Chapter

Ocimum Phytochemicals and Their Potential Impact on Human Health

Debjoy Bhattacharjya, Sinchan Adhikari, Arijit Biswas, Anil Bhuimali, Parthadeb Ghosh and Soumen Saha

Abstract

The genus Ocimum (Lamiaceae) is distributed all over the world and can be found in many environments. Ocimum species is a rich source of various phytochemicals including tannins, phenolic acids, anthocyanins, phytosterols, and policosanols. These phytochemicals have the potential to significantly impact human health. The economic importance of Ocimum is also evident; Ocimum oil and its constituents and derivatives are used as flavoring agents throughout the world in food, pharmaceutical, herbal, perfumery, and flavoring industry. The important advantages of Ocimum plants in various treatments are their safety besides being less expensive, efficacy and availability throughout the world. This paper will focus on the biological effects of Ocimum essential oils, with particular attention on the molecular mechanism underlying their action.

Keywords: Ocimum sp., essential oil, composition, biological activity

1. Introduction

Living plants produce a vast quantity of chemicals required for their performance and improvement. Some of these chemicals are primary metabolites, which consist of proteins (amino acids), carbohydrates, fats, nucleic acids, etc. but, besides these primary chemicals, the plants further provide just so-called secondary metabolites, which are specific to some taxonomic groups (families, genera). About 80% of the world’s population still depends on the traditional system of medicine for curing several health hazards [1]. Despite the vast scientific development in contemporary medicine, Ayurvedic system of medicine is widely practiced and accepted by people not only in India but also in many developed countries. According to the World Health Organization (WHO), about 80% of patients in India still, rely on the practitioners of the traditional system of medicines. The therapeutic use of herbal crude medicines in different rural and urban communities is most of the time regulated by their traditional beliefs, and thus a majority of the herbal drugs are used as “folk” medicines and well practiced since long past. Furthermore, increasing dependency on medicinal plants in the industrialized communities have been found to the extraction and improvement of several remedies and chemotherapeutics from these plants and from traditionally established rural herbal remedies [2]. In these communities, herbal remedies become deeply engaged in the practice of minor conditions and again on the explanation of the increasing costs of specific health maintenance. Although synthetic drugs enhanced the
demand against green remedies because of their rapid-acting implements, people have been turned up to understand the benefits correlated with essential remedies. Chemically prepared drugs may act at earlier, but they side effects which influence the human body separately in the long run, because medicinal plants work in an integrated or probiotic with limited or no negative effects on the body [3].

The genus *Ocimum* includes approximately 150 species, possessing a great variation in plant morphology and biology, essential oil content, and chemical composition [4]. The economic importance and global dissemination of *Ocimum*, with its many uses in cooking and folk medicine, make it important to investigate its pharmacological and toxicological effects in order to ensure its efficacy and safety. In India, among the medicinal herbs known for their healing properties, the genus *Ocimum* (commonly known as 'Basil' or 'Tulsi') is very important for its curative potential. Basils contain a wide range of essential oils rich in phenolic compounds and a wide array of other natural products including flavonoids and anthocyanins [5] having great pharmacological importance.

Nowadays, scientists are mainly focused on exploring the potential of plant antioxidants for curing several diseases. Antioxidants are compounds that can delay or inhibit the oxidation of lipids or other molecules by inhibiting the initiation or propagation of oxidative chain reactions [6]. Antioxidants counteract the harmful reactive oxygen species (ROS) and free radicals generated in the living organism during regular metabolism, especially under stress conditions. Several in vitro and in vivo studies have already proved the antioxidative property of beta-carotene, alfa-tocopherol, ascorbic acids, phenolics, flavonoids present in different plants [7].

Presently due to our regular stressful lifestyle, we are suffering from several types of diseases like aging, diabetes, degenerative disorders, etc., which mainly develop due to the development of ROS in our body. A dynamic balance is already operating in our body to reduce the harmful effects of generated ROS that is not adequate enough. Therefore, it is obvious to enrich our diet with antioxidants for developing protection. The purpose of this paper will focus on the recent research of the major nutrients and phytochemicals of *Ocimum* and their potential health benefits related to the dietary prevention of chronic diseases.

### 2. Health benefits of phytochemicals

“Phyto” in the word of phytochemicals is derived from the Greek word “phyto,” which means plant. Phytochemicals are a naturally occurring group of chemicals in plants and plant-derived foods, which may function in reducing the risk of chronic diseases [8]. Although it is estimated at least more than 5000 dietary phytochemicals have been discovered, it is believed that a high percentage of phytochemicals in foods still remain unknown [8]. Critical reviews of studies available in the literature support the concept that phytochemicals (polyphenols, tocopherols, tocotrienols, carotenoids, and ascorbic acid) has been associated with the maintenance of good health as well as prevention/treatment of many health conditions including cancer, cardiovascular diseases, diabetes, hypertension, stroke, metabolic syndrome, and other degenerative diseases. It is largely accepted that the additive effects of the combinations of various phytochemicals in whole plant-based foods are shown to have stronger protective actions than single, isolated phytochemical compounds [9].

### 3. Role of secondary metabolites

New drug model seeks to meet on bringing compounds active toward target proteins. Even though newly pharmaceutical companies and support organizations
take influence in molecular design, combinatorial chemistry and synthetic chemistry, natural productions, and especially those of plant source, remain as a prerequisite cause of new remedies, current medicine leads and other new synthetic entities (NCEs) [10, 11].

Plants produce a diverse array of compounds that can broadly be categorized into primary and secondary metabolites. Primary metabolites are the ones which are required for the normal growth and biological processes and are produced in the pathways that are crucial for plant survival. The other class of metabolites, though generally termed secondary, is also very crucial for plants from the ecological perspective.

These secondary metabolites are classified on the basis of their biosynthetic pathway and the following types are frequently observed-terpenes, phenylpropanoids, alkaloids, saponins, and glucosinolates. The availability of carbon, nitrogen, and sulfur along with energy from the primary metabolism governs the biosynthesis of these compounds [12].

4. Classification of secondary metabolites

Metabolites are the mediators and amounts of metabolism. The term metabolite is commonly confined to narrow fragments. Metabolites have specific functions,
consisting of fuel, structure, signaling, stimulatory and inhibitory effects on enzymes, and the catalytic activity of their holding (mostly as a cofactor to a stimulant), defense and interaction with distinct pathogens. Plant metabolites are categorized based on their biosynthetic pathways. The pathways of biosynthesis are responsible for the occurrence of both primary and secondary metabolites (Figure 1) [13, 14]. Plant secondary metabolites can be classified on the basis of chemical structure (for example, having rings, containing a sugar), composition (consisting of nitrogen or not), their solubility in numerous solvents, or the pathway by which they are synthesized (e.g., phenylpropanoid, which provides tannins).

