Ocimum Species: A Review on Chemical Constituents and Antibacterial Activity

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Abstract: Infection by bacteria is one of the main problems in health. The use of commercial antibiotics is still one of the treatments to overcome these problems. However, high levels of consumption lead to antibiotic resistance. Several types of antibiotics have been reported to experience resistance. One solution that can be given is the use of natural antibacterial products. There have been many studies reporting the potential antibacterial activity of the Ocimum plant. Ocimum is known to be one of the medicinal plants that have been used traditionally by local people. This plant contains components of secondary metabolites such as phenolics, flavonoids, steroids, terpenoids, and alkaloids. Therefore, in this paper, we will discuss five types of Ocimum species, namely O. americanum, O. basilicum, O. gratissimum, O. campechianum, and O. sanctum. The five species are known to contain many chemical constituents and have good antibacterial activity against several pathogenic bacteria.

Keywords: Ocimum species; chemical constituents; antibacterial

1. Introduction

Infection by microbes is one of the main problems that causes several diseases. One of the causes of infection is bacteria that can have an impact on public health. Based on the collection of data from 52 sentinel hospitals in North America for 7 years (1998–2004) on contemporary strains of 12,737 strains of pediatric patients under 18 years of age, E. coli as a pediatric pathogen ranks in the top six [1]. Mapanguy et al. [2] also reported that oral antibiotics such as cefixime, amoxicillin, and ciprofloxacin were resistant to E. coli infection about 50–60%. In addition, microorganisms can also cause wound infections and inhibit healing. Some of the bacteria associated with wound infections are Staphylococcus aureus, Escherichia coli, Pseudomonas aeruginosa, Klebsiella pneumoniae, Streptococcus pyogenes, Proteus spp., Streptococcus spp., and Enterococcus spp. [3,4]. Bacteria is also can be pathogenic in the skin, such as Staphylococcus, Micrococcus, and Corynebacterium sp. [5]. In relation to dental and oral health, Streptococcus sanguinis and Streptococcus mutans can cause dental caries [6]. Some of the infections mentioned can be treated with antibiotics. However, several studies have proven that antibiotics can cause resistance [7]. Antibiotic resistance occurs due to the use of drugs in large quantities, causing selection pressures on human and natural microbial systems. Microbes can undergo mutations to survive, thereby reducing antibiotic sensitivity [8,9]. Infections due to drug resistance have caused the death of up to 700,000 people every year worldwide [10]. There are several antibiotic resistances, namely vancomycin and teicoplanin against S. aureus [11], gentamicin aminoglycoside
against *E. faecalis* and *E. faecium* with percent resistance of 30% to 50% [12], penicillin against *S. pneumonia* [13], and *E. coli* caused resistance of fluorouquinolone more than 80% and gentamicin more than 40% [12].

Therefore, the use of natural antibacterial ingredients is one solution that has great potential. *Ocimum* species are herbal plants that are available in Indonesia. *Ocimum* species are native to tropical areas such as southern Asia, Africa, and India [14]. *Ocimum* comes from the *Lamiaceae* family, which has about 50 to 150 species [15]. Due to its pharmacological effects, this plant has been widely used traditionally for the treatment of headaches, coughs, diarrhea, constipation, warts, and kidney damage [16]. These properties come from the secondary metabolite components that are abundant in *Ocimum* plants such as steroids, tannins, alkaloids, flavonoids, and phenolics [17]. In addition, the abundant components of essential oils make *Ocimum* a plant that can fight the growth of organisms [18,19]. Therefore, in this paper, we will discuss five species of *Ocimum* that have been tested in vitro to have antibacterial activity against several Gram-positive and Gram-negative bacteria.

2. Chemical Constituents and Antibacterial Activity of *Ocimum* Species

2.1. *Ocimum americanum*

*O. americanum* is native to Africa and is 15 to 60 cm tall with sub-rectangular striated branches [20,21]. The leaf shape is intact or faintly serrated, lanceolate ellipse, glandular spots, and glabrous. The color of flower is pink, white, or purplish with an elongated circle shape. The fruits are small, pitted notelets, and mucilaginous [21]. It is commonly known as hoary basil or mosquito plant and has three chemotypes, namely spicy, camphoraceous, and floral-lemony [22]. Traditionally, this plant is used for the treatment of digestive, respiratory, and sedative disorders. It also has benefits as a cough medicine, treating bronchitis, immune disorders, relieving toothache, and dysentery, which is commonly used orally [20,23]. The extract of *O. americanum* was also used for tobacco flavoring, tea, and body fragrance. The leaves and branches were used for insecticides against mosquitoes, bees, flies, and other insects. In Africa, the Swahili tribe utilizes the aerial parts of the plant for the treatment of high blood pressure and stomach aches [24]. In addition, local people in the Tamil Nadu area use a decoction of the leaves as a medicine for diabetes, constipation, diarrhea, hemorrhoids, and dysentery [25].

*O. americanum* has several phytochemical components, such as alkaloids, flavonoids, phenolic, tannins, terpenoids, saponin, steroids and glicosides. Some studies reported that saponin, phenolic, and tannins are found in less polar solvent such as ethyl acetate leave extract [24], while glicosides and steroids are commonly found in methanol extract [25]. Moreover, phenolic, flavonoids, saponin, and tannins were found in the aqueous extract of leaves and flowers [26]. The pharmacological activities found in *O. americanum* are antioxidant, antifungal, antimicrobial, anti-insecticide and larvicide, and gastric cytoprotective antulcer effect [27,28]. Chemical compounds in *O. americanum* can be seen in Table 1, Figure S1.
Table 1. The Chemical Constituents of *O. americanum*.

| Class of Chemical Constituents | Chemical Constituents | RT (min) | References |
|-------------------------------|-----------------------|----------|------------|
| **Fatty acids**               | 3-Hydroxy-3-methyl pentanoic acid (1) | 4.71  | [26,29–31] |
|                               | Citronellic acid (2) | -        |            |
|                               | Stearic acid (3)     | 29.32    |            |
|                               | Linoleic acid (4)    | 30.40    |            |
|                               | α-Linolenic acid (5) | 31.49    |            |
|                               | Stearidonic acid (6) | -        |            |
|                               | Palmitoleic acid (7) | 26.70    |            |
| **Fatty alcohols**            | 2-Hexyl-1-decanol (8) | 21.67   | [29]       |
|                               | Octyl acetate (9)    | 10.48    | [29]       |
| **Organic acids**             | Chicoric acid (10)   | -        | [26,31]    |
| **Ketones**                   | 2-Hydroperoxyheptane (11) | 5.27    |            |
|                               | 3-Hepten-2-one (12)  | 6.53     |            |
|                               | Pulegone (13)        | -        |            |
|                               | Carvone (14)         | -        |            |
| **Enone**                     | Mesityl oxide (15)   | 5.52     | [29]       |
|                               | Octan (16)           | 6.14     | [29,30]    |
|                               | Citral (17)          | 11.79    |            |
| **Aldehydes**                 | Citronellal (18)     | 5.96     |            |
|                               | Perillaldehyde (19)  | nd       |            |
| **Ester**                     | Hexyl acetate (20)   | 6.32     | [29]       |
| **Organic nitro**             | Nitrocyclohexane (21) | 7.05    | [29]       |
| **Alcohols**                  | 1-Octanol (22)       | 7.54     |            |
|                               | Quinic acid (23)     | -        |            |
|                               | Menthol (24)         | -        |            |
|                               | 4-Carvomenthol (25)  | -        | [26,29,30,32] |
|                               | Safrole (26)         | -        |            |
|                               | Carveol (27)         | -        |            |
|                               | Verbenol (28)        | -        |            |
| **Dialkyldisulfides**         | 2-Methyl-7-octadecyne (29) | 21.91 | [29] |
| **Unsaturated hydrocarbons**  | 9-Eicosyne (30)      | 22.14    | [29]       |
| **Phenolic**                  | Vanillin (31)        | 6.72     | [26,30]    |
|                               | Ellagic acid (32)    | -        |            |
|                               | Eugenol (33)         | 20.36    |            |
| **Monoterpenoids**            | α-Thujone (34)       | 11.19    | [29,30,33,34] |
|                               | Neral (35)           | 11.19    |            |
|                               | Geranyl acetate (36) | 21.3     |            |
|                               | Linalool (37)        | 7.41     |            |
|                               | β-Myrcene (38)       | -        |            |
|                               | Geraniol (39)        | 5.76     |            |
|                               | Linalyl acetate (40) | -        |            |
|                               | α-Pinene (41)        | 4.87     |            |
|                               | Fenchone (42)        | -        |            |
|                               | Verbenone (43)       | -        |            |
|                               | Verbenol (44)        | -        |            |
|                               | p-Cymene (45)        | -        |            |
|                               | α-Terpine (46)       | -        |            |
|                               | α-Phellandrene (47)  | -        |            |
|                               | β-Phellandrene (48)  | -        |            |
|                               | Limonene (49)        | 10.60%   |            |
|                               | Carvacrol (50)       | -        | [29,30,33,34] |
|                               | Borneol (51)         | -        |            |
|                               | Thymol (52)          | -        |            |
|                               | 1-Menthone (53)      | -        |            |
| **Diterpenoids**              | Phytol (54)          | 24.80    | [29]       |
|                               | Phytene-2 (55)       | 21.51    |            |
| **Sesquiterpenoids**          | β-Bisabolene (56)    | 16.45    | [29]       |
|                               | Humulene (57)        | 15.54    |            |
|                               | (E)-β-Farnesene (58) | -        | [26]       |
| **Triterpenoids**             | Verbascoside (59)    | -        | [26,30]    |
| **Phenylpropanoids**          | Cinnamic acid (60)   | -        | [26,30]    |
|                               | Fertaric acid (61)   | -        |            |
Table 1. Cont.

| Class of Chemical Constituents | Chemical Constituents          | RT (min) | References |
|-------------------------------|-------------------------------|----------|------------|
| Flavonoids                    | Vicenin-2 (62)                | -        | [26,35]    |
|                               | Eriodictyol-7-O-glucoside (63)| -        |            |
|                               | Vitexin (64)                  | -        |            |
|                               | Rutin (65)                    | 4.55     |            |
|                               | Genkwanin (66)                | -        |            |
|                               | Dihydroxy-tetramethoxy(iso)flavone (67) | - |          |
|                               | Cirsilineol (68)              | -        |            |
|                               | Cirsimaritin (69)             | -        |            |
|                               | Pilosin (70)                  | -        |            |
| Alloxazines and isoalloxazines| Riboflavin (71)               | -        | [26]       |

(-) = Test not performed; RT = Retention Time; RI = Retention Index.

2.2. Ocimum basilicum

*Ocimum basilicum*, commonly called sweet basil, is one of the species of genus *Ocimum* from Asia, Africa, and South America regions [36,37]. *O. basilicum* can live in different climates and ecology, grows in cool humid areas to tropical areas with the temperatures between 6 and 24 °C, and also favors warm conditions [38]. This plant is the species of *Ocimum* which is commercially available in the market [39]. It has six different morphologies, namely true basil with green leaves, small-leaf basil, which belongs to green cultivars with short narrow leaves and grows rounded, lettuce-leaf with broad leaves, purple basil A, which has green leaves with purple flowers and stems, purple basil B, where the leaves, flower, and stems are purple, and purple basil C, which has a similarity to purple basil B and has broad listered leaves [40,41]. *O. basilicum* is 20 to 80 cm tall with glabrous and woody stems, large green leaves, and is broadly elliptical, measuring 2.5 to 5 cm × 1 to 2.5 cm. The flowers are red, pink, or white, with a size of 3 mm, and are arranged in terminal spikes [42].

Traditionally, the fruit of *O. basilicum* was used as folk medicine against inflammation, diarrhea, worm infestation, and eye-related disease [43]. Leaves and flowers of *O. basilicum* were used as tonic and vermifuge, and can also be used as a tea to treat nausea, flatulence, and dysentery. *O. basilicum* contains essential oils that are commonly used to treat colds, seizures, and treatment of wasp stings and snakebites [44]. The polysaccharide component of *O. basilicum* was traditionally used as cancer treatment in China [45,46]. In South Europe, they used *O. basilicum* as Mediterranean food, such as the cuisines of Italian and Greek [47].

