrin. Four minutes posttreatment, the median lethal concentration (LC50) values were 2.74%, 7.28%, 12.35%, 18.67%, and 22.79% for camphor (*C. camphora*), onion (*A. cepa*), peppermint (*M. piperita*), chamomile (*M. chamomilla*), and rosemary (*R.officinalis*) oils, respectively, whereas for *d*-phenothrin, it was 1.17%. The lethal time (LT50) values were 0.89, 2.75, 15.39, 21.32, 11.60, and 1.94 min after treatment with 7.5% camphor, onion, peppermint, chamomile, rosemary, and *d*-phenothrin, respectively. All the materials used except rosemary, which was not applied, were ovicidal to the eggs of *H. tuberculatus*. Despite the results of the *in vitro* assays, the *in vivo* treatments revealed that the pediculicidal activity was more pronounced with oils. All treated lice were killed after 0.5–2 min, whereas with *d*-phenothrin, 100% mortality was reached only after 120 min. The number of lice infesting buffaloes was significantly reduced 3, 6, 4, 6, and 9 days after treatment with camphor, peppermint, chamomile, onion, and *d*-phenothrin, respectively. Moreover, the oils and *d*-phenothrin significantly repelled flies, *Musca domestica*, *Stomoxys calcitrans*, *Haematobia irritans*, and *Hippobosca equina*, for 6 and 3 days posttreatment, respectively. No adverse effects were noted on either animals or pour-on operators after exposure to the applied materials.

Seven essential oils of *C. camphora*, *Cymbopogon winterianus*, *M. chamomilla*, *Mentha viridis*, *Prunus amygdalus* var. *amara*, *R. officinalis*, and *Simmondsia chinensis* were evaluated in the laboratory for their toxicities and repellent effectiveness against adults of the sawtoothed grain beetle, *Oryzaephilus surinamensis* (L.), and rust-red flour beetle, *Tribolium castaneum* (Herbst) [60]. Five concentrations of every essential oil (0.125%, 0.25%, 0.5%, 0.75%, and 1%) were tested. Adult beetles were exposed to the treated wheat for 2 weeks. Percent mortality was recorded after 3 days, 1 week, and 2 weeks from exposure. The repellent action of the previous essential oils was also studied using the same concentrations used in toxicity tests. Results showed that complete mortality of *O. surinamensis* was achieved by *M. viridis*, *M. chamomilla*, and *C. camphora* at concentrations more than 0.5%, although 1% *P. amygdalus* or *C. winterianus* resulted in complete mortality of *T. castaneum* after 2 weeks of exposure. Conversely, *R. officinalis* was the least toxic to both insect species. The rest of the essential oils gave adequate toxicity to both insect species. A pronounced increase of mortality was observed for most of the essential oils with increasing time of exposure. *T. castaneum* was less susceptible to tested oils than *O. surinamensis*. Moreover, *M. chamomilla* exhibited a high repellency of 81.94% and 84.73% at 1% concentration against *O. surinamensis* and *T. castaneum*, respectively.

The lesser grain borer, *Rhyzopertha dominica*, is a major insect pest of stored grain in the tropics. Vegetable oils (chamomile, sweet almond, and coconut) at 2.5, 3.5, 5.0, 7.0, and 10.0 ml/kg were tested against *R. dominica* (F.) in wheat grain. All bioassays were conducted at 30°C and 65% ± 2% relative humidity (RH). Treatments with vegetable oils at a high dose (10.0 ml/kg) achieved more than 95% control within 24 h of exposure to freshly treated grain. There was little difference between the three oils in their effect. The persistence of the oils in grains was tested at short-term storage intervals (48, 72, and 96 h) and intermediate-term intervals (10, 20, and 30 days) after treatments. The activity of all products decreased with storage period. Seed viability was reduced by a high dose rate (10.0 ml/kg) of oil treatments. The potential of acaricidal activity of chamomile flower extract was studied against engorged *Rhipicephalus annulatus* tick under laboratory condition [61]. For this purpose, the engorged females of *R. annulatus* were exposed to twofold serial dilutions of chamomile flower extract (0.5%, 1.0%, 2.0%, 4.0%, and 8.0%) using the "dipping method" *in vitro*. The engorged ticks were immersed in different plant dilutions (five ticks for each dilution) for 1 min, and they were immediately incubated in separate Petri dishes for each replicate at 26°C and 80% relative humidity. The mortality rate for each treatment was recorded 5 days after incubation.