5. Essential oil of Ocimum species

Since ancient times, essential oils are known for their medicinal use, and they are very much interesting and impressive natural plant commodities. They continue to be of paramount importance until the present day. Essential oils have been tested as perfumes, flavors for foods and beverages, or to provide both bodies and care for thousands of years [16].

| Species          | Class of compounds                  | Reference       |
|------------------|-------------------------------------|-----------------|
| O. basilicum L.  | **Monoterpane hydrocarbons**       | [18–20, 23]     |
|                  | α-Phellandrene, α-pinene, α-terpinene, α-terpinolene, α-myrcene, β-phellandrene, β-pinene, camphene, cis-β-ocimene, cis-ocimene, δ-3-carene, β-ocimene, (E)-β-ocimene, limonene, myrcene, ρ-cymene, sabinene, terpinolene, thujene, γ-terpinene | |
|                  | **Oxygenated monoterpane**          | [18, 19, 21, 25]|
|                  | α-Citral, α-fenchyl acetate, α-terpineol, borneol, bornyl acetate, camphor, carvacrol, carvone, 1,8-cineole, cis-linalool oxide, cis-rose oxide, citronellol, endo-fenchol, estragol, eugenol, exo-2-hydroxycineole-aceotate, fenchone, geranial, geraniol, geranyl acetate, hotrienol, iso-neomenthol, iso-pinocamphone, trans-pinocamphone, l-camphor, l-carvone, lavandulol, linalool, linalool cis-furanoid, linalool trans-furaloid, linalyl acetate, menthol, menthone, methyl chavicol, myrtenal, myrtenol, neral, nerol, ocimene oxide, pinocarvone, P-meth-1,8-dien-4-ol, piperitone, pulegone, terpinen-4-ol, terpinyl formate, trans-linalool oxide, trans-myroxide, trans-sabinene hydrate, trans-p-menth-2-en-1-ol, thymol, verbeneone, (Z)-sabinene hydrate | |
|                  | **Sesquiterpane hydrocarbons**      | [19, 26, 21–24]|
|                  | β-acoradiene, β-bourbonene, β-caryophyllene, β-cedrene, β-copaene, β-cubebene, β-elemene, β-guaiene, β-ocimene, β-selinene, cyclohexane, 2,4 disopropenyl-1-methyl-1-vinyl, 1,4,7-cycloundecatriene,1,5,9,9-tetramethyl, α-acoradiene, α-amorphene, α-bulnesene, α-cadinene, α-cedrene, α-copaene, α-cubebene, α-guiaene, α-gurjunene, γ-gurjunene, α-7-epi-selinene, α-humulene, aromadendrene, α-(Z)-bergamotene, α-zingiberene, epsilon-muurolene, dehydroaromadendrene, germacrene-A, bicycloelemene, bicyclogermacrene, cadinene, cadina-3,5-diene, cis-calamene, cis-muurola-4(14),5-diene, (E)-β-farnesene, (E)-caryophyllene, 1-epicyclosessquiphellandrene, germacrene-B, germacrene-D, guaia-1(10),11-diene, iso-caryophyllene, isoledenne, longifolene, δ-selinene, St α-ylangene, trans-α-bisabolene, trans-α-bergamotene, trans-β-farnesene, trans-β-ocimene, trans-caryophyllene, valencene, γ-cadinene, γ-terpin, δ-cadinene, γ-muurolene, (Z)-calamene |
| Species               | Class of compounds                                                                 | Reference |
|----------------------|------------------------------------------------------------------------------------|-----------|
| **Ocimum**           | **Phytochemicals and Their Potential Impact on Human Health**                       | DOI: http://dx.doi.org/10.5772/intechopen.88555 |
| **Species**          | **Class of compounds**                                                             | **Reference** |
| **Ocimum**           | **Phytochemicals**                                                                | [19, 21] |
| **Species**          | **Class of compounds**                                                             | **Reference** |
| **Ocimum** kilimandscharicum Guerke | **Monoterpenoid hydrocarbons**                                                     | [28, 29, 34] |
| **Species**          | **Class of compounds**                                                             | **Reference** |
| **Ocimum** gratissimum L. | **Phenolic compounds**                                                            | [33]       |
| **Species**          | **Class of compounds**                                                             | **Reference** |
| **Ocimum** canum Sims. | **Terpenoids**                                                                    | [42]       |

**Species**

**Class of compounds**

- **Oxigenated sesquiterpenes**
  - α-Cadinol, α-humulene oxide, alloaromadendrene, β-basibolol, β-basibolol isomer, β-eudesmol, cubenol, caryophyllene oxide, 1,10-di-epi-cubenol, dihydroactinidiolide, isospathulenol, muurolol, spathulenol, T-cadinol, viridiflorol, (Z)-nerolidol

- **Triterpene**
  - Alphitolic acid, betulin, betulinic acid, 3-epimaslinic acid, euscaphic acids, oleonolic acid, pomolic acid, ursolic acid, basilol, ocimol

- **Aromatic compounds**
  - 4-Allylphenol, anethole, anisaldehyde, benzyl alcohol, cuminaldehyde, estragole, ethyl cinnamate, methyl benzoate, methyl cinnamate, methyl eugenol, methyl salicylate, p-methoxy-caffinoldehyde, phenethyl alcohol, phenyl acetaldehyde, safranal, benzaldehyde, cis-hex-3-enyl acetate

- **Monoterpenoid hydrocarbons**
  - α-Phellandrene, α-pinene, α-terpinene, γ-terpinene, β-pinene, camphene, limonene, δ-limonene, β-ocimene, (E)-β-ocimene, myrcene, β-cymene, terpinolene, thujene, α-terpinolene, isosylvestrene, γ-himachalene

- **Oxigenated monoterpenes**
  - α-Citral, α-terpineol, borneol, bornyl acetate, camphor, linalool, citronellol, geraniol, myrtenol, 1,8-cineole, eugenol, terpinen-4-ol, trans-sabinene hydrate, (Z)-sabinene hydrate, α-campholenal, isoborneol, endo-borneol, globulol

- **Sesquiterpenoid hydrocarbons**
  - α-Copaene, α-gurjunene, α-humulene, β-caryophyllene, β-copaene, β-cubebene, β-elemene, δ-cadinene, γ-muurolene, trans-caryophyllene, germacrene-D, germacrene-B, β-selinene

- **Sesquiterpenoid hydrocarbons**
  - trans-Caryophyllene, germacrene-D, α-farnesene, β-bisabolene, cis-β-ocimene, trans-β-ocimene, α-copaene, β-elemene, β-caryophyllene, α-humulene, germacrene-D, β-selinene, trans-β-Farnesene, β-bisabolene, γ-cadinene, δ-cadinene, γ-muurolene, β-cubebene, α-cubebene