*O. basilicum* contains the main components that are beneficial for health such as calcium, phosphorus, vitamin A, vitamin C, and beta carotene [48]. Phytochemical constituents contained in *O. basilicum* are alkaloids, flavonoids, phenols, saponins, tannins, terpenoids, carbohydrates, cardiac glycosides, cholesterol, glycosides, and phlobatannis [49,50]. Therefore, it has the potential to have anti-inflammatory, antimicrobial, antivirals, anticancer, antifungal, anti-diabetic, anti-allergic, analgesic, cardioprotective, and immunomodulatory properties [50–53]. Then, flavonoids and phenolic compounds gave antioxidant activity [54,55]. Chemical compounds in *O. basilicum* can be seen in Table 2, Figure S2.
Table 2. The chemical constituents of *O. basilicum*.

| Class of Chemical Constituents | Chemical Constituents                  | RT (min) | RI          | References                      |
|-------------------------------|----------------------------------------|----------|-------------|---------------------------------|
| Carboxylic acid ester         | Cyclohexyl formate (72)                | 7.30     | 1304        | [56,57]                         |
| Aliphatic aldehydes           | Citral (16)                            | 6.57     | -           | [56,58]                         |
| Aliphatic alcohol             | 3-Octanol (73)                         | 11.64    | -           | [59]                            |
| Amines                        | Phenylethanolamine (74)                | 8.77     | -           | [56,57]                         |
| Phenols                       | 2,3,5-Trimethylphenol (75)             | 7.10     | -           | [56,58]                         |
|                                | Eugenol (33)                           | 7.19     | -           |                                  |
| Fatty alcohols                | 4-Hexen-1-ol acetate (76)              | 857      | 4.428       | [56,58,60,61]                   |
|                                | 1-Octen-3-ol (77)                      | 10.78    | 979         | [56,58,60,61]                   |
| Pyrans                        | 2,3-Dehydro-1,8-cineole (78)           | 11.18    | -           | [57]                            |
| Organohetocyclic compounds    | cis-Linalool oxide (79)                | -        | 1070        | [56–58]                         |
| Phenylpropanoids              | 3-Methyl-2-phenylindole (80)           | 12.73    | 1710        | [56–58]                         |
|                               | trans-4-Methoxycinnamaldehyde (81)    | 8.57     | -           | [56,58,60,62]                   |
|                               | Methyl cinnamate (82)                  | -        | 1338        |                                  |
| Cycloalkenes                  | Methyl ethyl cyclopentene (83)         | 5.63     | -           | [56,58]                         |
| Monoterpenoids                | α-Terpine (84)                         | 20.16    | -           |                                  |
|                               | 1-Menthone (49)                        | 5.76     | -           |                                  |
|                               | Levomenthol (85)                       | 5.91     | -           | [56–58,60,62–64]                |
|                               | Nerol (86)                             | -        | 1229        |                                  |
|                               | Neral (34)                             | -        | 1249        |                                  |
|                               | Geraniol (38)                          | -        | 1256        |                                  |
|                               | Citral (16)                            | 6.57     | 1270        |                                  |
|                               | β-Myrcene (37)                         | 11.38    | -           |                                  |
|                               | p-Menth-3-ene (87)                     | 6.74     | 977.5       |                                  |
|                               | Bormyl acetate (88)                    | -        | 1286        |                                  |
|                               | α-Pinene (40)                          | 3.95     | -           |                                  |
|                               | Fenchone (41)                          | -        | 1089        |                                  |
|                               | Camphor (89)                           | 18.14    | -           |                                  |
|                               | Camphene (90)                          | 8.86     | -           |                                  |
|                               | Sabinene (91)                          | 10.27    | -           |                                  |
|                               | trans-α-α-Bergamotene (92)             | 7.73     | -           |                                  |
|                               | β-Pinene (93)                          | 10.36    | -           |                                  |
|                               | α-Phellandrene (46)                    | 11.94    | -           |                                  |
|                               | α-Terpine (45)                         | 12.52    | -           |                                  |
|                               | γ-Terpine (94)                         | 14.57    | -           |                                  |
|                               | Terpinolene (95)                       | 16.00    | -           |                                  |
|                               | Estragole (96)                         | 6.06     | -           |                                  |
|                               | 1-8-Cineole (97)                       | 13.16    | -           |                                  |
|                               | p-Cymene (44)                          | 12.88    | -           |                                  |
|                               | cis-β-Terpineol (98)                   | 16.30    | -           |                                  |
| Sesquiterpenoids              | β-Copaene (99)                         | 8.10     | -           |                                  |
|                               | α-Humulene (57)                        | 29.26    | -           | [56–60,62,63,65–70]             |
|                               | trans-β-Farnesene (100)                | 29.98    | -           |                                  |
|                               | β-Cubebene (101)                       | -        | 1394        |                                  |
|                               | α-Cadinene (102)                       | -        | 1537        |                                  |
|                               | aromadendrene (103)                    | -        | 1529        |                                  |
|                               | α-Bisabolene (104)                     | -        | 1561        |                                  |
|                               | β-Bisabolene (56)                      | 8.17     | -           |                                  |
|                               | α-Bisabolol (105)                      | -        | 1642        |                                  |
|                               | Neoisoolongifolene (106)               | -        | -           |                                  |
|                               | trans-β-Guaiene (107)                   | 8.31     | 1499        |                                  |
|                               | cis-Murola-3,5-diene (108)             | 8.31     | 1502        |                                  |
|                               | Nerolidol (109)                        | 8.47     | -           |                                  |
|                               | Bicyclogermacrene (110)                | 30.60    | -           |                                  |
|                               | β-Elemene (111)                        | -        | 1387        |                                  |
|                               | β-Caryophyllene (112)                  | -        | 1419        |                                  |
|                               | δ-Cadinene (113)                       | 31.45    | -           |                                  |
|                               | Spathulenol (114)                      | 32.96    | -           |                                  |
|                               | α-Selinene (115)                       | 30.85    | -           |                                  |
|                               | Bicyclosesquiphellandrene (116)        | 29.05    | -           |                                  |
|                               | α-Bergamotene (117)                    | 28.79    | -           |                                  |
|                               | Caryopyllene oxide (118)               | -        | 1550        |                                  |
|                               | 1,10-Di-eucubenol (119)                | 34.06    | -           |                                  |

RT = Retention Time; RI = Retention Index.
2.3. Ocimum gratissimum

*O. gratissimum*, with the common name of clove basil, is a species of family *Labiate* which grows in tropical region, namely India and West Africa [71,72]. It is 1–3 m tall and has leaves that are 3–4 cm × 1–2 cm [73]. The flowers have several colors, such as yellowish white, greenish purple, hairy, calyx greenish purple, brown seeds, and not slimy [74]. In Africa, eastern, central, and western Kenya, *O. gratissimum* is commonly found in scrub and disturbed highland forests at elevations of 600 to 2400 m above sea level [75].

Traditionally, *O. gratissimum* was used for the treatment of cough, fever, snakebites, mosquito repellent, anemia, inflammation, and diarrhea [75,76]. It has several bioactivities, namely antioxidant, anti-inflammation, antimycotoxicogenic, antibacterial, antifungal, antimalaria, and antiseptic activities [77–80]. The phytochemical components of *O. gratissimum* are alkaloids, saponins, tannins, phlobatannins, glycosides, phenols, anthraquinones, flavonoids, and terpenoids [81,82]. Some of the chemical compounds contained in *O. gratissimum* are listed in Table 3, Figure S3.

### Table 3. The chemical constituents of *O. gratissimum*.

| Class of Chemical Constituents | Chemical Constituents | RT (min) | Percentage (%) | References |
|-------------------------------|-----------------------|----------|----------------|------------|
| Alcohols                      | Chlorogenic acid (120) | -        | -              | [83]       |
| Fatty acids                   | Methyl acetate (121)   | 30.55    | -              | [84]       |
|                              | Palmitic acid (122)    | 28.35    | -              | [84]       |
| Flavonoids                    | Luteolin (123)         | 9.06     | -              | [47,84–88] |
|                              | Apigenin (124)         | 12.36    | -              |            |
|                              | Quercetin (125)        | -        | -              |            |
|                              | Epicatechin (126)      | -        | -              |            |
|                              | Nevdensin (127)        | 18.45    | -              |            |
|                              | Salvigenin (128)       | 25.13    | -              |            |
|                              | Morin (129)            | -        | -              |            |
|                              | Xanthomicrol (130)     | 18.23    | -              |            |
|                              | Apigenin dimethyl ether (131) | 27.46 | - |            |
| Phenols                       | Eugenol (33)           | -        | 74.83          | [38]       |
|                              | Methyl eugenol (132)   | 6.36     | -              |            |
| Phenylpropanoids              | Sinapic acid (133)     | 2.72     | -              | [36,89]    |
|                              | Rosmarinic acid (134)  | 3.82     | -              |            |
|                              | Nepetolidin A (135)    | 17.54    | -              |            |
| Monoterpenoids                | Methyl carvacrol (136) | -        | 1.19           | [89–92]    |
|                              | Carvacrol (50)         | -        | 0.20–8.40      |            |
|                              | 1-β-cineole (97)       | -        | 0.30–23.04     |            |
| Sesquiterpenoids              | *trans*-α-Bergamotene (92) | -      | 0.20–0.70      | [83,84,86,90–94] |
|                              | β-Cadinene (113)       | -        | 0.30–3.00      | [83,84,86,90–94] |
|                              | β-selinene (148)       | -        | 0.82–7.96      | [83,84,86,90–94] |
|                              | β-Caryophyllene (112)  | -        | 0.39–7.23      | [83,84,86,90–94] |
|                              | Humulene (57)          | -        | 4.40           |            |
|                              | β-Bergamotene (149)    | -        | 1.03–2.29      |            |
|                              | δ-Cadinene (113)       | -        | 0.30           |            |
|                              | γ-Cadinene (150)       | -        | 0.61           |            |
|                              | Caryophyllene oxide (118) | -    | 0.50–3.02      |            |
|                              | α-Cadinol (151)        | -        | 3.5            |            |
|                              | α-Panasinsene (152)    | -        | -              |            |
|                              | β-Chamigrene (153)     | -        | 1.61–2.84      |            |
|                              | β-Copaene (99)         | -        | 0.27           |            |
|                              | Germacrene-D (154)     | -        | 0.10–29.9      |            |
|                              | β-Bisabolol (155)      | -        | -              |            |
|                              | β-Cubebeine (101)      | -        | 0.08           |            |
|                              | *Epi*-Cubebeol (156)   | -        | 0.21           |            |
|                              | *Epi*-Cubanol (157)    | -        | 0.23           |            |
|                              | Copaene (158)          | -        | 0.30–7.20      |            |
|                              | β-Bourbonene (159)     | -        | 0.21–0.89      |            |
|                              | β-Selinene (160)       | -        | 0.85–7.96      |            |
Table 3. Cont.

| Class of Chemical Constituents | Chemical Constituents | RT (min) | Percentage (%) | References |
|-------------------------------|-----------------------|----------|----------------|------------|
| Bicyclogermacrene (110)       | -                     | 0.40–2.90|                |            |
| Calamenene (161)              | -                     | 0.38     |                |            |
| α-Thujone (33)                | -                     | 0.1      |                |            |
| β-Myrcone (37)                | -                     | 0.14     |                |            |
| Camphene (90)                 | -                     | 0.10–0.60|                |            |
| Sabinene (91)                 | -                     | 0.18–0.90|                |            |
| 2-Carene (137)                | -                     |          |                |            |
| Camphor (89)                  | -                     | 0.10–0.60|                |            |
| β-Pinene (93)                 | -                     | 0.11–2.22|                |            |
| trans-Longipinocarveol (138)  | -                     |          |                |            |
| γ-Terpinene (94)              | -                     | 8.23–22.90|                |            |
| 4-Carene (139)                | -                     |          |                |            |
| β-(E)-Ocimene (140)           | -                     | 0.10–0.43|                |            |
| β-(Z)-Ocimene (141)           | -                     | 0.21–4.00|                |            |
| Allo-Ocimene (142)            | -                     |          |                |            |
| 4-Methylstyrene (143)         | -                     |          |                |            |
| Styrene (144)                 | -                     |          |                |            |
| Limonene (48)                 | -                     | 1.25–5.27|                |            |
| p-Cymene (44)                 | -                     | 12.04–25.00|               |            |
| Terpinene-4-ol (145)          | -                     | 1.90–4.35|                |            |
| Borneol (51)                  | -                     | 0.20–0.55|                |            |
| Umbellulone (146)             | -                     |          |                |            |
| α-Terpineol (147)             | -                     | 0.10–0.92|                |            |
| Estragole (96)                | -                     | 0.20–1.50|                |            |
| Thymol (29)                   | -                     | 8.50–46.99|               |            |
| α-Pinene (40)                 | -                     | 0.24–2.66|                |            |
| α-Curcumene (162)             | -                     | 0.26     |                |            |
| Isolongifolol (163)           | -                     | 0.10     |                |            |
| Isopinocamphone (164)         | -                     | 0.40     |                |            |
| Longifolene (165)             | -                     | 3.00     |                |            |
| γ-Muuroline (166)             | -                     | 0.16–3.88|                |            |
| α-p-Dimethyl styrene (167)    | -                     | 1.19     |                |            |
| β-Ylangene (168)              | -                     | 2.7      |                |            |
| Triterpenoids                 | Oleanolic acid (169)  | 33.60    |                |            |
| Stigmastanes                  | Basilimoside (170)    | 29.12    |                |            |

(-) = Test not performed; RT = Retention Time; RI = Retention Index.