The mortality rate caused by different dilutions of chamomile flower extract ranged from 6.67% to 26.7%, whereas no mortality was recorded for the nontreated control group. The mass of produced eggs varied from 0.23 g (in 8.0% solution) to 0.58 g (in control), with no statistical differences between the treatments and control ($p > 0.05$). Also, the chamomile flower extract in the highest concentration used (8.0%) caused 46.67% failure in egg laying in engorged females, while no failure was observed for the nontreated control group. Macroscopic observations indicated that in effective concentrations of plant (4.0% and 8.0%), patchy hemorrhagic swelling appeared on the skin of treated ticks. Pesticide residues are found in chamomile drug due to agricultural practices during cultivation. The pesticide residues usually have compounds such as chlorinated hydrocarbons or sulfur-containing dithiocarbamate or organophosphorus. These can be detected by column chromatography (CC) and GC. A purified chamomile extract is specifically prepared for the detection of the pesticide residues in it by GC. Abdel-Gawad et al. [62] suggested that the insecticide ^{14}C-ethion could be satisfactorily eliminated from the essential oil of chamomile if adsorbents such as calcium oxide and sawdust were added during the distillation process. Such methods that can efficiently eliminate pesticide residues need to be developed.

19.9 Antibacterial Activity

The extract and essential oil of Roman chamomile flower head showed antibacterial activity against *Porphyromonas gingivalis*. The antimicrobial effects were evaluated by the disk diffusion method. The results indicated that the means of the inhibition zone for chamomile extract and essential oil were 13.33 ± 3.4 and 20.5 ± 0.5, respectively [63]. Two hydroperoxide compounds isolated from *A. nobilis* showed a medium antibacterial activity [64]. The antimicrobial activity of an essential oil of the flower of *A. nobilis* from Provence (France) was tested against various strains of Gram-positive bacteria (*S. aureus* and *Enterococcus faecalis*) and Gram-negative bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*, *Proteus vulgaris*, *Klebsiella pneumoniae*, and *Salmonella* sp.), as well as against the yeast *Candida albicans* using a modified agar dilution and agar diffusion method. In addition, some pure main and minor compounds (chemical composition obtained by means of GC and GC–mass spectrometry [MS] measurements), such as isobutyl angelate (32.1%), 2-methylbutyl angelate (16.2%), isobutyl isobutyrate (5.3%), methyl 2-methylbutyrate (1.9%), prenyl acetate (1.4%), 2-methylbutyl 2-methylbutyrate (1.2%), and 2-methylbutyl acetate (1.2%), were also studied for their antimicrobial effects. The Roman chamomile sample showed high antimicrobial activity against all strains of tested microbes. A similar result was found for 2-methylbutyl 2-methylbutyrate, 2-methylbutyl acetate, and prenyl acetate [65]. The volatile oil of *A. nobilis* showed activity against Gram-positive bacteria, especially *Bacillus subtilis*, *Bacillus anthracis*, *Micrococcus glutamicus*, *Bacillus saccharolyticus*, *Bacillus thuringiensis*, *Sarcina lutea*, *Bacillus*, *Lactobacillus plantarum*, *S. aureus*, *Staphylococcus* sp., and *Lactobacillus casei*, whereas the oil showed no activity against Gram-negative bacteria species, including *Salmonella* group B, *Citrobacter* sp., *Enterobacter* sp., *E. coli*, *Pseudomonas* sp., *Salmonella saintpaul* and *Salmonella weltevreden*. The volatile oil also inhibited the growth of dermatophytons, *Alternaria* sp., *Aspergillus fumigatus*, and *Aspergillus parasiticus*. Volatile oil was inactive against *C. albicans*, *Cryptococcus neoformans*, *Histoplasma capsulatum*, and *Aspergillus niger.* Hydroperoxides (*Z*-2-methyl-2-butyric acid-(2-hydroperoxy-2-methyl-3-butenyl) ester and *Z*-2-methyl-2-butyric acid-(3-hydroperoxy-2-methylidenebutyl) ester), isolated from the ethanolic extract of the *A. nobilis* flowers, showed antibacterial activity against *E. coli*, *P. aeruginosa*, and *E. faecalis*. The minimum inhibitory concentration (MIC) values of the first compound were 256 µg/ml against *E. coli* and 512 µg/ml against *P. aeruginosa*. The MIC values of the second compound were 512 and 128 µg/ml against the same microorganisms, respectively [66]. Volatile oil of *A. nobilis* showed high activity against the whitefly (*Trialeurodes vaporariorum*) nymphs at 0.0047 and 0.0093 µg/ml using an impregnated filter paper test, whereas it was ineffective against the adult or egg forms.

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