- **Sesquiterpenoid oxygenated**
  - β-Caryophyllene epoxide

- **Aromatic compounds**
  - Methyl cinnamate

- **Terpenoids**
  - Cyclosativen
| Species | Class of compounds | Reference |
|---------|--------------------|-----------|
| **Monoterpenes hydrocarbon** | α-Thujene, α-pinene, camphene, β-pinene, limonene, γ-terpinene, terpinolene, sabine, myrcene, α-terpinene, p-cymene, (Z)-β-ocimene, (E)-β-ocimene, perillene, (E)-β-epoxyocimene, α-phellandrene, α-terpinene, cis-β-ocimene, cis-sabinene hydrate, carene, tricyclene | [43, 45, 48] |
| Oxygeneated monoterpenes | Eugenol, linalool, 1,8-cineole, 5-isopropyl-2-methylbicyclo[3.1.0]hexan-2-ol, fenchone, trans-linalool oxide (furanoid), camphor, δ-terpineol, terpinen-4-ol, α-terpineol, fenchyl acetate (endo), isobornyl acetate, borneol, thymol, menthone, geranial, α-fenchyl acetate, bornyl acetate, exo-2-hydroxycineole acetate, verbenone, camphenol, myrtenyl acetate | [43, 46, 48] |
| **Sesquiterpenes hydrocarbon** | α-Copaene, β-elemene, β-caryophyllene, germacrene D, β-bisabolene, E, α-farnesene, δ-cadinene, α-cadinene, trans-α-bergamotene, aromadendrene, α-humulene, epibicyclosesquiphellandrene, bicyclogermacrene, δ-guaiene, calamenene, (E)-α-bisabolene, valencene, trans-α-bergamotene, γ-muurolene, α-muurolene, epi-α-muurolol, elemol, β-selinene, α-selinene, (Z,E)-α-farnesene, trans-β-ocimene, (E)-β-farnesene | [45, 46, 49] |
| Oxygeneated sesquiterpenes | α-Cadinol, spathulenol, (Z)-nerolidol, caryophyllene oxide, β-eudesmol, viridiflorol | [42, 46] |
| **Aromatic compounds** | Methyl eugenol, estragole, benzyl benzoate | [45, 47] |
| **Esters** | 1-Octen-3-yl acetate | [44] |
| Others | Naphthalene | [46] |
| *O. tenuiflorum* L. *syn. O. sanctum* L. (purple type) | | |
| **Monoterpenes hydrocarbon** | α-Pinene, β-pinene, β-terpinene, α-limonene, camphene, sabine, myrcene, p-cymene, limonene, α-terpinene, α-thujene, α-myrcene, α-terpinolene, terpinolene, γ-terpinene, (E)-β-ocimene, β-myrcene, α-camphene, β-terpinolene, β-cis-ocimene | [50–52] |
| Oxygeneated monoterpenes | Linalool, menthol, methyl chavicol, α-citral, carvone, lavandulol, hotrienol, eugenol, 1,8-cineole, globulol, borneol, bornyl acetate, camphor, thymol, geranial, citronellol, E-linalool, β-citral, carvacrol, methyl chavicol, α-fenchyl acetate, myrtenol, terpinen-4-ol, trans-sabinene hydrate, cis-geraniol, cis-α-terpineol, cis-linalool oxide, eucalyptol, cis-linalool oxide (furanoid), trans-linalool oxide (furanoid), δ-terpineol | [52–54] |
| **Sesquiterpenes hydrocarbon** | Caryophyllene, β-farnesene, germacrene-D, isolatedene, β-selinene, β-cubebene, β-elemene, β-caryophyllene, β-bourbonene, α-humulene, γ-muurolene, bicyclogermacrene, δ-cadinene, α-copaene, trans-caryophyllene, selinene, β-elemene, β-guaiene, β-bisabolene, α-guaiene, germacrene-B, valencene, (E)-β-farnesene, trans-α-bergamotene, α-cubebene, β-germacrene, α-farnesene, α-caryophyllene, α-selinene, (Z)-β-farnesene | [50, 52–54] |
Chemical diversification is of special significance if at the genus or species level both terpenes and phenylpropenes can be formed in the essential oil. Most Lamiaceae preferentially accumulate mono-(and sesqui-)terpenes in their erratic oils but some genera show oils too rich in phenylpropenes [17].

The action of essential oils begins by entering the human body via three possible different ways including direct absorption through inhalation, ingestion or diffusion through the skin tissue.

Table 1 presents published compositions of species-wise distribution of bioactive compounds in Ocimum species.

### Table 1. Compositions of species-wise distribution of bioactive compounds in Ocimum species.

| Species     | Class of compounds                                      | Reference         |
|-------------|---------------------------------------------------------|--------------------|
|             | **Sesquiterpenes oxygenated**                           |                    |
|             | α-Cadinol, alloaromadendrene, caryophyllene oxide, cubenol, t-cadinol, spathulenol, viridiflorol | [53, 54]           |
| O. tenuiflorum (white type) | **Aromatic compounds** | $p$-Methoxycinnamaldehyde, estragole, benzaldehyde | [51, 54] |
|             | **Monoterpenes hydrocarbons**                           |                    |
|             | α-pinene, camphene, β-pinene, limonene, (E)-β-ocimene, p-cymene, γ-terpinene, camphene hydrate, carene, terpinolene, sabine hydrate, terpinene, ocimene, limonene, terpinene, phellandrene, myrcene, sabinene, camphene, thujene, tricyclene | [55–57] |
|             | **Oxygenated monoterpenes**                             |                    |
|             | Linalool, borneol, eugenol, methyl eugenol, 1,8-cineole, α-terpineol, geraniol, trans-linalool oxide (furanoid), δ-terpineol, terpineol, terpinen-4-ol, δ-terpineol, camphor, fenchone, trans-sabine hydrate, eucalyptol | [56–59] |
|             | **Sesquiterpenes hydrocarbons**                         |                    |
|             | β-Elemene, β-caryophyllene, α-humulene, germacrene D, β-selinene, α-selinene, α-cubebe, δ-cadinene, elemol, bicyclogermacrene, α-cadinene, copaene, β-elemen, α-guaiene, γ-muurolene, δ-cadinene, amorphene, cubebe, α-bisabolene, cadinene, β-bisabolene, muurolene, germacene, humulene, farnesene, sesquiphellandrene, bergamotene, guaiene, elemene, bourbonene, zingiberene | [55–59] |
|             | **Sesquiterpenes oxygenated**                           |                    |
|             | Spathulenol, caryophyllene oxide, viridiflorol, β-eudesmol, γ-eudesmol | [60, 61] |
|             | **Aromatic compounds**                                  |                    |
|             | Estragole                                               | [55, 60]           |

6. Biological activities of Ocimum species

The genus Ocimum (family Lamiaceae), collectively known as basil, is composed of a diverse and rich source of essential oil containing plants. The main issues of concern with the use of herbal drugs remain safety, validation of claims and standardization of product. Different species and forms of Ocimum spp. vary in growth habit, color, and aromatic composition, making the true botanical identity of basil difficult (Figure 2). There exist the problems of significant variation in the content of Ocimum plants across and within species, with the implication of varied
biological activities. During the last two decades, it has been shown that *Ocimum* oil and its constituents possess different biological activities including antioxidant, antimicrobial, anticancer, and anti-inflammatory properties.

### 6.1 Oxidant activity

Anti-oxidants play an important function in protecting the body against free radicals. They achieve this by stopping the formation of new free radicals species, converting older ones to free radicals, less toxic molecules that can be easily mopped up and preventing radical chain reaction [62]. The principal function of anti-oxidants is in suspending the oxidation of other molecules, by inhibiting the initiation or propagation of oxidizing chain reactions by free radicals and thereby reducing oxidative damage to the human body [63]. Two great mechanisms of procedure have been proposed for antioxidants [64]. The initial is a chain breaking method by which the initial antioxidant provides an electron to the free radical stage in the systems. The second technique involves the destruction of ROS/reactive nitrogen species initiators (secondary antioxidants) by cutting off chain starting catalysts (Figure 2). The potential role in the food industry and human health, antioxidants are getting acceptance all across the globe. Antioxidants are defined as a substance that easily in small amounts, can inhibit or prohibit the oxidation of readily oxidizable elements. The antioxidant is also defined as a substance qualified of inhibiting special oxidizing stimulants or a substance that serves with oxidizing agents prior to creating damage to other fragments or a substance that sequesters metal ions or even a substance efficient of the recovering system such as iron transporting protein [65].