2.4. Ocimum campechianum

O. campechianum is a plant of the Lamiaceae family group which originates from the tropics of South and Central America. This plant is commonly known as “Albahaca de campo” or “Albahaca silvestre”, used by local people for traditional medicine or culinary purposes [95,96]. This plant has a height of 1 m and contains essential oil components with two types of aromatic leaves, namely glandular trichomes, peltate, and capitate. In addition, O. campechianum contains components of flavonoids, polyphenols, and tannins [97,98]. Traditionally, this plant is used as a decoction of leaves, ointments, and for the treatment of fever, cough, bronchitis, diarrhea, dysentery, and hypertension. In addition, O. campechianum can also be used as an emmenagogue that helps childbirth [99]. In terms of pharmacological effects, this plant extract is known to have antifungal, antioxidant, antiradical, antiproliferative, and analgesic activities [96,100,101]. In addition, it also has potential as a natural larvicide and pesticide [102]. The data of chemical constituents in O. campechianum can be seen in Table 4, Figure S4.
Table 4. The chemical constituents of *O. campechianum*.

| Class of Chemical Constituents | Chemical Constituents | KI  | Percentage (%) | References |
|-------------------------------|-----------------------|-----|----------------|-----------|
| Aliphatic alcohol             | 3-Octanol (73)        | 988 | -              | [99]      |
| Fatty alcohol                 | 1-Vinylhexanol (77)   | 974 | -              | [99]      |
|                               | (3Z)-Hexenol (171)    | 850 | -              | [99]      |
| Monocyclic ketone             | Carvone (13)          | 1239| -              | [99]      |
| Benzenoids                    | Benzene acetaldehyde  | 1036| -              | [99]      |
|                               | Eugenol (33)          | -   | 9.00           | [99]      |
|                               | Methyl eugenol (132)  | -   | 12.00          |           |
| Phenols                       | Polymethoxyflavones   |     |                |           |
|                               | 5-Demethinobiletin (173) | - | - | [99,103] |
|                               | 5-Demethylsinensetin (174) | - | - |           |
| Organoxygen compounds         | (2E)-Hexenal (175)    | 846 | -              | [99]      |
|                               | 3-Octanone (176)      | 979 | -              |           |
| Carboxylic acid esters        | (3E)-Hexenyl acetate (177) | 1001 | - | [104] |
| Monoterpenoids                | δ-3-Carene (178)      | 1008| -              | [99,104,105] |
|                               | α-Terpine (45)        | 1014| -              |           |
|                               | ρ-Cymene (44)         | 1020| -              |           |
|                               | β-(E)-Ocimene (139)   | 1044| 0.80           |           |
|                               | β-(Z)-Ocimene (140)   | 1032| -              |           |
|                               | Neoalloocimene (179)  | 1140| -              |           |
|                               | Terpinolene (95)      | 1086| -              |           |
|                               | Limonene (48)         | -   | 0.30           |           |
|                               | α-Terpinol (84)       | -   | 0.30           |           |
|                               | Estragole (96)        | -   | -              |           |
|                               | L,8-Cineole (97)      | -   | 3.30           |           |
|                               | Isobornol (180)       | 1155| -              |           |
|                               | (+)-4-Terpinol (144)  | 1174| -              |           |
|                               | Linalool (36)         | -   | 2.90           |           |
|                               | Myrcene (37)          | -   | 0.20           |           |
|                               | β-Pinene (93)         | -   | 0.80           |           |
|                               | α-Thujene (181)       | 924 | -              |           |
|                               | Tricycletene (182)    | 921 | -              |           |
|                               | Cis-sabinen hydrate (183) | 1065 | - |           |
|                               | α-Pinene (40)         | -   | 0.20           |           |
|                               | Camphene (90)         | -   | 0.40           |           |
|                               | trans-α-Bergamotene (92) | 1432 | - |           |
|                               | Sabinene (91)         | -   | 0.10           |           |
|                               | Camphor (89)          | 1141| -              |           |
| Sesquiterpenoids              | Sesquisabinene (184)  | -   | 0.20           |           |
|                               | Humulene epoxide II (185) | 1608 | - | [99,105] |
|                               | β-Bisabolene (56)     | 1505| -              |           |
|                               | Germacrene-D (154)    | -   | 10.10          |           |
|                               | Bicyclogermacrene (110) | 1500 | - |           |
|                               | Germacrene-B (186)    | 1559| -              |           |
|                               | α-Humulene (57)       | -   | 2.80           |           |
|                               | Aromadendrene (103)   | 1439| -              |           |
|                               | α-Copaene (158)       | -   | 1.90           |           |
|                               | β-Bourbonene (139)    | 1387| -              |           |
|                               | α-Gurjunene (187)     | 1409| -              |           |
|                               | Viridiflorol (188)    | 1592| -              |           |
|                               | β-Eudesmol (189)      | 1649| -              |           |
|                               | 3,7(11)-Eudesmadiene (190) | - | - |           |
|                               | α-Guaiene (191)       | -   | 5.60           |           |
|                               | γ-Murolene (192)      | -   | 0.30           |           |
|                               | α-Bulnesene (193)     | -   | 7.10           |           |
|                               | Spathulenol (114)     | -   | 0.40           |           |
|                               | τ-Cadinol (151)       | -   | -              |           |
|                               | Junenol (194)         | 1618| -              |           |
|                               | β-elinene (148)       | -   | -              |           |
|                               | δ-Cadinene (113)      | -   | 2.00           |           |
|                               | Caryophyllene oxide (195) | - | 0.40 |           |
|                               | E-Caryophyllene (112) | -   | 4.05           |           |
|                               | β-Elemene (111)       | -   | 0.53           |           |
|                               | γ-Elemene (196)       | -   | 0.60           |           |
|                               | Bicycloelemene (197)  | -   | 0.20           |           |

(-) = Test not performed; KI = Kovat’s Index.
2.5. Ocimum sanctum

*O. sanctum* is a plant from the Lamiaceae family, commonly known as basil or tulsi, which is native to India and is widely distributed as a cultivated plant throughout Southeast Asia [106]. It is known as a sacred plant in India and a symbol of purity. It got the name of "Tulasi" from Tulasi Devi, one of the Lord Krishna’s eternal consorts. Tulasi was a Gopi who was said to have fallen in love with Krishna and was cursed by his wife Radha. He is very similar to Vishnu [107]. In India, it is used for religious plants and important events such as weddings [108]. *O. sanctum* is 30–75 cm tall with an herbaceous shape, and is erect, more-branched, and hairy-soft [107]. It has pointed or blunt leaves, the leaves are oval, and the flowers are tightly coiled with a pale red or dark red color [109].

Traditionally, *O. sanctum* was used for the treatment of diarrhea, chronic fever, malaria, skin disease, bronchitis, dysentery, insect bite, arthritis, and bronchial asthma [110,111]. *O. sanctum* has several bioactivities such as anticancer, antispasmodic, antifertility, antimicrobial, anti-inflammatory, antioxidant, fungicidal, antiarthritic, cardio protective, adaptogenic, antiemetic, and hepatoprotective [112–115]. It has several phytochemicals, namely terpenoids, phenolic, flavonoids, glycosides, and propenyl phenols [116]. Moreover, it also contains vitamin C, A, and minerals such as zinc, iron, and calcium [117]. The protein content in *O. sanctum* is 4.2 g, then 0.5 g fat, 25 mg carbohydrates, 287 mg phosphorus, 25 mg calcium, vitamin C per 100 g, and 15.1 mg iron [118]. The chemical constituents included in *O. sanctum* are listed in Table 5, Figure S5.

Table 5. The chemical constituents of *O. sanctum*.

| Class of Chemical Constituents | Chemical Constituents | RT (min) | RI | References |
|-------------------------------|-----------------------|----------|----|------------|
| Fatty acids                   | Ocimumnaphthanoic acid (196) | -        | -  | [119–121]  |
|                              | Methyl 9-methyltetradecanoate (199) | -        | -  |            |
|                              | Ethyl 13-methyltetradecanoate (200) | -        | -  |            |
|                              | Methyl 7-Z-hexadecanoate (201) | -        | -  |            |
|                              | Ethyl palmitate (202) | -        | -  |            |
|                              | Ethyl isovalerate (203) | -        | -  |            |
| Carboxylic acids              | (Z)-3-Hexenyl acetate (204) | -        | 1005 | [122]      |
| Aliphatic aldehydes           | Citronellial (17) | -        | -  | [113]      |
| Benzenoids                    | Protocatechuic acid (205) | -        | -  | [113,120]  |
| Unsaturated hydrocarbons      | 1,2,4-Trimethylcyclohexane (207) | 13.36    | -  | [113]      |
| Organoxygen compounds         | 1,2-Cyclopentanediene (208) | -        | -  | [119,120]  |
| Phenolic                      | Citrusin C (209) | -        | -  |            |
|                              | Vanillin (31) | -        | -  | [113,115,123] |
|                              | Methylisouegenol (210) | -        | 7.50 |            |
|                              | Vanillic acid (211) | -        | -  |            |
|                              | Sinapic acid (132) | -        | 7.20 |            |
|                              | p-coumeric acid (212) | -        | -  |            |
|                              | p-hydroxybenzoic acid (213) | -        | -  |            |
|                              | Ferulic acid (214) | -        | -  |            |
|                              | Eugenol (33) | -        | 1382 |            |
|                              | Bieugenol (215) | -        | -  | [113,119]  |
|                              | Galuteolin (216) | -        | -  |            |
|                              | Isovitexin (217) | -        | -  | [113,119]  |
|                              | Chrysoeriol (218) | -        | -  |            |
|                              | Cirsilineol (68) | -        | -  |            |
|                              | Isothymunin (219) | -        | -  |            |
|                              | Isothymusin (220) | -        | -  |            |
|                              | Cirsimaritin (221) | -        | -  |            |
|                              | Molludistin (222) | -        | -  |            |
|                              | Vitexin (64) | -        | -  |            |
|                              | Orientin (223) | -        | -  |            |
Table 5.

| Class of Chemical Constituents | Chemical Constituents | RT (min) | RI | References |
|-------------------------------|-----------------------|----------|----|------------|
| Isoorientin (224)             | -                     | -        | -  | -          |
| Vicenin (62)                  | -                     | -        | -  | -          |
| Luteolin-5-glucoside (225)    | -                     | -        | -  | -          |
| Esculin (226)                 | -                     | -        | -  | -          |
| Esceletin (227)               | -                     | -        | -  | -          |
| Phenylpropanoids              | Rosmarinic acid (133) | 6.20     | -  | [115,124]  |
| Monoterpenoids                | Estragole (96)        | -        | 1229 |            |
|                              | Carvacrol (50)        | -        | -  | -          |
|                              | Linalool (36)         | -        | 1109 |            |
|                              | α-Terpinyl acetate (228)| -    | -   | -          |
|                              | Terpiniolene (95)     | -        | -  | -          |
|                              | Bornyl acetate (88)   | -        | 1289 |            |
|                              | α-Bergomartene (117)  | -        | 1469 |            |
| Sesquiterpenoids              | Spathulenol (114)     | -        | 1578 |            |
|                              | α-Humulene (57)       | -        | 1482 |            |
|                              | α-Guaiol (229)        | -        | -   | -          |
|                              | 2-Methylene-4,8,8-trimethyl-4-vinyl-| -    | -   | -          |
|                              | bicyclo[5.2.0]nonane (230)| - | -   | -          |
| Triterpenoids                 | Oleanolic acid (169)  | -        | -   | -          |
|                              | Ursolic acid (231)    | 8.50     | -   | -          |

(-) = Test not performed; RT = Retention Time; RI = Retention Index.

3. Antibacterial Activity of Ocimum Species

Tests of antibacterial activity against Ocimum species have been carried out on both Gram-positive and Gram-negative bacteria. Based on the data in Tables 6–8, the Ocimum extracts that were widely tested and gave relatively high activity were essential oil extracts. In general, the five Ocimum species have good antibacterial activity. However, based on the inhibition zone data in Table 6, it can be seen that O. americanum, O. basilicum, and O. sanctum had higher activity than the other two species, where the diameter of the inhibition zone reached 20 to 40 mm. In Gram-positive bacteria, O. americanum, O. basilicum, and O. sanctum gave the highest inhibition zone against S. aureus, while O. gratissimum gave the highest inhibition zone against E. faecalis, and O. campechianum gave the highest inhibition against L. ivanovii. Furthermore, in Gram-negative bacteria, O. americanum gave the highest inhibition zone against P. gingivalis and P. intermedia, O. basilicum against P. aeruginosa, O. gratissimum against P. mirabilis, O. campechianum against E. coli, and O. sanctum against Yersinia enterocolitica.

Table 6. Data of inhibition zone of Ocimum species.

| Microorganism | Extract | Inhibition Zone (mm) | Positive Control (mm) | Reference |
|---------------|---------|----------------------|-----------------------|-----------|
| S. mutans     | Essential oil | 28 - - - - - - | 1a21 [126–128] |
| L. casei      | Essential oil | 19 - - - - - - | 2a10.90 [5b,29.40]  |
| E. faecalis   | Essential oil | 15.67 - - - - - - | - [126] |
| E. faecium    | Essential oil | 15.67 - - - - - - | 2a15.50; 3a20 [41,129–131] |
| S. aureus     | Essential oil | 33.33 29.20-30.56 - | 11.67 41.50 [2a,23.93] |
| 70% hydroethanol | 9.33–11.17 - - - - - | - [41,128,131–136] |
Table 6. Cont.

| Microorganism       | Extract                | Inhibition Zone (mm) | Positive Control (mm) | Reference     |
|---------------------|------------------------|----------------------|-----------------------|---------------|
|                     |                        | 1 | 2 | 3 | 4 | 5 |                        |                       |
| B. cereus           | Ethyl acetate          | 10| - | - | - | 21| ^50|29.30 | ^25,128,132,136,137  |
|                     | 70% hydroethanol       | 9.50–16.33           | - | - | - | - | - | - |                       |
|                     | Essential oil          | - | 10.66–16.11          | - | - | - | - | - | ^2e|20.53 | ^3|15  |
|                     | Chloroform             | - | 12                | - | - | - | - | - | - |                       |
| Clostridium          | Ethyl acetate          | 10| - | - | - | - | - | - | - | ^2b|11.00 | ^138           |
| perfringens         |                        |                      |                      |               |
| S. phyogenes        | Essential oil          | - | 19.00            | - | - | - | - | - | - | ^2b|11.00 | ^139,140  |
|                     | Ethanol                | - | 6–10              | - | - | - | - | - | - |                       |
| Cutibacterium       | Essential oil          | - | 16.78–18.13        | - | - | - | - | - | - | ^2b|13.13 | ^141           |
| acnes                |                        |                      |                      |               |
| Lactococcus         | Ethanol                | - | 1.90             | - | - | - | - | - | - | ^2b|20.00 | ^142           |
| garvieae             |                        |                      |                      |               |
| B. subtilis         | Methanol               | - | 13.58            | - | - | - | - | - | - | ^2d|22.01 | ^128,143  |
|                     | Ethyl acetate          | - | -                | - | - | - | 26| - | - | ^5b|28.70 | ^128,143  |
| S. sanguinis         | Methanol               | - | 7.80–11.40        | - | - | - | - | - | - | ^2b|17.90 | ^129           |
|                     | Ethanol                | - | 10               | - | - | - | - | - | - | ^2b|17.90 | ^129           |
| S. faecalis          | Essential oil          | 12| 10.60–11.70       | 8 | - | - | - | - | - | ^3|13,3|93.70 | ^92,131,138  |
| L. monocytogenes     | Ethanol                | - | 8–26              | - | - | - | - | - | - |                       |
| L. livanovii        | Essential oil          | 13.67| - | - | 12.67 | - | - | - | ^4|1,131 |                   |
| S. epidermidis       | Essential oil          | 22.67| - | - | 11 | - | - | - | ^4|1,131,135,145         |
|                     | Ethanol                | - | -                | - | - | - | 9 | - | - | ^2k|22 |                   |
|                     | Bark                   | - | 15               | - | - | - | - | - | - | ^2k|22 |                   |
| M. luteus           | Essential oil          | 14| - | - | - | 17.50| - | - | - | ^4|1|1.39 | ^25           |
| C. perfringens      | Essential oil          | - | -                | - | - | - | 15.00| - | - | ^4|1|1.39 | ^25           |
| Lb. plantarum       | Essential oil          | - | -                | - | - | - | 12.58| - | - | ^3|15.38 | ^138           |
| S. agalactiae       | Ethyl acetate          | - | -                | - | - | - | 20 | - | - | ^3|0.40 | ^128           |
|                        |                        |                      |                      |               |
| Gram-Negative Bacteria |                      |                      |                      |               |
| P. gingivalis       | Essential oil          | 30| - | - | - | - | - | - | - | ^4|16 |                   |
| P. intermedia       | Essential oil          | 30| - | - | - | - | - | - | - | ^4|16 |                   |
| F. nucleatum        | Essential oil          | 24| - | - | - | - | - | - | - | ^4|16 |                   |
| P. vulgaris         | Essential oil          | - | -                | 11.33| - | - | - | - | - | ^4|1,131 |                   |
| E. coli            | Essential oil          | 10.67| 17.48–23.58      | 12| 11.67| 15.40| - | ^4|1,131,134,147 |                   |
|                     | Ethyl acetate          | 9 | - | - | - | 15.70| - | - | ^5b|31.30 | ^134,147  |
|                     | Hexane                 | - | -                | - | - | 2.26| - | - | - | ^25 |                   |
| Klebsiella         | Ethyl acetate          | 10| - | - | - | 15.30| - | - | ^5b|29.30 | ^128,148  |
| pneumonia           |                        |                      |                      |               |
|                     | Methanol               | - | -                | 16–23| - | - | - | - | - | ^4|16 |                   |
| Salmonella         | Ethyl acetate          | 9 | - | - | - | - | - | - | - | ^4|16 |                   |
| paratyphi           |                        |                      |                      |               |
| V. cholera         | Essential oil          | 18| - | - | - | - | - | - | - | ^30 |                   |
| S. typhimurium      | Essential oil          | 13.00–20.10| 20.00| - | - | - | - | - | - | ^3|28.80;2b|11.00 | ^92,128,139  |
| S. dysenteria      | Ethyl acetate          | - | - | - | - | 16.70| - | - | ^5b|29.70 |                   |
|                     | Essential oil          | 18| - | - | - | - | - | - | - | ^1c|17 | ^30,145  |
|                     | Bark                   | - | 16               | - | - | - | - | - | - | ^2k|25 |                   |
| P. aeruginosa       | Essential oil          | - | Max              | - | - | - | 12| - | - | ^3k|12.64 | ^128,132,135,149,150 |
|                     | Leaves                 | - | 16              | - | - | - | - | - | - | ^3k|12.64 | ^128,132,135,149,150 |
|                     | Ethyl acetate          | - | -                | - | - | - | 10.30| - | - | ^5b|22.30 | ^128,132,135,149,150 |
|                     | Ethanol                | - | -                | - | - | - | 11 | - | - | ^5b|22.30 | ^128,132,135,149,150 |
| A. baumannii        | Essential oil          | - | 15.30            | - | - | - | - | - | - | ^151          |
| Salmonella         | Essential oil          | - | 18.00            | - | - | - | - | - | - | ^152          |
| enteritidis        |                        |                      |                      |               |
| S. typhi           | Essential oil          | - | 24.80            | - | - | - | - | - | - | ^153          |
| Chloroform         | - | 14               | - | - | - | - | - | - | ^136,153  |
| P. multocida       | Essential oil          | - | 13.60–18.40       | - | - | - | - | - | - | ^2b|31.10 | ^154           |
| Listerella         | Essential oil          | - | 3.90             | - | - | - | - | - | - | ^2b|20.00 | ^142           |
| anguillarum        |                        |                      |                      |               |
| Yersinia          | Ethanol                | - | 1.50             | - | - | - | - | - | - | ^2b|20.80 | ^142           |
| ruckeri            |                        |                      |                      |               |
Table 6. Cont.

| Microorganism          | Extract                | Inhibition Zone (mm) | Positive Control (mm) | Reference |
|------------------------|------------------------|----------------------|-----------------------|-----------|
|                        |                        | 1        | 2    | 3     | 4 | 5     |                        |                        |
| *P. mirabilis*         | Leaves                 | -        | -    | 11-22 | - | -     |                        |                         |
|                        | Methanol               | -        | -    | 25-32 | - | -     |                        |                         |
|                        | Ethyl acetate         | -        | -    | -     | - | 15.10 |                        |                         |
| *Shigella* *gexineri*  | Essential oil          | -        | -    | 16    | - | -     |                        |                         |
| *Proteus mirabilis*    | Flavonoids             | -        | -    | 12-28 | - | -     |                        |                         |
| *Shigella* *sp.*       | Ethanol                | -        | -    | 8     | - | -     |                        |                         |
| *Salmonella*           | Ethanol                | -        | -    | 6     | - | -     |                        |                         |
| *Shigella* *sp.*       | Chloroform             | -        | -    | 2     | - | -     |                        |                         |
| *P. fluorescens*       | Essential oil          | -        | -    | -     | - | 2.50  |                        |                         |
| *Shigella* *boydii*    | Ethyl acetate         | -        | -    | -     | - | 14.30 |                        |                         |
| *Yersinia* *enterocolitica* | Ethyl acetate | -        | -    | -     | - | 20.10 |                        |                         |
| *Aeromonas* *hydrophila* | Ethanol             | -        | -    | -     | - | 12.30 |                        |                         |
| *Vibrio* *harveyi*     | Ethanol                | -        | -    | -     | - | 12.30 |                        |                         |

(-) = Test not performed; 1 = *O. americanum*, 2 = *O. basilicum*, 3 = *O. gratissimum*, 4 = *O. campechianum*, 5 = *O. sanctum*. Positive control: *(Chlorhexidine), *(Ciprofloxacin), *(Gentamicin), *(Ciprofloxacin), *(Tetracycline), *(Clindamycin), *(Rifampicin), *(Amoxicillin), *(Oxytetracycline), *(Amoxicillin), *(Streptomycin), *(Ketoconazole), *(Penicillin), *(Clavulanic acid).

Furthermore, MIC is an antibacterial test used to determine its inhibitory activity. Based on de Aguiar et al. [157], MIC concentrations in the range 101–500 µg/mL have strong activity and in the range 500–1000 µg/mL have moderate activity. As for Table 7, testing of *O. basilicum* against several bacteria, such as *S. mutans, S. aureus, B. cereus, L. monocytogenes, E. coli, P. aeruginosa, and S. typhi*, showed MIC values below 100 µg/mL, which means that they provide very strong activity, as well as in *O. sanctum*. The other three *Ocimum* species only showed strong to weak activity.

Table 7. Data of minimum inhibitory concentration (MIC) of *Ocimum* species.

| Microorganism          | Extract                | MIC (µg/mL) | Positive Control (µg/mL) | Reference |
|------------------------|------------------------|-------------|--------------------------|-----------|
|                        |                        | 1    | 2    | 3     | 4 | 5     |                        |                        |
| **Gram-Positive Bacteria** |                        |     |     |      |   |       |                        |                        |
| *S. mutans*            | Essential oil          | 0.04% v/v | -    | 18    | - | -     |                        |                         |
|                        | Lauric acid            | -        | 156  | -     | - | -     |                        |                         |
|                        | β-Sitosterol           | -        | 25,000 | -   | - | -     |                        |                         |
| *L. casei*             | Essential oil          | 0.04% v/v | -    | -     | - | -     |                        |                         |
| *E. faecalis*          | Essential oil          | 500      | -    | -     | - | -     |                        |                         |
| *E. faecium*           | Essential oil          | 500      | -    | -     | - | -     |                        |                         |
| *S. aureus*            | Essential oil          | 200      | 1000 | -     | 2.50 | -     |                        |                         |
|                        | 70% hydroethanolic     | 1840      | -    | -     | - | -     |                        |                         |
|                        | Ethanol                | -        | -    | -     | - | 4280  |                        |                         |
|                        | Hexane                 | -        | -    | -     | - | 2.30  |                        |                         |
|                        | Linalool               | -        | 32   | -     | - | -     |                        |                         |
|                        | Methanol               | -        | -    | >2000 | - | -     |                        |                         |
|                        | Rosmarinic acid        | -        | -    | >2000 | - | -     |                        |                         |
|                        | Eugenol                | -        | -    | 1000  | - | -     |                        |                         |
|                        | Caryophyllene          | -        | -    | -     | - | 50    |                        |                         |
Table 7. Cont.

| Microorganism | Extract | MIC (µg/mL) | Positive Control (µg/mL) | Reference |
|---------------|---------|-------------|--------------------------|-----------|
|               |         | 1           | 2            | 3    | 4    | 5    |           |           |
| B. cereus     | 70%     | hydroethanolic 1540 | - | - | - | - | [132,137,159] |
|               |         | Essential oil - | 18–36 | - | - | - | - | [132,137,159] |
|               |         | Eugenol - | - | - | - | 25 | - | [41,145] |
| S. epidermidis | Essential oil 300 | | Bark | 500 | - | - | - | [139,140] |
| S. phyogenes  | Essential oil - | 50 | - | - | - | - | - | [139,140] |
| Listeria mono- | Essential oil - | 36 | - | - | - | - | - | [41,145] |
| cytophages    | Ethanol - | 2150 | - | - | - | - | - | [41,145] |
| B. subtilis   | Methanol - | 625 | - | - | - | - | - | [143] |
| S. sanguinis  | Lauric acid - | 78 | - | - | - | - | - | [158,161] |
| S. faecalis   | Nevadensin - | 3750 | - | - | - | - | - | [158,161] |