Natural antioxidants have been studied intensively during the past years which are mainly phenolic compounds. Moreover, oxidation is a degenerative process in...
biological systems due to the endogenous reactive oxygen species (ROS). Reactive oxygen species (ROS) are chemical properties originate in the body during metabolism that is overmuch reactive and may have one or expanded unpaired electrons. Oxidative stress, i.e., an inequality between ROS and antioxidant defenses have delerious aftereffect, such as the peroxidation of membrane lipids and the aggression on biomolecules (proteins, membrane enzymes, carbohydrates and DNA) [66].

Various Ocimum species and their extracts or essential oils have been determined to achieve antioxidant activity [67, 68]. Phenolic acids, hydroxycinnamates, and flavonoids are perhaps the major antioxidants [67]. Vitamin antioxidants (e.g., ascorbic acid and carotenoids) are secondary contributors to the overall antioxidant capacity [69]. In essential oils, unsaturated terpenes having a cyclohexadiene structure (e.g., terpinene) and secondary cyclic oxygenated terpenes (e.g., thymol) may lead to antioxidant capacity, while acyclic unsaturated oxygenated monoterpenes (e.g., linalool), aromatic oxygenated monoterpenes (e.g., eugenol), methylchavicol (estragole), sesquiterpene hydrocarbons (e.g., α-bergamotene, germacrene D, γ-cadinene, δ-cadinene, β-selinene, sesquiterpenes oxygenated (e.g., spathulenol) may act as pro-oxidants [68].

Different test methods have been applied, and it becomes to be understood between the complete essential oil and individual components [70–73]. A strong chelating effect on metals as iron or copper has been reported to diminish the presence of ROS obtained from reactions bar with these metals [74]. In addition, the antioxidant actions of Ocimum essential oils have also been found employing metal-independent oxidative processes [75] or controlling stable free radicals, such as 2,2-diphenyl-1-picrylhydrazyl (DPPH) radical [71, 76]. The DPPH test, a test widely used to measure the ability to donate hydrogen atoms [77], was applied to measure the antioxidant capacities of Ocimum species extracted by different solvent systems; these include the methanol extracts of O. basilicum L., O. canum Sims., O. gratissimum L., O. kilimandscharicum Guerke, O. sanctum, O. tenuiflorum [67, 71, 76, 78–80]; the ethanol extracts from O. basilicum L., O. gratissimum L., O. kilimandscharicum Guerke, O. sanctum [76, 79, 81–83].

Particular attention has been focused on the scavenger ability to inhibit the process of low-density lipoprotein (LDL) cholesterol oxidation since it represents a major prevention mechanism against atherosclerosis. Various experimental evidence, using in vitro and in vivo preclinical models, showed a strong action of Ocimum essential oils [84]. Moreover, Aqueous extracts Ocimum sanctum and 70% ethanol extracts Ocimum basilicum L. were able to reduce 5-lipoxygenase-driven cellular recruitment of leukocytes and the damaging consequences of their ability to release ROS while leaving unimpaired the generation of prostaglandins, which promote microvascular blood flow and act as immunomodulators [85–87].

In many cases, the antioxidative activity (Figure 3) of essential oils cannot be attributed to the main compounds; minor compounds and synergistic effect may significantly contribute to the activity.

### 6.2 Antimicrobial

For thousands of years, folk medicine has used Ocimum leaf for the treatment of infections. Such protective properties have been confirmed by several studies performed in the last decades using Ocimum essential oil [29] or isolated compounds. Gram-positive and Gram-negative bacteria, as well as antiprotozoal and also anti-Trichomonas vaginalis, resulted sensitive to the antiproliferative action of Ocimum oil and its derivatives [29, 88–90]. At present, the exact mechanism responsible for the antimicrobial activity of Ocimum oil and its derivatives is still not completely
clarified, although various modes of action in the bacterial cell have been discussed including degradation of the cell wall, damage to cytoplasmic membrane and membrane proteins, leakage of cell contents, coagulation of cytoplasm, and depletion of proton motive force [91–93].

The antibacterial and antifungal activities of Ocimum species have been studied on various bacteria and fungi [29, 94–96]. These studies indicate that essential oils are more efficient antifungals and antibacterials compared to the polar extracts [97–99]. Ocimum sanctum essential oils showed remarkable antimicrobial activity against bacteria and other microorganisms, such as periodontopathogens [100], mainly due to the presence of oxygenated monoterpenes in their chemical compositions [101].

The essential oil and methanol extracts of five Ocimum species have an appreciable activity against seven human pathogenic bacteria [29], essential oils of Ocimum species showed strong antimicrobial activity against all seven microorganisms tested. Oils of seven Ocimum taxa (O. americanum L., O. basilicum L., O. campechianum Mill., O. x citriodorum Vis., O. kilimandscharicum Baker ex Gürke and three botanical varieties and cultivars of Ocimum basilicum L.: ‘Genovese’, var. difforme and var. purpurascens)) showed strong antimicrobial activity against all 8 microorganisms tested by Carovic-Stanko et al. [102].

Among the antifungal activities, the in vitro antifungal activity of O. basilicum L. essential oil against Aspergillus flavus fungal growth and aflatoxin B1 production [103], essential oils of O. basilicum L. showed strong antifungal activity against A. flavus, and the main components were linalool, 1,8-cineol, eugenol, methyl cinnamate, α-cubebe, caryophyllene, β-ocimene and α-farnesene.
6.3 Anticancer activity

For a long time, the polyphenols of the *Ocimum* oil of the diet have been considered to play a role for the prevention of certain types of cancer in the Asian origin [104]. Even more than in *Ocimum* oil, constituents present in *Ocimum* leaf extract has shown strong antioxidant potency and inhibition of cancer cell proliferation, thus suggesting the protection against the genotoxic action of the ROS as one of the mechanisms explaining the anticancer effects of these compounds. Indeed, either methanol aqueous *Ocimum basilicum* L. leaf extract or the isolated constituents eugenol epoxide free radical scavenging activity and growth inhibition at low micromolar concentration on human breast cancer cell lines (MCF-7 and MDA-MB-231) [105, 106] and Human cancerous cell lines (HL60-promyelocytic blood leukemia cells) [107]. Such findings were further confirmed by other in vitro reports, testing the effects of *Ocimum basilicum* L. against four different humans cancer cell lines viz. human cervix adenocarcinoma HeLa cells, human melanoma FemX cells, human chronic myelogenous leukemia K562 cells, and human ovarian SKOV3 cells [108]. Furthermore, Karthikeyan et al. [109] demonstrated regression of tumors caused by orally administrated aqueous and ethanolic extracts of *Ocimum sanctum* in mice that developed spontaneous soft tissue sarcomas.