**Gram-Negative Bacteria**

| Microorganism | Extract | MIC (µg/mL) | Positive Control (µg/mL) | Reference |
|---------------|---------|-------------|--------------------------|-----------|
| P. gingivalis | Essential oil 350 | | - | - | - | - | [146] |
| P. intermedia | Essential oil 350 | | - | - | - | - | [146] |
| E. nucleatum  | Essential oil 700 | | - | - | - | - | [41] |
| P. vulgaris   | Essential oil 400 | | - | - | - | - | [153,160] |
| E. coli       | Essential oil - | 9–18 | 1000 | - | 2.25 | - | [132–134] |
|               | Hexane - | - | - | - | 2.50 | - | [132–134] |
|               | (−)-β-elemene - | - | - | - | >200 | - | [132–134] |
| S. typhimurium | Methanol-DMSO >200 | | - | - | - | - | [26,139,159] |
|               | Essential oil - | 1600 | - | - | - | - | [26,139,159] |
|               | Leave - | - | - | 60–250 | - | - | [26,139,159] |
|               | (−)-β-elemene - | - | - | - | 100 | - | [26,139,159] |
| S. dysenteriae | Essential oil - | 10,000 | - | - | - | - | [145] |
| P. aeruginosa | Essential oil - | 9–18 | - | - | >4.50 | - | [162] |
|               | Linalool - | 1024 | - | - | - | - | [162] |
| P. multocida  | Essential oil - | 2300 | - | - | - | - | [154] |
| K. pneumoniae | Hydroethanolic - | 20,000 | - | - | - | - | [164] |
|               | 2b<7.80 | | - | - | - | - | [164] |
| M. morganii   | Hydroethanolic - | 10,000 | - | - | - | - | [164] |
| P. mirabilis  | Hydroethanolic - | >20,000 | - | - | - | - | [164] |
| Coliform bacilli | Seed - | - | 2500–7000 | - | - | - | [165] |
| Shigella sp.  | Ethanol - | - | 40,000 | - | - | - | [165] |
| Salmonella sp. | Ethanol - | - | 60,000 | - | - | - | [165] |
| P. syringae  | Methanol - | - | - | >2000 | - | 4p2.50 | [96] |
|               | Rosmarinic acid - | - | - | >2000 | - | 4p2.50 | [96] |
|               | Eugenol - | - | - | 500 | - | 4p2.50 | [96] |
| S. flexneri   | (−)-β-elemene - | - | - | - | 100 | - | [159] |
| S. typhi      | Essential oil - | 9 | - | - | - | - | [153,159] |
|               | Methyl eugenol - | - | - | - | 50 | - | [153,159] |
| E. herbicola  | Essential oil - | - | - | - | 2 µL/mL | 5h8 | [166] |
| P. putida     | Essential oil - | - | - | - | 1 µL/mL | 5h4 | [166] |
| Aeromonas hydrophila | Ethanol - | - | - | 3820 | - | 5h5 | [135] |
| Vibrio harveyi | Ethanol - | - | - | 4460 | - | 5h7 | [135] |
| Vibrio vulnificus | Ethanol - | - | - | 580 | - | 5h6 | [135] |

(-) = Test not performed; 1 = O. americanum, 2 = O. basilicum, 3 = O. gratissimum, 4 = O. campechianum, 5 = O. sanctum; Positive control: b(Ciprofloxacin), e(Tetracycline), k(Streptomycin), o(Imipenem), p(Cloramphenicol).

The MBC data were used to show the ability of the compound to kill bacterial growth. Based on the MBC data in Table 8, the species from Ocimum that had the best activity in
killing bacterial growth was *O. sanctum* which could be seen in the MBC values against *B. cereus*, *E. herbicola*, and *P. putida*. Therefore, based on the data of inhibition zone, MIC, and MBC, the *Ocimum* species that have more potential as natural antibacterials are *O. basilicum* and *O. sanctum*.

Table 8. Data of minimum bactericidal concentration (MBC) of *Ocimum* species.

| Microorganism    | Extract                  | MBC (µg/mL) | Reference       |
|------------------|--------------------------|-------------|-----------------|
|                  |                          | 1           | 2               | 3           | 4           | 5           |                |
| **Gram-Positive Bacteria** |                      |             |                 |             |             |             |                |
| *S. mutans*      | Essential oil            | 0.08% *v/v* | -               | -           | -           | -           | [126,129,158] |
|                  | Lauric acid              | -           | 2500            | -           | -           | -           |                |
|                  | β-Sitosterol             | -           | 50,000          | -           | -           | -           |                |
| *L. casei*       | Essential oil            | 0.30% *v/v* | -               | -           | -           | -           | [126]         |
|                  | β-Sitosterol             | -           | 50,000          | -           | -           | -           | [129]         |
| *S. aureus*      | Essential oil            | -           | 70% hydroethanolic | -   |                 | -           |                |
|                  |                          | -           | 7340            | -           | -           | -           |                |
|                  |                          | -           | >1024           | -           | -           | -           | [24,55,133,155]|
|                  |                          | -           | Caryophyllene   | -           | -           | -           | >200          |
| *B. cereus*      | hydroethanolic ethanol   | 70%        | 6150            | -           | -           | -           |                |
|                  |                          | -           | -               | -           | -           | -           |                |
| *S. phylgenes*   | Essential oil            | -           | 100             | 4.2         | -           | -           | [139,140]     |
| *Listeria mono-cytogenes* | Essential oil      | -           | >20,000         | -           | -           | -           | [160,164]     |
| *S. epidermidis* | Ethanol                  | -           | 2150            | -           | -           | -           |                |
| *B. subtilis*    | Methanol                 | -           | 625             | -           | -           | -           | [143]         |
| *S. sanguinis*   | Lauric acid              | -           | 1250            | -           | -           | -           | [158,161]     |
|                  | Nevadensin               | -           | 15,000          | -           | -           | -           |                |
| **Gram-Negative Bacteria** |                          |             |                 |             |             |             |                |
| *P. gingivalis*  | Essential oil            | 700         | -               | -           | -           | -           | [146]         |
| *P. intermedia*  | Essential oil            | 700         | -               | -           | -           | -           | [146]         |
| *F. nucleatum*   | Essential oil            | 1400        | -               | -           | -           | -           |                |
| *A. baumannii*   | Essential oil            | 8000        | -               | -           | -           | -           | [151]         |
| *E. coli*        | Essential oil            | -           | 1000            | -           | -           | -           | [133,159]     |
|                  | (−)-β-elemene            | -           | -               | -           | -           | -           | 200           |
| *S. typhimurium* | Essential oil            | 3200        | 100–300         | -           | -           | -           | [139,159,163]|
|                  | (−)-β-elemene            | -           | -               | -           | -           | -           | >200          |
| *S. dysenteriae* | Bark                     | -           | 20,000          | -           | -           | -           | [145]         |
| *P. aeruginosaa* | Linalool                 | -           | >1024           | -           | -           | -           | [55]          |
| *K. pneumoniae*  | Hydroethanolic           | -           | >20,000         | -           | -           | -           |                |
| *M. morganii*    | Hydroethanolic           | -           | >20,000         | -           | -           | -           | [164]         |
| *P. mirabilis*   | Hydroethanolic           | -           | >20,000         | -           | -           | -           |                |
| *S. flexneri*    | (−)-β-elemene            | -           | -               | -           | -           | -           |                |
| *S. typhi*       | Methyl eugenol           | -           | -               | -           | -           | -           |                |
| *E. herbicola*   | Essential oil            | -           | -               | -           | -           | -           |                |
| *P. putida*      | Essential oil            | -           | -               | -           | -           | -           |                |

(-) = Test not performed; 1 = *O. americanum*, 2 = *O. basilicum*, 3 = *O. gratissimum*, 4 = *O. campechianum*, 5 = *O. sanctum*.

4. Interaction of Essential Oils to Bacteria

Essential oils usually contain chemical components in the terpenoid and phenylpropanoid groups. The five *Ocimum* species were proven to contain many essential oil components, especially in the monoterpenoid and sesquiterpenoid groups, as well as some phenylpropanoids [167,168]. Therefore, studies on antibacterial activity have also been carried out on the essential oil components. Essential oils of a plants can inhibit both Gram-positive and negative bacteria. However, some studies reported that essential oils
were more sensitive to Gram-positive bacteria, but others reported more sensitive to Gram-negative bacteria [169]. Based on El-Shenaway et al. [170], essential oils were more sensitive against Gram-positive bacteria. This was because of differences in cell wall structures. In Gram-negative bacteria, there was an external capsule which prevented penetration of essential oils into microbial cells. The capsule is composed of a more complex bacterial cell wall with a 2–3 nm thick peptidoglycan layer, where there is an outer membrane on the outer layer of peptidoglycan. The presence of the outer membrane is one of the differences between the cell walls of Gram-negative and Gram-positive bacteria. Peptidoglycan and this outer membrane have strong covalent bonds to Braun lipoproteins. This causes the hydrophobic structure of the essential oil to more easily penetrate the cell walls of Gram-positive bacteria [169].

The ability of essential oils to inhibit bacterial growth is due to their hydrophobicity. It increases cell permeability and leak cell constituents [171]. Essential oils will cross cell wall and cytoplasmic membrane which arrange a lot of polysaccharide layers, fatty acids, and phospholipids. As a result, the interaction between lipophilic compounds from essential oils and various structures found in cell walls and membranes causes a cytotoxic effect [172]. Furthermore, essential oils can also agglomerate in the cytoplasm and cause damage to the protein and lipid layers [173].

In the cell membrane, there is a process of ATP production. The action of essential oils can affect changes in intracellular and external ATP balance. This results in a disturbance with ion loss and a decrease in membrane potential, a decrease in the amount of ATP, and a collapse of the proton pump. [174,175]. This will compromise vital functions such as energy systems, synthesis of structural macromolecules, and secretion of enzymes for growth [171]. In addition, essential oils can affect the pH conditions of bacteria. The presence of essential oils on the membrane can disrupt pH homeostasis and cause a significant decrease in pH. Then, the membrane will lose its capacity to block protons. This is because at low pH, the hydroxyl groups in essential oils do not dissociate so that their hydrophobicity will increase, resulting in easier interaction with bacterial cell membrane lipids [176,177].

There are several methods for extracting essential oils from Ocimum species, such as hydrodistillation, steam distillation, solvent extraction, enfleurage, cohabation, and maceration [178]. However, this method requires a fairly long process if it is to be consumed simply in the community. As an alternative, the Ocimum plant has been widely used traditionally to cure bacterial infections. Ocimum can be processed into juice to relieve toothache and treat otitis. This plant can also be made into an infusion for mouthwash. Decoction of this plant can provide an anesthetic effect and act as an antiseptic. Decoction of the leaves and stems can treat diarrhea, fever, and inflammation of the mucous membranes of the nose [179].

5. Conclusions

O. americanum, O. basilicum, O. gratissimum, O. campechianum, and O. sanctum are five types of Ocimum species that have abundant chemical components and antibacterial activity. Based on data on the chemical components of the five Ocimum species, it is known that the most abundant compounds are terpenoids. O. basilicum is the most commonly used and widely available on the market. However, the activity data of the five Ocimum species show that this plant can be a natural product that has potential as a natural antibacterial agent.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/molecules27196350/s1, Figure S1: Chemical Compound Structures of O. Americanum, Figure S2: Chemical Compound Structures of O. basilicum, Figure S3: Chemical Compound Structures of O. gratissimum, Figure S4: Chemical Compound Structures of O. campechianum, Figure S5: Chemical Compound Structures of O. sanctum.
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References

1. Wu, D.; Ding, Y.; Yao, K.; Gao, W.; Wang, Y. Antimicrobial Resistance Analysis of Clinical Escherichia coli Isolates in Neonatal Ward. Front. Pediatr. 2021, 9, 670470. [CrossRef] [PubMed]

2. Mașpangu, C.C.M.; Adedoja, A.; Kecka, L.G.V.; Vououngui, J.C.; Nguimbi, E.; Velavan, T.P.; Ntoumi, F. High prevalence of antibiotic-resistant Escherichia coli in Congolese students. Int. J. Infect. Dis. 2021, 103, 119–123. [CrossRef] [PubMed]

3. Tom, I.M.; Ibrahim, M.M.; Umoru, A.M.; Umar, J.B.; Bukar, M.A.; Haruna, A.B.; Aliyu, A. Infection of Wounds by Potential Virulence Agents. Int. J. Agric. For. 2019, 12, 1227–1249. [CrossRef]

4. Sani, R.; Garba, S.; Oyejole, O. Antibiotic resistance profile of gram negative bacteria isolated from surgical wounds in Minna, Bida, Kontagora and Sulua areas of Niger state. Am. J. Med. Med. Sci. 2012, 2, 20–24.

5. Chiller, K.; Selkin, B.A.; Murakawa, G.J. Skin microflora and bacterial infections of the skin. J. Investig. Dermatol. Symp. Proc. 2001, 6, 170–174. [CrossRef]

6. Huang, R.; Li, M.; Gregory, R.L. Bacterial interactions in dental biofilm. Virulence 2011, 2, 435–444. [CrossRef]

7. Wang, L.; Hu, C.; Shao, L. The antimicrobial activity of nanoparticles: Present situation and prospects for the future. Int. J. Nanomed. 2017, 12, 1227–1249. [CrossRef]

8. Ben, Y.; Fu, C.; Hu, M.; Liu, L.; Wong, M.H.; Zheng, C. Human health risk assessment of antibiotic resistance associated with antibiotic residues in the environment: A review. Environ. Res. 2019, 169, 483–493. [CrossRef]

9. Martinez, J.L. The role of natural environments in the evolution of resistance traits in pathogenic bacteria. Proc. R. Soc. B Biol. Sci. 2009, 276, 2521–2530. [CrossRef]

10. Benítez-Chao, D.F.; León-Buitimea, A.; Lerma-Escalera, J.A.; Morones-Ramírez, J.R. Bacteriocins: An overview of antimicrobial, toxicity, and biosafety assessment by in vivo models. Front. Microbiol. 2021, 12, 630695. [CrossRef]

11. Appelbaum, P.C. Reduced glycopeptide susceptibility in methicillin-resistant Staphylococcus aureus (MRSA). Int. J. Antimicrob. Agents 2007, 30, 398–408. [CrossRef] [PubMed]

12. Livermore, D.M.; Hope, R.; Brick, G.; Lillie, M.; Reynolds, R.; on behalf of the BSAC Working Parties on Resistance Surveillance. Non-susceptibility trends among Enterobacteriaceae from bacteraemias in the UK and Ireland, 2001–06. J. Antimicrob. Chemother. 2009, 63, i125–i130. [CrossRef] [PubMed]

13. Jacobs, M.R. Streptococcus pneumoniae: Epidemiology and patterns of resistance. Am. J. Med. Suppl. 2004, 117, 3–15. [CrossRef] [PubMed]

14. Stefan, M.; Zamfirache, M.; Paduraru, C.; Trută, E.; Gostin, I. The composition and antibacterial activity of essential oils in three Ocimum species growing in Romania. Cent. Eur. J. Biol. 2013, 8, 600–608. [CrossRef]

15. Runyoro, D.; Ngassapa, O.; Vagionas, K.; Aligiannis, N.; Graikou, K.; Chinou, I. Chemical composition and antimicrobial activity of the essential oils of four Ocimum species growing in Tanzania. Food Chem. 2010, 119, 311–316. [CrossRef]

16. Pavithra, K.H.; Narase Gowda, P.N.; Prasad, M.P. Studies on Antimicrobial Activity of Ocimum Species of Karnataka against Clinical Isolates. Int. J. Pure Appl. Biosci. 2019, 7, 245–254. [CrossRef]

17. Joshi, B.; Lekhak, S.; Sharma, A. Antibacterial Property of Different Medicinal Plants: Ocimum sanctum, Cinnamomum zeylanicum, Xanthoxyllum armatum and Origanum majorana. Kathmandu Univ. J. Sci. Eng. Technol. 2009, 5, 143–150. [CrossRef]

18. Kačáňiová, M.; Galovičková, L.; Borotová, P.; Vuković, N.L.; Vukic, M.; Kunová, S.; Hanus, P.; Bakay, L.; Zagrabelna, E.; Kluž, M.; et al. Assessment of Ocimum basilicum essential oil anti-insect activity and antimicrobial protection in fruit and vegetable quality. Plants 2022, 11, 1030. [CrossRef]

19. Abd-Alla, M.; Haggag, W.M. Use of some plant essential oils as post-harvest botanical fungicides in the management of anthracnose disease of mango fruits (Mangi Feraindica L.) caused by Colletotrichum Gloeosporioides (Penz). Int. J. Agric. For. 2013, 3, 1–6.
20. Shanaida, M.; Jasicka-Misiak, I.; Makowicz, E.; Stanek, N.; Shanaida, V.; Wieczorek, P.P. Development of high-performance thin layer chromatography method for identification of phenolic compounds and quantification of rosmarinic acid content in some species of the Lamiaceae family. J. Pharm. Biomed. Sci. 2020, 12, 139–145. [CrossRef]
21. Maddi, R.; Amani, P.; Bhavitha, S.; Gayathri, T.; Lohitha, T. A review on Ocimum species: Ocimum americanum L., Ocimum basilicum L., Ocimum gratissimum L. and Ocimum tenuiflorum L. Int. J. Res. Ayurveda Pharm. 2019, 10, 41–48.
22. Abd El-Aziz, S.; Omer, E.; Sabra, A. Chemical composition of Ocimum americanum essential oil and its biological effects against, Agrotis ipsilon, (Lepidoptera: Noctuidae). Res. J. Agric. Biol. Sci. 2007, 3, 740–747.
23. Zahrani, E.M.; Abdelmohsen, U.R.; Khalil, H.E.; Desouky, S.Y.; Fouad, M.A.; Kamel, M.S. Diversity, phytochemical and medicinal potential of the genus Ocimum L. (Lamiaceae). Phytochem. Rev. 2020, 19, 907–953. [CrossRef]
24. Ali, H.M.; Nguta, J.M.; Mapenay, I.O.; Musila, F.M.; Omambia, V.M.; Mataroa, D.N. Ethnopharmacological uses, biological activities, chemistry and toxicological aspects of Ocimum americanum var. americanum (Lamiaceae). J. Phytopharm. 2021, 10, 56–60. [CrossRef]
25. Vidhya, E.; Vijayakumar, S.; Rajalakshmi, S.; Kalaiselvi, S.; Pandiyam, P. Antimicrobial activity and phytochemical screening of Ocimum americanum L. extracts against pathogenic microorganisms. Acta Ecol. Sin. 2020, 40, 214–220.
26. Zengin, G.; Ferrante, C.; Gnapi, D.E.; Sinan, K.I.; Orlando, G.; Recinella, L.; Dzuzeva, A.; Jekó, J.; Cziáky, Z.; Chiavaroli, A.; et al. Comprehensive approaches on the chemical constituents and pharmacological properties of flowers and leaves of American basil (Ocimum americanum L.). Food Res. Int. 2019, 125, 108610. [CrossRef]
27. Sutilli, F.J.; Velasquez, A.; Pinheiro, C.G.; Heinizmann, B.M.; Gatlin, D.M., III; Baldisserotto, B. Evaluation of Ocimum americanum essential oil as an additive in red drum (Sciaenops ocellatus) diets. Fish Shellfish. Immunol. 2016, 56, 155–161. [CrossRef]
28. Javanmardi, J.; Stushnoff, C.; Locke, E.; Vivanco, J. Antibacterial activity and total phenolic content of Iranian Ocimum Accessions. Food Chem. 2003, 83, 547–550. [CrossRef]
29. Mustafa, A.A.; El-Kamali, H.H. Chemical Composition of Ocimum americanum In Sudan. Res. Pharm. Health Sci. 2019, 5, 172–178. [CrossRef]
30. Saha, S.; Dhar, T.; Sengupta, C.; Ghosh, P. Biological activities of essential oils and methanol extracts of five Ocimum species against pathogenic bacteria. Czech J. Food Sci. 2013, 31, 195–202. [CrossRef]
31. Shanaida, M.; Kernychna, I.; Shanaida, Y. Chromatographic analysis of organic acids, amino acids, and sugars in Ocimum americanum L. Acta Pol. Pharm. Drug Res. 2017, 74, 729–734.
32. Radha, S. A review on phytochemical and pharmacological activities of selected Ocimum species. J. Pharmacogn. Phytochem. 2021, 10, 100–108.
33. Barchuk, O.; Przyshlyak, A.; Shanaida, M. Chemical compositions and sedative activities of the Dracocephalum moldavica L. and Ocimum americanum L. essential oils. Pharmaceut. OnLine 2021, 2, 179–187.
34. Pandey, A.K.; Singh, P.; Tripathi, N.N. Chemistry and bioactivities of essential oils of some Ocimum species: An overview. Asian Pac. J. Trop. Biomed. 2014, 4, 682–694. [CrossRef]
35. Farag, M.; Ezzat, S.; Salama, M.; Tadros, M. Anti-acetylcholinesterase potential and metabolome classification of 4 Ocimum species as determined via UPLC/qTOF/MS and chemometric tools. J. Pharm. Biomed. Anal. 2016, 125, 292–302. [CrossRef] [PubMed]
36. Chenni, M.; El Abed, D.; Rakotomanana, N.; Fernandez, M.; Chemat, F. Comparative Study of Essential Oils Extracted from Egyptian Basil Leaves (Ocimum basilicum L.) Using Hydro-Distillation and Solvent-Free Microwave Extraction. Molecules 2016, 21, 113. [CrossRef]
37. Altemimi, A.B.; Mohammed, M.J.; Yi-Chen, L.; Watson, D.G.; Lakhssassi, N.; Cacciola, F.; Ibrahim, S.A. Optimization of Ultrasonicated Kaempferol Extraction from Ocimum basilicum Using a Box–Behnken Design and Its Densitometric Validation. Foods 2020, 9, 1379. [CrossRef]
38. Calderón Bravo, H.; Vera Céspedes, N.; Zura-Bravo, L.; Muñoz, L.A. Basil Seeds as a Novel Food, Source of Nutrients and Functional Ingredients with Beneficial Properties. A Review. Foods 2021, 10, 1467. [CrossRef] [PubMed]
39. Filip, S. Basil (Ocimum basilicum L.) of a Sourceable Valuable Phytonutrients. Int. J. Clin. Nutr. Diet. 2017, 3, 118. [CrossRef]
40. Bajomo, E.M.; Aing, M.S.; Ford, L.S.; Niemeyer, E.D. Chemotyping of commercially available basil (Ocimum basilicum L.) varieties: Cultivar and morphotype influence phenolic acid composition and antioxidant properties. NFS J. 2022, 26, 1–9. [CrossRef]
41. Carović-Stanko, K.; Šalinović, A.; Gridiša, M.; Liber, Z.; Kolak, I.; Satovic, Z. Efficiency of morphological trait descriptors in discrimination of Ocimum basilicum L. accessions. Plant Biosyst. Int. J. Deai. All Asp. Plant Biol. 2011, 145, 298–305.
42. Ghasemzadeh, A.; Ashkani, S.; Baghdadi, A.; Pazzoki, A.; Jaafar, H.Z.E.; Rahmat, A. Efficiency in flavonoids and Phenolic Acids Production and Pharmaceutical Quality of Sweet Basil (Ocimum basilicum L.) by Ultraviolet-B Irradiation. Molecules 2016, 21, 1203. [CrossRef] [PubMed]
43. Osei Akoto, C.; Acheampong, A.; Boakyie, Y.D.; Naazo, A.A.; Adomah, D.H. Anti-inflammatory, antioxidant, and anthelmintic activities of Ocimum basilicum (sweet basil) fruits. J. Chem. 2020, 2020, 2153534. [CrossRef]
44. Ch, M.A.; Naz, S.B.; Sharif, A.; Akram, M.; Saeed, M.A. Biological and Pharmacological Properties of the Sweet Basil (Ocimum basilicum). Br. J. Pharm. Res. 2015, 7, 330–339. [CrossRef]
45. Kaefer, C.M.; Milner, J.A. The role of herbs and spices in cancer prevention. J. Nutr. Biochem. 2008, 19, 347–361. [CrossRef]
46. Shahrajabian, M.H.; Sun, W.; Cheng, Q. Chemical components and pharmacological benefits of Basil (Ocimum basilicum): A review. Int. J. Food Prop. 2020, 23, 1961–1970. [CrossRef]
47. Zhan, Y.; An, X.; Wang, S.; Sun, M.; Zhou, H. Basil polysaccharides: a review on extraction, bioactivities and pharmacological applications. Bioorganic Med. Chem. 2020, 28, 115179. [CrossRef]
48. Pedro, A.C.; Moreira, E.; Granato, D.; Rosso, N.D. Extraction of bioactive compounds and free radical scavenging activity of purple basil (Ocimum basilicum L.) leaf extracts as affected by temperature and time. An. Acad. Bras. Ciências 2016, 88, 1055–1068. [CrossRef]
49. Gebrehiwot, H.; Bachetti, R.; Dekebo, A. Chemical composition and antimicrobial activities of leaves of sweet basil (Ocimum basilicum L.) herb. Int. J. Basic Clin. Pharmacol. 2015, 4, 869–875. [CrossRef]
50. Prinsi, B.; Morgutti, S.; Negrini, N.; Faoro, F.; Espen, L. Insight into Composition of Bioactive Phenolic Compounds in Leaves and Flowers of Green and Purple Basil. Plants 2019, 9, 22. [CrossRef]
51. Da Silva, L.A.L.; Pezzini, B.R.; Soares, L. Spectrophotometric determination of the total flavonoid content in Ocimum basilicum L. Ind. Crop. Prod. 2021, 172, 114068. [CrossRef]
52. Falowo, A.B.; Mukumbo, F.E.; Idamokoro, E.M.; Afolayan, A.J.; Muchenje, V. Phytochemical constituents and antioxidant activity of Ocimum basilicum L. essential oil on ground beef from Boran and Nguni cattle. Int. J. Food Sci. 2019, 2019, 2628747. [CrossRef]
53. Ion, V.A.; Nicolau, F.; Petre, A.; Bujor, O.-C.; Badulescu, L. Variability in essential oil composition produced by micropropagated (in vitro), acclimated (ex vitro) and in-field plants of Ocimum basilicum (Lamiaceae). Ind. Crop. Prod. 2016, 86, 180–185. [CrossRef]
54. Ion, V.A.; Nicolau, F.; Petre, A.; Bujor, O.-C.; Badulescu, L. Phytocomposition and some biological activities of the essential oils from basil Ocimum different cultivars. BMC Complement. Altern. Med. 2017, 17, 2–8. [CrossRef]
55. Prinsi, B.; Morgutti, S.; Negrini, N.; Faoro, F.; Espen, L. Insight into Composition of Bioactive Phenolic Compounds in Leaves and Flowers of Green and Purple Basil. Plants 2019, 9, 22. [CrossRef]
56. Tavallali, V.; Rowshan, V.; Ghomali, H.; Hojati, S. Iron-urea nano-complex improves bioactive compounds in essential oils of Ocimum basilicum Lamiaceae leaves. Pharmaceutic. Mag. 2015, 11, 96–101. [CrossRef]
57. Tiede, V.; Akhtar, S.; Sestili, P.; Ismail, T.; Neungart, S.; Qamar, M.; Esatbeyoglu, T. Toxicity, antioxidant activity, and phytochemicals of basil (Ocimum basilicum L.) leaves cultivated in southern Punjab, Pakistan. Foods 2022, 11, 1239. [CrossRef]
58. Ion, V.A.; Nicolau, F.; Petre, A.; Bujor, O.-C.; Badulescu, L. Variation of bioactive compounds in organic Ocimum basilicum L. during freeze-drying processing. Sci. Pap. Ser. B Hortic. 2020, 64, 397–404. [CrossRef]
59. Ion, V.A.; Nicolau, F.; Petre, A.; Bujor, O.-C.; Badulescu, L. Variation of bioactive compounds in organic Ocimum basilicum L. during freeze-drying processing. Sci. Pap. Ser. B Hortic. 2020, 64, 397–404. [CrossRef]
60. Tiede, V.; Akhtar, S.; Sestili, P.; Ismail, T.; Neungart, S.; Qamar, M.; Esatbeyoglu, T. Toxicity, antioxidant activity, and phytochemicals of basil (Ocimum basilicum L.) leaves cultivated in southern Punjab, Pakistan. Foods 2022, 11, 1239. [CrossRef]
61. Tirillini, B.; Maggi, F. Volatile Organic Compounds of the Glandular Trichomes of Ocimum basilicum and Artifacts during the Distillation of the Leaves. Appl. Sci. 2021, 11, 7312. [CrossRef]
71. Prabhu, K.S.; Lobo, R.; Shirwaikar, A.A.; Shirwaikar, A. Ocimum gratissimum: A Review of its Chemical, Pharmacological and Ethnomedicinal Properties. Open Complement. Med. J. 2009, 1, 1–15. [CrossRef]