Monga et al. [110] studied the antimelanoma and radioprotective activity of essential oils obtained by 50% alcoholic aqueous leaf extract from five species of *Ocimum* viz. *Ocimum sanctum* (SE), *Ocimum gratissimum*, *Ocimum basilicum*, *Ocimum canum*, and *Ocimum kilimandscharicum*, were evaluated using C57BL and Swiss albino mice tumorigenesis; growth inhibition has in fact been associated with (a) reduction of tumor volume (b) blockage of messengers of pathways involved in cell proliferation was evident in all the oils but the greater was shown by that obtained from *Ocimum tenuiflorum* (syn. *O. sanctum*) compared to other *Ocimum* species. In various experiments and test systems, some mono- and sesquiterpenes showed activity, where camphor, 1,8-cineole and limonene were of greatest interest. Camphor, 1,8-cineole and limonene, the anti-inflammatory compound of *Ocimum kilimandscharicum* oil, showed a strong time-and dose-dependent cytotoxic effect on human ovarian cancer cell [111]. The potential antitumor effects of camphor have been shown previously [112, 113], and the mechanistic action of camphor against cancer included the improvement of immune function [114] and the radiosensitizing effect on transplantable mammary adenocarcinoma in mice [112]. Ursolic acid showed some potentiating effect on the anticancer activity of rosmarinic acid, cinnamic acid, caffeic acid, sinapic acid, and ferulic acid on various cell lines [106].

6.4 Cardiovascular protection

For decades, investigation on the health-promoting effects of Asian diet has been revealed that *Ocimum* oil consumption is a key factor in the cardiovascular protection found in Asian origin [115]. It is well established that the healthful properties of *Ocimum basilicum* L. oil depend largely on its Cardiac glycosides and catecholamines content [116]. But, many arguments prove that in *Ocimum* oil there are little bioactive components, much than Cardiac glycosides and catecholamines, effective for its cardiovascular protective properties: among them, the ethanolic fraction of *Ocimum* oil, and in specific omega-3 fatty acids have proved antioxidant, anti-platelet aggregation, vasodilatory, and anti-inflammatory effects, all engaged in this health beneficial action [117–119].
Oxidation of LDL cholesterol is one of the key steps in the induction of atherosclerotic lesions by increasing damage to the arterial side through several processes, including growth factor and chemotactic protein expression, inflammation, and build up local macrophages [120, 121] have indicated that ethanolic leaf extract of *Ocimum basilicum* L. oil strongly inhibits copper sulfate-induced oxidation of LDL, as a result of the step of different indicators of lipid oxidation [phospholipids (PL), cholesterol ester (CE), triacylglycerol (TG)].

Although the contraction of plasmatic cholesterol and LDL is the primary technique regulating the antiatherogenic activity of *Ocimum basilicum* L. extract, other implements are further identified [121]. It is well settled that local leukocyte and monocyte recruitment into the vessel wall is initial walk-in atherogenesis. This fact takes combined with the statement in the endothelial cells of adhesion fragments such as intercellular adhesion fragment-1 (ICAM-1) and vascular adhesion fragment-1 (VCAM-1). Aqueous extract of *Ocimum gratissimum* L. showed the capacity to reduce LPS-stimulated expression of BEAS-2B cell in human lung epithelial cells inhibiting its mRNA levels. Moreover, Li et al. [122], investigating the action of distillate and residue fractions of basil essential oil (viz. estragole, methyl eugenol, linoleic acid, α-cadinol, and α-bergamotene) in-a Raw 264.7 cells line, have demonstrated that residue fractions prevents the expression of gene and suppressed the production of cytokines (TNF-a, IL-b, IL-6) in LPS-induced Raw264.7 cells, which contribute to treating various disorders caused by extreme oxidative stress.

6.5 Anti-inflammatory

The inflammatory response involves long been compartmentalized into multiple attributes commonly termed redness, heat, pain, and edema. Inflammatory injuries lead to the discharge of a variety of fundamental mediators, cytokines, and chemokines that balance cellular infiltration that consequentially brings about resolving inflammatory response and restoration of tissue scrupulosity. However, immutable inflammatory stimuli or dysregulation of mechanisms of the resolution phase can lead to chronic inflammation [123, 124].

*Ocimum* extracts contain numerous constituents which could have anti-inflammatory effects. The anti-inflammatory effects of *Ocimum* oil phenolics, in RAW 264.7 macrophage cells have been described by Aye et al. [125]. When added to murine macrophages stimulated with bacterial lipopolysaccharide (LPS), *Ocimum* oil phenolics did not cause cytotoxicity in RAW 264.7 macrophage cells in vitro, as evaluated by a significant increase in the production of nitric oxide [125]. Additionally, NO is a significant inflammatory mediator generated by NOS (neuronal, inducible, and endothelial) under physiological and pathophysiological conditions [126]. It further serves as a crucial mediator during the inflammatory process. Enhanced NO production and iNOS expression contributes to the great cytotoxic function of LPS stimulated macrophages [127]. Thus, the reduction in NO production indicates the anti-inflammatory activities of the treatment in the cells. However, *Ocimum basilicum* L. ethyl acetate extract and butanol extract inhibited the growth of normal RAW 264.7 macrophage cells [128]. Also, *Ocimum basilicum* L. crude methanolic extract suppressed the induction of iNOS and the subsequent production of NO in LPS-stimulated RAW 264.7 macrophage cells [129, 130]. To test the anti-inflammatory activity of the *Ocimum basilicum* L. methanolic extracts has been determined by PBMC (peripheral blood mononuclear cells) in mitogenic lymphocyte proliferative assay, methanolic extracts enhanced the functional activity of these immune-competent cells, as evaluated by a significant inhibitory effects of methanolic leaf extracts, PHA activated PBMC proliferation could be suggestive of suppression of T cell proliferation [130]. This effect arose from its pivotal role in
immune regulation [131, 132], T cell activation provides a target for pharmacological modulation aimed at achieving clinically useful immune-suppression [133].

Złote et al. [134] studied the capacity of phenolic-rich fraction obtained from the elicited basil leaves to inhibit the activity of two enzymes of inflammatory process (LOX and COX). This research found that a higher LOX and COX inhibition efficiency was positively correlated with the increased contents of rosmarinic, benzoic and o-coumaric acids determined after elicitation of basil. This result partially corresponds with the study of [135]. More recently, to gain insight into the mechanism of action and pharmacological value of the anti-inflammatory activity of aqueous and methanolic extracts of Ocimum basilicum L. in macrophage (RAW264.7) and human chondrosarcoma (SW1353) cell lines, and human primary chondrocytes to correlate their efficacy in terms of management of osteoarthritis (OA). Raina et al. [136] evaluated aqueous extract of O. basilicum L. significantly acclimated the production of inflammatory mediators such as NO, PGE2, LTB4, and MMPs increased than the methanolic extract. The regulation of these inflammatory intermediaries is pivotal in OA, as it would have a direct effect on (1) chondrocyte survival, (2) production of proinflammatory cytokines, prostaglandins and leukotrienes, and (3) production of extracellular matrix-degrading enzymes such as MMPs. Due to the significant side-effects related to the use of NSAIDs, the check for natural products that would regulate the inflammatory cascade related to OA, without engaging chondrocyte survival, is extremely important. To investigate the anti-inflammatory effect of Ocimum basilicum L. oil, Rodrigues et al. [137] investigated an acute and chronic in vivo test as paw edema, peritonitis, and vascular permeability and granulomatous inflammation model. The anti-inflammatory mechanism of action was also analyzed by the participation of histamine and arachidonic acid pathways. These researchers found that the Ocimum basilicum L. essential oil and estragole significantly reduced paw edema induced by carrageenan and dextran. The smallest quantities of Ocimum basilicum L. essential oil (50 mg/kg) and estragole (30 mg/kg) revealed effectiveness in the decrease of paw edema created by histamine and arachidonic acid, vascular permeability inhibition and leukocyte emigration in the peritoneal fluid. These dosages were carried out of decrease the assured inflammatory process. The results followed between the Ocimum basilicum L. essential oil and estragole determine efficacy in anti-inflammatory activity, however, the essential oil is higher efficacious in the acute and chronic anti-inflammatory action. Dextran is a high molecular weight polysaccharide, which differently to carrageenan, induces anaphylactic reactions characterized by extravasation and formation of edema due to mastocyte degranulation with release of histamine and serotonin. Carrageenan induces an inflammatory response through opinion with sulfated polysaccharides, initially encouraging the free of chemical substances which encourage multifactorial facts, mostly concerning the free of substance P, bradykinin, histamine, serotonin, cytokines, and nitric oxide and, subsequently on commodity arise from the arachidonic acid pathway [138].