72. Tella, J.O.; Oseni, S.O. Comparative Profiling of Solvent-mediated Phytochemical Expressions in Ocimum gratissimum and Vernonia amygdalina Leaf Tissues via FTIR Spectroscopy and Colorimetric Assays. J. Adv. Med. Pharm. Sci. 2019, 19, 1–25. [CrossRef]

73. Monga, S.; Dhanpal, P.; Kumar, R.; Kumar, A.; Chhokar, V. Pharmacological and physico-chemical properties of Tulsi (Ocimum gratissimum L.): An updated review. Pharma Innov. 2016, 6, 181–186.

74. Chowdhury, T.; Mandal, A.; Roy, S.C.; De Sarker, D. Diversity of the genus Ocimum (Lamiaceae) through morpho-molecular (RAPD) and chemical (GC-MS) analysis. J. Genet. Eng. Biotechnol. 2017, 15, 275–286. [CrossRef]

75. Akara, E.U.; Emmanuel, O.; Ude, V.C.; Uche-Ikonne, C.; Eke, G.; Ugboogu, E.A. Ocimum gratissimum leaf extract ameliorates phenylhydrazine-induced anaemia and toxicity in wistar rats. Drug Metab. Pers. Ther. 2021, 36, 311–320. [CrossRef] [PubMed]

76. Usunomena, U.; Eseosa, U. In vitro medicinal studies on Ocimum gratissimum leaves. ARC J. Pharm. Sci. 2016, 2, 1–5.

77. Costa, R.S.; Carneiro, T.C.B.; Cerqueira-Lima, A.T.; Queiroz, N.V.; Alcântara-Neves, N.M.; Pontes-De-Carvalho, L.C.; da Silva Velozo, E.; Oliveira, E.J.; Figueiredo, C.A. Ocimum gratissimum Linn. and rosmarinic acid, attenuate eosinophilic airway inflammation in an experimental model of respiratory allergy to Blomia tropicalis. Int. Immunopharmacol. 2012, 13, 126–134. [CrossRef]

78. Usunomena, U.; Eseosa, U. In vitro medicinal studies on Ocimum gratissimum leaves. ARC J. Pharm. Sci. 2016, 2, 1–5.

79. Naveed, M.; Hejazi, V.; Abbas, M.; Mirza, A.; Ahmad, F.; Babazadeh, D.; FangFang, X.; Modarresi-Entezari-Neves, N.M.; Pontes-De-Carvalho, L.C.; da Silva Velozo, E.; Oliveira, E.J.; Figueiredo, C.A. Ocimum gratissimum Linn. and rosmarinic acid, attenuate eosinophilic airway inflammation in an experimental model of respiratory allergy to Blomia tropicalis. Int. Immunopharmacol. 2012, 13, 126–134. [CrossRef]

80. Alam, A.; Pathan, S.; Ali, M.; Ahmad, S.; Ahmad, F.; Babazadeh, D.; FangFang, X.; Modarresi-Entezari-Neves, N.M.; Pontes-De-Carvalho, L.C.; da Silva Velozo, E.; Oliveira, E.J.; Figueiredo, C.A. Ocimum gratissimum Linn. and rosmarinic acid, attenuate eosinophilic airway inflammation in an experimental model of respiratory allergy to Blomia tropicalis. Int. Immunopharmacol. 2012, 13, 126–134. [CrossRef]

81. Olamisoye, K.P.; Akomolafe, R.O.; Akinsomiseoye, O.S.; Adefisayo, M.A.; Alabi, Q.K. The aqueous extract of Ocimum gratissimum leaves ameliorates acetic acid-induced colitis via improving antioxidant status and hematological parameters in male Wistar rats. Egypt. J. Basic Appl. Sci. 2018, 5, 220–227. [CrossRef]

82. Talabi, J.Y.; Makanjuola, S. Proximate, Phytochemical, and In Vitro Antimicrobial Properties of Dried Leaves from Ocimum gratissimum. Prev. Nutr. Food Sci. 2017, 22, 191–194. [CrossRef] [PubMed]

83. Naveed, M.; Hejazi, V.; Abbas, M.; Kamboh, A.A.; Khan, G.J.; Shunzaid, M.; Ahmad, F.; Babazadeh, D.; FangFang, X.; Modarresi-Entezari-Neves, N.M.; Pontes-De-Carvalho, L.C.; da Silva Velozo, E.; Oliveira, E.J.; Figueiredo, C.A. Ocimum gratissimum Linn. and rosmarinic acid, attenuate eosinophilic airway inflammation in an experimental model of respiratory allergy to Blomia tropicalis. Int. Immunopharmacol. 2012, 13, 126–134. [CrossRef]

84. Okoye, F.B.; Obonga, W.O.; Onyegbule, F.A.; Ndu, O.O.; Ihekwereme, C.P. Chemical composition and anti-inflammatory activity of essential oils from the leaves of Ocimum basilicum L. and Ocimum gratissimum L. (Lamiaceae). Int. J. Pharm. Sci. Res. 2014, 5, 2174–2180.

85. Abdulkhaleq, L.A.; Assi, M.A.; Noor, M.H.M.; Abdullah, R.; Saad, M.Z.; Taufiq-Yap, Y.H. Therapeutic uses of epicatechin in diabetes and cancer. Vet. World 2017, 10, 869–872. [CrossRef]

86. Mith, H.; Yayi-Ladékan, E.; Sikpe-Borou, S.; Yu, Y.; Moudachirou, M.; Taube, G.; Clinicar, A. Chemical Composition and Antimicrobial Activity of Essential Oils of Ocimum basilicum, Ocimum canum and Ocimum gratissimum in Function of Harvesting Time. J. Essent. Oil Bear. Plants 2016, 19, 1413–1425. [CrossRef]

87. Sen, A. Prophylactic and therapeutic roles of oleic acid and its derivatives in several diseases. World J. Clin. Cases 2020, 8, 1767–1792. [CrossRef] [PubMed]

88. Vieira, A.; Beserra, F.; Souza, M.; Totti, B.; Rozza, A. Limonene: Aroma of innovation in health and disease. Chem.-Biol. Interact. 2018, 283, 97–106. [CrossRef]
122. Saaban, K.F.; Ang, C.H.; Chuah, C.H.; Khor, S.M. Chemical constituents and antioxidant capacity of *Ocimum basilicum* and *Ocimum sanctum*. *Iran. J. Chem. Eng.* (IJCE) 2019, 38, 139–152.

123. Hussain, A.I.; Chatha, S.A.S.; Kamal, G.M.; Ali, M.A.; Hanif, M.A.; Lazhari, M.I. Chemical composition and biological activities of essential oil and extracts from *Ocimum sanctum*. *Int. J. Food Prop.* 2017, 20, 1569–1581. [CrossRef]

124. Fanchal, P.; Parvez, N. Phytochemical analysis of medicinal herb (*Ocimum sanctum*). *Int. J. Nanomater. Nanotechnol. Nanomed.* 2019, 5, 008–011. [CrossRef]

125. Ijaz, B.; Hanif, M.; Mushtaq, Z.; Khan, M.; Bhatti, I.; Jilani, M. Isolation of bioactive fractions from *Ocimum sanctum* essential oil. *Oxid. Commun.* 2017, 40, 158–167.

126. Thaweboon, S.; Thaweboon, B. In vitro antimicrobial activity of *Ocimum americanum* L. essential oil against oral microorganisms. *Southeast Asian J. Trop. Med. Public Health* 2009, 40, 1025–1033.

127. Verma, R.S.; Bisht, P.S.; Padalia, R.C.; Saikia, D.; Chauhan, A. Chemical composition and antibacterial activity of essential oil from two *Ocimum* spp. grown in sub-tropical India during spring-summer cropping season. *J. Tradit. Med.* 2011, 6, 211–217.

128. Tufiq, M.; Darah, I. Antibacterial activity of an endophytic fungus *Lasiodiplodia pseudotheobromae* IBRL OS-64 residing in leaves of a medicinal herb, *Ocimum sanctum* Linn. *J. Appl. Biol. Biotechnol.* 2019, 7, 35–41.

129. Evangelina, I.A.; Herdiyati, Y.; Laviana, A.; Rikmasari, R.; Anisah; Kurnia, D. Bio-mechanism inhibitory prediction of B-Sitosterol from Kemangiri (*Ocimum basilicum*) as an inhibitor of MurA Enzyme of Oral bacteria: In vitro and in silico study. *Adv. Appl. Bioinform.* Chem. AABC 2021, 14, 103–115. [CrossRef]

130. Jesuwenu, A.D.; Michael, O.O. Antibacterial activity of *Ocimum gratissimum* L. Against some selected human bacterial pathogens. *J. Pharm. Res. Int.* 2020, 10, 1–8. [CrossRef]

131. Carovič-Stanko, K.; Orlić, S.; Politoe, O.; Strikić, F.; Kolak, I.; Milos, M.; Satovic, Z. Composition and antibacterial activities of essential oils of seven *Ocimum* taxa. *Food Chem.* 2010, 119, 196–201. [CrossRef]

132. Moghaddam, A.M.D.; Shayegh, J.; Mikaili, P.; Sharaf, J.D. Antimicrobial activity of essential oil extract of *Ocimum basilicum* L. Leaves on a variety of pathogenic bacteria. *J. Med. Plants Res.* 2011, 5, 3453–3456.

133. Melo, R.S.; Azevedo, M.A.; Pereira, A.M.G.; Rocha, R.R.; Cavalcante, R.M.B.; Matos, M.N.C.; Lopes, P.H.R.; Gomes, G.A.; Rodrigues, T.H.S.; dos Santos, H.S.; et al. Chemical Composition and Antimicrobial Effectiveness of *Ocimum gratissimum* L. Essential Oil Against Multidrug-Resistant Isolates of *Staphylococcus aureus* and *Escherichia coli*. *Molecules* 2019, 24, 3864. [CrossRef]

134. Rajesh, T.; Venkatanagaraju, E.; Goli, D.; Basha, S.J. Evaluation of antimicrobial activity of different herbal plant extracts. *Int. J. Pharm. Sci. Res.* 2014, 5, 1460–1468.

135. Harikrishnan, R.; Kim, M.-C.; Kim, J.-S.; Balasundaram, C.; Jawahar, S.; Heo, M.-S. Identification and Antimicrobial Activity of Combined Extract from *Azadirachta indica* and *Ocimum sanctum*. *Isr. J. Aquac.-Baniqeh* 2010, 62, 85–95. [CrossRef]

136. Ogundare, A. Antibacterial properties of the leaf extracts of *Vernonia amygdalina*, *Ocimum gratissimum*, *Corchorus olitorius* and *Manihot palmate*. *J. Microbiol. Antimicrob.* 2011, 3, 77–86.

137. Ali, H.; Nguta, J.; Musila, F.; Ole-Mapenay, I.; Matara, D.; Mailu, J. Evaluation of antimicrobial activity, cytotoxicity, and phytochemical composition of *Ocimum americanum* L. (Lamiaceae). *Evid. Based Complement. Altern. Med.* 2022, 2022, 6484578. [PubMed]

138. Torpol, K.; Wiriayacharee, P.; Sririsawatana, S.; Sangsuwan, J.; Prinyawiwatkul, W. Antimicrobial activity of garlic (*Allium sativum* L.) and holy basil (*Ocimum sanctum* L.) essential oils applied by liquid vs. vapour phases. *Int. J. Food Sci. Technol.* 2018, 53, 2119–2128. [CrossRef]

139. Helal, I.M.; El-Bessoumy, A.; Al-Bataineh, E.; Joseph, M.R.P.; Rajagopalan, P.; Chandramouorthy, H.C.K.; Ahmed, S.B.H. Antimicrobial Efficiency of Essential Oils from Traditional Medicinal Plants of Asir Region, Saudi Arabia, over Drug Resistant Isolates. *BioMed. Res. Int.* 2019, 2019, 8928306. [CrossRef]

140. Opara, A.; Egbruobi, R.; Ndudim, J.N.D.; Onyewuchi, C.; Nnodim, J. Antibacterial Activity of *Ocimum gratissimum* (Nchu-Anwu) and *Vernonia amygdalina* (Bitter-Leaf) Antibacterial Activity of *Ocimum gratissimum* (Nchu-Anwu) and *Vernonia amygdalina* (Bitter-Leaf). *Br. J. Microbiol.* 2014, 4, 1115–1126. [CrossRef]

141. Hapsari, I.P.; Feronisianti, Y.M.L. Phytochemical screening and in vitro antibacterial activity of sweet basil leaves (*Ocimum basilicum L.*) essential oil against *Cutibacterium acnes* ATCC 11827. *AIP Conf. Proc.* 2019, 2099, 020007. [CrossRef]

142. Bulfon, C.; Volpatti, D.; Galeotti, M. In Vitro Antibacterial Activity of Plant Ethanolic Extracts against Fish Pathogens. *J. World Aquac. Soc.* 2014, 45, 545–557. [CrossRef]

143. Gupta, P.C.; Batra, R.; Chauhan, A.; Goyal, P.; Kaushik, P. Antibacterial activity and TLC bioautography of *Ocimum basilicum* L. against pathogenic bacteria. *J. Pharm. Res.* 2009, 2, 407–409.

144. Stanley, M.C.; Iseanyi, O.E.; Chinedum, O.K.; Chinenye, N.D. The Antibacterial Activity of Leaf Extracts of *Ocimum gratissimum* and *Sida Acuta*. *Int. J. Microbiol. Res.* 2014, 5, 124–129. [CrossRef]

145. Issazadeh, K.; Majid, K.P.M.R.; Massiha, A.; Bidarigh, S.; Giahi, M.; Zulfagar, M.P. Analysis of the phytochemical contents and anti-microbial activity of *Ocimum basilicum* L. *Int. J. Mol. Clin. Microbiol.* 2012, 2, 141–147.

146. Thaweboon, S.; Thaweboon, B. *Ocimum americanum* L. essential oil exhibits antimicrobial activity against oral bacteria related to periodontal disease. *Adv. Mater. Res.* 2014, 1025–1026, 755–759. [CrossRef]

147. Mahmoud, K.; Yaqoob, U.; Bajwa, R. Antibacterial activity of essential oil of *Ocimum sanctum* L. *Mycopath* 2008, 6, 2.
148. Nweze, E.I.; Eze, E.E. Justification for the use of Ocimum gratissimum L in herbal medicine and its interaction with disc antibiotics. BMC Complement. Altern. Med. 2009, 9, 37. [CrossRef]

149. Londhe, A.; Kulkarni, A.; Lawand, R. In-vitro comparative study of antibacterial and antifungal activities: A case study of Ocimum kilimandscharicum, Ocimum tenuiflorum and Ocimum gratissimum. Int. J. Pharmacoogn. Phytochem. Res. 2015, 7, 104–110.

150. Helen, M.; Raju, V.; Gomathy, S.; Nizzy, S.; Sree, S. Essential oil analysis in Ocimum spp. Herb. Technol. Ind. 2011, 8, 12–15.

151. Intorasoot, A.; Chornchoem, P.; Sookkhee, S.; Intorasoot, S. Bactericidal activity of herbal volatile oil extracts against multidrug-resistant Acinetobacter baumannii. J. Intercell. Ethnopharmacol. 2017, 6, 218–222. [CrossRef] [PubMed]

152. Niculăe, M.; Spinu, M.; Sandru, C.D.; Brudăşcu, F.; Cadăr, D.; Szakacs, B.; Scurtu, I.; Bolăş, P.; Mateş, C. Antimicrobial potential of some Lamiaceae essential oils against animal multiresistant bacteria. Lucr. Ştiinţifice Med. Vet. 2009, 42, 170–175.

153. Moghaddam, A.M.D.; Shayegh, J.; Sharaf, J.D. Comparison between Two Groups of Pathogenic Bacteria under Different Essential Oil Extract of Ocimum basilicum L. J. Med. Plants By-Prod. 2017, 6, 241–245. [CrossRef]

154. Hussain, A.I.; Anwar, F.; Sherazi, S.T.H.; Przybylski, R. Chemical composition, antioxidant and antimicrobial activities of basil (Ocimum basilicum) essential oils depends on seasonal variations. Food Chem. 2008, 108, 986–995. [CrossRef] [PubMed]

155. Ighodaro, O.; Agunbiade, S.; Akintobi, O. Phytotoxic and anti-microbial activities of flavonoids in Ocimum gratissimum. J. Agric. Food Chem. 2022, 27, 6350.

156. Katara, A.; Pradhan, C.K.; Singh, P.; Singh, V.; Ali, M. Volatile Constituents and Antimicrobial Activity of Aerial parts of Ocimum gratissimum Linn. J. Essent. Oil Bear. Plants 2013, 16, 283–288. [CrossRef]

157. De Aguiar, F.C.; Solarte, A.L.; Tarradas, C.; Luque, I.; Maldonado, A.; Galán-Relaño, Á.; Huerta, B. Antimicrobial activity of selected essential oils against Streptococcus suis isolated from pigs. MicrobiologyOpen 2018, 7, e00613. [CrossRef]

158. Herdiyati, Y.; Astrid, Y.; Shadrina, A.A.N.; Iani, I.; Satari, M.H.; Kurnia, D. Potential Fatty Acid as Antibacterial Agent against Oral Bacteria of Streptococcus mutans and Sanguinis from Basil (Ocimum americanum): In vitro and In silico Studies. Curr. Drug Discov. Technol. 2021, 18, 532–541. [CrossRef]

159. Phanthong, P.; Lomarat, P.; Chomnawang, M.T.; Bunyapraphatsara, N. Antibacterial activity of essential oils and their active components from Thai spices against foodborne pathogens. ScienceAsia 2013, 39, 472. [CrossRef]

160. Koche, D.; Kokate, P.; Suradkar, S.; Bhadange, D. Preliminary phytochemical and antibacterial activity of ethanolic extract of Ocimum gratissimum L. Biosci. Discov. 2012, 3, 20–24.

161. Shadrina, A.A.N.; Herdiyati, Y.; Iani, I.; Satari, M.H.; Kurnia, D. Prediction Mechanism of Nevadensin as Antibacterial Agent against S. sanguinis: In vitro and In silico Studies. Comb. Chem. High Throughput Screen. 2022, 25, 1488–1497. [CrossRef] [PubMed]

162. Yamani, H.A.; Pang, E.C.; Mantri, N.; Deighton, M.A. Antimicrobial Activity of Tulsi (Ocimum tenuiflorum) Essential Oil and Their Major Constituents against Three Species of Bacteria. Front. Microbiol. 2016, 7, 681. [CrossRef] [PubMed]

163. Onyebuchi, C.; Kavaz, D. Effect of extraction temperature and solvent type on the bioactive potential of Ocimum gratissimum L. extracts. Sci. Rep. 2020, 10, 21760. [CrossRef]

164. Majdi, C.; Pereira, C.; Dias, M.I.; Calhelha, R.C.; Alves, M.J.; Rhouri-Frih, B.; Charrouf, Z.; Barros, L.; Amaral, J.S.; Ferreira, I.C. Phytochemical Characterization and Bioactive Properties of Cinnamon Basil (Ocimum basilicum cv. ‘Cinnamon’) and Lemon Basil (Ocimum × citriodorum). Antioxidants 2020, 9, 369. [CrossRef] [PubMed]

165. Ejele, A.; Duru, I.; Ogukwe, C.; Iwu, I. Phytochemistry and antimicrobial potential of basic metabolites of Piper umbellatum, Piper guineense, Ocimum gratissimum and Neem compounds laevic extracts. J. Emerg. Trends Eng. Appl. Sci. 2012, 3, 309–314.

166. Pandey, A.K.; Singh, P.; Palini, U.; Tripathi, N. In-vitro antibacterial activities of the essential oils of aromatic plants against Erwinia herbicola (Lohnis) and Pseudomonas putida (Kris Hamilton). J. Serb. Chem. Soc. 2012, 77, 313–323. [CrossRef]

167. Maffei, M.E.; Gertsch, J.; Appendino, G. Plant volatiles: Production, function and pharmacology. Nat. Prod. Rep. 2011, 28, 1359–1380. [CrossRef]

168. Bhattacharya, D.; Adhikari, S.; Biswas, A.; Bhumiali, A.; Ghosh, P.; Saha, S. Ocimum Phytochemicals and Their Potential Impact on Human Health. In Phytochemicals in Herbal Products; IntechOpen: London, UK, 2020.

169. Nazzaro, F.; Fratianni, F.; De Martino, L.; Coppola, R.; De Feo, V. Effect of Essential Oils on Pathogenic Bacteria. Pharmaceuticals 2013, 6, 1451–1474. [CrossRef]

170. El-Shenawy, M.A.; Baghdadi, H.H.; El-Hosseiny, L.S. Antibacterial activity of plants essential oils against some epidemiologically relevant food-borne pathogens. Open Public Health J. 2015, 8, 30–34. [CrossRef]

171. Faleiro, M.L. The mode of antibacterial action of essential oils. Sci. Against Microb. Pathog. Commun. Curr. Res. Technol. Adv. 2011, 2, 1143–1156.

172. Murbach Teles Andrade, B.F.; Nunes Barbosa, L.; da Silva Probst, I.; Fernandes Júnior, A. Antimicrobial activity of essential oils. J. Essent. Oil Res. 2014, 26, 34–40. [CrossRef]

173. Akthar, M.S.; Degaga, B.; Azam, T. Antimicrobial activity of essential oils extracted from medicinal plants against the pathogenic microorganisms: A review. Issues Biol. Sci. Pharm. Res. 2014, 2, 1–7.

174. Turgis, M.; Han, J.; Caillet, S.; Lacroix, M. Antimicrobial activity of mustard essential oil against Escherichia coli O157:H7 and Salmonella typhii. Food Control 2009, 20, 1073–1079. [CrossRef]

175. Di Pasqua, R.; Hoskins, N.; Betts, G.; Mauriello, G. Changes in Membrane Fatty Acids Composition of Microbial Cells Induced by Addiction of Thymol, Carvacrol, Limonene, Cinnamaldehyde, and Eugenol in the Growing Media. J. Agric. Food Chem. 2006, 54, 2745–2749. [CrossRef] [PubMed]
176. Calsamiglia, S.; Busquet, M.; Cardozo, P.; Castillejos, L.; Ferret, A. Invited Review: Essential Oils as Modifiers of Rumen Microbial Fermentation. *J. Dairy Sci.* 2007, 90, 2580–2595. [CrossRef] [PubMed]

177. Oussalah, M.; Caillet, S.; Saucier, L.; Lacroix, M. Antimicrobial effects of selected plant essential oils on the growth of a *Pseudomonas putida* strain isolated from meat. *Meat Sci.* 2006, 73, 236–244. [CrossRef]

178. Rassem, H.H.; Nour, A.H.; Yunus, R.M. Techniques for extraction of essential oils from plants: A review. *Aust. J. Basic Appl. Sci.* 2016, 10, 117–127.

179. Ugbogu, O.C.; Emmanuel, O.; Agi, G.O.; Ibe, C.; Ekweogu, C.N.; Ude, V.C.; Uche, M.E.; Nnanna, R.O.; Ugbogu, E.A. A review on the traditional uses, phytochemistry, and pharmacological activities of clove basil (*Ocimum gratissimum* L.). *Heliyon* 2021, 7, e08404. [CrossRef]