6.6 Antidiabetic

Diabetes mellitus is a chronic metabolic disorder caused by an absolute or relative lack of insulin and or reduced insulin activity which results in hyperglycemia and abnormalities in carbohydrate, fat and protein metabolism [139, 140]. The hypoglycemic effect of O. tenuiflorum L., O. canum Sims. and O. gratissimum L. in animals with alloxan-induced diabetes was applied to potentiation of glucose-induced insulin free and parallel increased peripheral uptake of glucose [141, 142]. Successive studies have reported a greater link of antidiabetic deal with the antioxidant effects of Ocimum oil. The character played by OS for diabetes complications
such as retinopathy, nephropathy, and cardiovascular disease are well set up so that dietary antioxidant compounds was fixed to protect from the damages of oxidative stress and free radicals in diabetic cases [143].

In animal experimental designs of alloxan-induced diabetes, both antioxidant and hypoglycemic effects of *O. basilicum* L., *O. tenuiflorum* L., *O. canum* Sims. and *O. gratissimum* L. have been reported. By treating alloxan-diabetic rabbits [141, 142, 144], made a significant decrease in blood glucose levels as corresponded with diabetic control rabbits. Such a hypoglycemic work was related to its powerful antioxidant potentiality: in evidence, in interact, the rabbits studied with *Ocimum* oil showed further a renewal of the levels of malondialdehyde and most of the enzymatic and nonenzymatic endogenous antioxidants [141, 142, 144]. Similar results were achieved in alloxan-diabetic rats: the control, of *Ocimum tenuiflorum*-rich extracts showed significant hypoglycemic, hypolipidemic, and antioxidant effects in all the investigated diabetic rats [145, 146]. In an identical empirical design, *O. gratissimum* L. led to a decrease in the sugar level in plasma and a rise in superoxide dismutase, catalase, and glutathione peroxidase activities in liver and kidney. Furthermore, an opposed reaction against hepatic and renal toxicity in diabetic rats was also observed [147, 148]. Furthermore, the effects of *Ocimum sanctum* leaf polyphenols have been investigated also in insulin-secreting pancreatic β-cells, whose OS-induced alterations contribute to the pathogenesis of diabetes [149].

7. Future direction and conclusion

Despite the many appreciations of science and industry, present practice is filled with stress. Mobile devices and the web have vastly enhanced the pace of life so that many people feel that they are now going down in an endless-increasing ocean of data, while technical culture has overwhelmed us with growing vulnerability to unhealthy prepared and packed food and a profusion of pesticides, food container components, and many toxic modern chemicals. Urban citizens are nevertheless dealt with growing prosperity disparity, social segregation, excessive turbulence, air, water and soil pollution and disconnection from nature. Therefore, while industrialization experiences served to stronger lifespans and impressive expansions in human populations, it is now agreed that the extremest causes of death and disease on the globe are preventable lifestyle-related chronic diseases [150].

The biodiversity of essential oils containing the small molecular terpenoids remains an enchanted field of investigation, and the continuous usage of this reward in a broad field of studies suggested these demands in the consequent [151]. Screening, identifying, and dealing with this vast biodiversity will require a progressing progress of precise, rich-throughput experimental methods including new driving procedures.

The beneficial health effects of *Ocimum* oil compounds have also been proven by many randomized, crossover, controlled, human studies on biomarkers of health performed in the last decades. Several preclinical studies suggest that such beneficial effects may be mainly ascribed to the phenolic compounds. Further development of biotechnology with the genomic and metabolomic analyses and genetic engineering will advance a variety of fields involving bioactive compounds ranging from food and animal nutrition to plant protection. Although many biological activities as antimicrobial or antioxidative and other effects have been intensively studied and well documented. However, well studies are needed to further characterize the *in vivo* effects of individual *Ocimum* derivatives applied as specific agents or in a mixture, consisting of their safety analysis on mortals. Moreover, a better evidence of their molecular procedure of activity may appropriate the system to a better application in human pharmacology.
In inference, the tendency of the last moments in the treatment of herbal productions have indicated that nature prospects and trust in pure and healthful products including medicines, cosmetics, household products, since easily as foodstuffs of plant and animal origin have belonged to a vital issue. So, indeed a well-balanced risk-benefit assessment of bioactive essential oils is one of the major challenges and policymakers must be convinced that review on natural products as the volatile terpenoids in essential oils is a huge task to ensure the ultimate human and animal welfare [151].

Author details

Debjoy Bhattacharjya\textsuperscript{1}, Sinchan Adhikari\textsuperscript{2}, Arijit Biswas\textsuperscript{2}, Anil Bhuimali\textsuperscript{1}, Parthadeb Ghosh\textsuperscript{2} and Soumen Saha\textsuperscript{1,2,}\*  

\textsuperscript{1} Cytogenetics and Plant Breeding Section, Department of Sericulture, Raiganj University, Raiganj, West Bengal, India

\textsuperscript{2} Cytogenetics and Plant Biotechnology Research Unit, Department of Botany, University of Kalyani, Kalyani, West Bengal, India

\*Address all correspondence to: thustu@gmail.com
References

[1] Kunwar RM, Adhikari N. Ethnomedicine of Dolpa district, Nepal: The plants, their vernacular names and uses. Lyonia. 2005;8:43-49

[2] UNESCO. FIT/504-RAF-48 Terminal Report: Promotion of Ethnobotany and the Sustainable Use of Plant Resources in Africa; Paris. 1998. p. 60

[3] Idu M, Umweni AA, Odaro T, Ojelede L. Ethnobotanical plants used for oral healthcare among the Esan Tribe of Edo State, Nigeria. Ethnobotanical Leaflets. 2009;13:548-563

[4] Danesi F, Elementi S, Neri R, Maranesi M, D’antuono LF, Bordoni A. Effect of cultivar on the protection of cardiomyocytes from oxidative stress by essential oils and aqueous extracts of basil (Ocimum basilicum L.). Journal of Agriculture & Food Chemistry. 2008;56:9911-9917

[5] Joshi V, Bothara B, Surana J. Evaluation of aqueous extract of Ocimum sanctum in experimentally induced parkinsonism. Journal of Chemical and Pharmaceutical Research. 2011;3:478-487

[6] Velioglu YS, Mazza G, Gao L, Oomah BD. Antioxidant activity and total phenolics in selected fruits, vegetables, and grain products. Journal of Agricultural Food & Chemistry. 1998;46:4113-4117

[7] Cross CE, Halliwell B, Borish ET. Oxygen radicals and human disease. An International Medicine. 1987;107:526-545

[8] Liu RH. Potential synergy of phytochemicals in cancer prevention: Mechanism of action. Journal of Nutrition. 2004;134:3479S-3485S

[9] Xi P, Liu RH. Whole food approach for type 2 diabetes prevention. Molecular Nutrition & Food Research. 2016;60:1819-1836

[10] Balunasa MJ, Kinghorn D. Drug discovery from medicinal plants. Life Sciences. 2005;78:431-441

[11] Newman DJ, Cragg GM. Natural products as sources of new drugs from 1981 to 2014. Journal of Natural Products. 2016;79:629-661

[12] Dudareva N, Klempien A, Muhlemann JK, Kaplan I. Biosynthesis, function and metabolic engineering of plant organic volatile compounds. New Phytologist. 2013;198:16-32

[13] Herbert RB, editor. The Biosynthesis of Secondary Metabolites. 2nd ed. Chapman & Hall: London; 1989

[14] Nolaou KC, Chen JS, Corey EJ. Classics in Total Synthesis, Further Targets, Strategies, Methods III. Weinheim: Wiley; 2011. pp. 1-770

[15] Verpoorte R. Secondary metabolism. In: Verpoorte R, Alfermann AW, editors. Metabolic Engineering of Plant Secondary Metabolism. Springer: Dordrecht; 2000

[16] Wei A, Shibamoto T. Antioxidant/ Lipoxygenase inhibitory activities and chemical compositions of selected essential oil. Journal of Agriculture and Food Chemistry. 2010;58:7218-7225

[17] Bradu BL, Sobti SN, Pushpangadan P, Khosla KM, Rao BL, Gupta SC. Development of superior alternate source of clove oil from ‘Clocimum’ (Ocimum gratissimum Linn.). In: Proc. 11th Int. Congr. of Essential Oils, Fragrances and Flavours. Vol. 3. 1989. pp. 97-103
[18] Chang X, Alderson PG, Wright CJ. Enhanced UV-B radiation alters basil (Ocimum basilicum L.) growth and stimulates the synthesis of volatile oils. Journal of Horticulture and Forestry. 2009;1:027-031

[19] Martino LD, Feo VD, Nazzaro F. Chemical composition and in vitro antimicrobial and mutagenic activities of seven Lamiaceae essential oils. Molecules. 2009;14:4213-4230

[20] Ismail M. Central properties and chemical composition of Ocimum basilicum essential oil. Pharmaceutical Biology. 2006;44:619-626

[21] Lee SJ, Umano K, Shibamoto T, Lee KG. Identification of volatile components in basil (Ocimum basilicum L.) and thyme leaves (Thymus vulgaris L.) and their antioxidant properties. Food Chemistry. 2005;91:131-137

[22] Hassanpouraghdam MB, Gohari GR, Tabatabaei SJ, Dadpour MR. Inflorescence and leaves essential oil composition of hydroponically grown Ocimum basilicum L. Journal of the Serbian Chemical Society. 2010;75:1361-1368

[23] Lawrance BM, Mokheyee BD, Willis BJ. Developments in Food Sciences, Flavour and Fragrances; A World Perspective. The Netherlands: Elsevier; 1988

[24] Bassolé IH, Lamien-Meda A, Bayala B, Tirogo S, Franz C, Novak J, et al. Composition and antimicrobial activities of Lippia multiflora Moldenke, Mentha x piperita L. and Ocimum basilicum L. essential oils and their major monoterpane alcohols alone and in combination. Molecules. 2010;15:7825-7839

[25] Vani SR, Cheng SF, Chuah CH. Comparative study of volatile compounds from genus Ocimum. American Journal of Applied Sciences. 2009;6:523-528

[26] Özcan M, Chalchat JC. Essential oil composition of Ocimum basilicum L. and Ocimum minimum L. in Turkey. Czech Journal of Food Science. 2002;20:223-228

[27] Poonkodi K. Chemical composition of essential oil of Ocimum Basilicum L. (basil) and its biological activities—An overview. Journal of Critical Reviews. 2016;3:56-62

[28] Pandey AK, Singh P, Tripathi NN. Chemistry and bioactivities of essential oils of some Ocimum species: An overview. Asian Pacific Journal of Tropical Biomedicine. 2014;4:682-694

[29] Saha S, Dhar TN, Sengupta C, Ghosh PD. Biological activities of essential oils and methanol extracts of five Ocimum species against pathogenic bacteria. Czech Journal of Food Science. 2013;31:194-202

[30] Joshi RK. Chemical composition of the essential oil of camphor basil (Ocimum kilimandscharicum Guerke). Global Journal of Medicinal Plant Research. 2013;1:207-209

[31] Mahesh SP, Patil MB, Kumar R, Patil SR. Evaluation of aqueous extract of leaves of Ocimum kilimandscharicum Guerke wound healing activity in albino wistar rats. International Journal of Pharmtech Research Coden (USA). 2009;1:544-550

[32] Kashyap CP, Kaur R, Arya V, Vipin K. Therapeutic potency of Ocimum kilimandscharicum Guerke—A review. Global Journal of Pharmacology. 2011;5:191-200

[33] Dolly G, Nidhi S, Bps S, Shweta R, Shikha A. Ocimum kilimandscharicum: A systematic review. Journal of Drug Delivery & Therapeutics. 2012;2:45-52
[34] Charles DJ, Simon JE. Essential oil constituents of Ocimum kilimandscharicum Guerke. Journal of Essential Oil Research. 1992;4:125-128

[35] Matasyoh LG, Matasyoh JC, Wachira FN, Kinyua MG, Muigai AWT, Mukiai TK. Chemical composition and antimicrobial activity of the essential oil of Ocimum gratissimum L. growing in Eastern Kenya. African Journal of Biotechnology. 2007;6:760-765

[36] Ntezurubanza L, Scheffer JJC, Svendsen AB. Composition of the essential oil of Ocimum gratissimum grown in Rwanda. Planta Medica. 1987;53:421-423

[37] Chimnoi N, Reuk-ngam N, Chuysinuan P, Khlaychan P, Khunnawutmanotham N, Chokchaichamnankit D, et al. Characterization of essential oil from Ocimum gratissimum leaves: Antibacterial and mode of action against selected gastroenteritis pathogens. Microbial Pathogenesis. 2018;118:290-300

[38] Nguemtchouin MGM, Ngassoum MB, Chalier P, Kamga R, Ngamo LST, Cretin M. Ocimum gratissimum essential oil and modified montmorillonite clay, a means of controlling insect pests in stored products. Journal of Stored Products Research. 2013;52:57-62

[39] Nakamura CV, Ueda-Nakamura T, Bando E, Melo AFN, Cortez DAG, Filho BPD. Antibacterial activity of Ocimum gratissimum L. essential oil. Memórias do Instituto Oswaldo Cruz, Rio de Janeiro. 1999;94:675-678

[40] Vieiraa RF, Grayerb RJ, Patonb A, Simonaj E. Genetic diversity of Ocimum gratissimum L. based on volatile oil constituents, flavonoids and RAPD markers. Biochemical Systematics and Ecology. 2001;29:287-304

[41] Pessoaa LM, Moraisb SM, BevilaquaCML, Lucianoj HS. Anthelmintic activity of essential oil of Ocimum gratissimum Linn. and eugenol against Haemonchus contortus. Veterinary Parasitology. 2002;109:59-63

[42] Belong P, Ntonga PA, Fils EMB, Dadji GAF, Tamesse JL. Chemical composition and residue activities of Ocimum canum Sims and Ocimum basilicum L essential oils on adult female Anopheles funestus s.s. Journal of Animal & Plant Sciences. 2013;19:2854-2863

[43] Kalita J, Khan ML. Commercial potentialities of essential oil of Ocimum members growing in north East India. International Journal of Pharmacy & Life Sciences. 2013;4:2559-2567

[44] Ntonga PA, Baldovini N, Mouray E, Mambu L, Belong P, Grellier P. Activity of Ocimum basilicum, Ocimum canum, and Cymbopogon citratus essential oils against Plasmodium falciparum and mature-stage larvae of Anopheles funestus s.s. Parasite. 2014;21:33

[45] Selvi MT, Thirugnanasampandan R, Sundarammal S. Antioxidant and cytotoxic activities of essential oil of Ocimum canum Sims. from India. Journal of Saudi Chemical Society. 2012;19:97-100

[46] Chagonda LS, Makanda CD, Chalchat JC. The essential oils of Ocimum canum Sims (basilic camphor) and Ocimum urticifolia Roth from Zimbabwe. Flavour and Fragrance Journal. 2000;15:23-26

[47] da Silvaa VD, Almeida-Souzab F, Teles AM, Netoa PA, Mondego-Oliveira R, Filho NEM, et al. Chemical composition of Ocimum canum Sims. essential oil and the antimicrobial, antiprotozoal and ultrastructural alterations it induces in Leishmania amazonensis promastigote. Industrial Crops and Products. 2018;119:201-208
by planting dates and harvest times in North Alabama. Journal of Medicinally Active Plants. 2014;2:33-41

[56] Pino JA, Rosado A, Rodriguez M, Garcia D. Composition of the essential oil of *Ocimum tenuiflorum* L. grown in Cuba. Journal of Essential Oil Research. 1998;10:437-438

[57] Brophy JJ, Goldsack RJ, Clarkson JR. The essential oil of *Ocimum tenuiflorum* L. (Lamiaceae) growing in northern Australia. Journal of Essential Oil Research. 1993;5:459-461

[58] Yamani HA, Pang EC, Mantri N, Deighton MA. Antimicrobial activity of Tulsi (*Ocimum tenuiflorum*) essential oil and their major constituents against three species of bacteria. Frontiers in Microbiology. 2016;7:681. DOI: 10.3389/fmicb.2016.00681

[59] Raina AP, Kumar A, Dutta M. Chemical characterization of aroma compounds in essential oil isolated from “holy basil” (*Ocimum tenuiflorum* L.) grown in India. Genetic Resources and Crop Evolution. 2013;60:1727-1735

[60] Sharma V, Sharma A, Seth R. A study on Antidermatophytic potential of *Ocimum tenuiflorum* essential oil and chemical composition evaluation. International Journal of PharmTech Research. 2016;9:151-160

[61] Tangpao T, Chung HH, Sommano SR. Aromatic profiles of essential oils from five commonly used Thai basils. Food. 2018;7:175. DOI: 10.3390/foods7110175

[62] Ismail HI, Chan KW, Marion AA, Ismail M. Phenolic content and antioxidanat activity of cantoloupe (*Cucumis melol*) methanolic extracts. Food Chemistry. 2010;119:643-647

[63] Ismail A, Margan ZM, Foong CW. Total activity and phenolic content in
selected vegetables. Food Chemistry. 2004;87:581-586

[64] Rice-Evans CA, Diplock AT. Current status of antioxidant therapy. Free Radical Biology & Medicine. 1993;15:77-96

[65] Brewer MS. Natural antioxidants: Sources, compounds, mechanisms of action, and potential applications. Comprehensive Reviews in Food Science and Food Safety. 2011;10:221-247

[66] Barroso MF, Ramalhosa MJ, Alves RC, Dias A, Soares CMD, OlivaTeles MT, et al. Total antioxidant capacity of plant infusions: Assessment using electrochemical DNA-based biosensor and spectrophotometric methods. Food Control. 2016;68:153-161

[67] Hakkim FL, Arivazhagan G, Boopathy R. Antioxidant property of selected Ocimum species and their secondary metabolite content. Journal of Medicinal Plants Research. 2008;2:250-257

[68] Filip S, Vidović S, Vladić J, Pavlić B, Adamović D, Zeković Z. Chemical composition and antioxidant properties of Ocimum basilicum L. extracts obtained by supercritical carbon dioxide extraction: Drug exhausting method. The Journal of Supercritical Fluids. 2016;109:20-25

[69] Bhattacharya A, Aggarwal A, Sharma N, Cheema J. Evaluation of some anti-oxidative constituents of three species of Ocimum. International Journal of Life Sciences. 2014;8:14-17

[70] Pripdeevech P, Chumpolsri W, Suttiarporn P, Wongpornchai S. The chemical composition and antioxidant activities of basil from Thailand using retention indices and comprehensive two-dimensional gas chromatography. Journal of Serbian Chemical Society. 2010;75:1503-1513

[71] Kwee EM, Niemeyer ED. Variations in phenolic composition and antioxidant properties among 15 basil (Ocimum basilicum L.) cultivars. Food Chemistry. 2011;128:1044-1050

[72] Farouk A, Fikry R, Mohsen M. Chemical composition and antioxidant activity of Ocimum basilicum L. essential oil cultivated in Madinah Monawara, Saudi Arabia and its comparison to the Egyptian Chemotype. Journal of Essential Oil Bearing Plants. 2016;19:1119-1128

[73] Falowo AB, Mukumbo FE, Idamokoro EM, Afolayan AJ, Muchenje V. Phytochemical constituents and antioxidant activity of sweet basil (Ocimum basilicum L.) essential oil on ground beef from Boran and Nguni Cattle. International Journal of Food Science. 2019;9:1-8

[74] Suanarunsawat T, Ayutthaya WDN, Songsak T, Thirawarapan S, Poungshompoo S. Lipid-lowering and antioxidative activities of aqueous extracts of Ocimum sanctum L. leaves in rats fed with a high-cholesterol diet. Oxidative Medicine and Cellular Longevity. 2011;1:1-9

[75] Cohen MM. Tulsi-Ocimum sanctum: A herb for all reasons. Journal of Ayurveda & Integrative Medicine. 2014;5:251-259

[76] Jayasinghe C, Gotoh N, Aoki T, Wada S. Phenolics composition and antioxidant activity of sweet basil (Ocimum basilicum L.). Journal of Agriculture and Food Chemistry. 2003;51:4442-4449

[77] Subramanian M, Chintalwar GJ, Chattopadhyay S. Antioxidant and radioprotective properties of an Ocimum sanctum polysaccharide. Redox Report. 2005;10:257-264

[78] Mahapatra SK, Roy S. Phytopharmacological approach of
free radical scavenging and antioxidative potential of eugenol and *Ocimum gratissimum* Linn. Asian Pacific Journal of Tropical Medicine. 2014;7:S391-S397

[79] Nahak G, Mishra RC, Sahu RK. Phytochemical investigation and in vitro antioxidant evaluation of some *Ocimum* species. Journal of Pharmacy Research. 2011;4:2340-2343

[80] Tewari D, Pandey HK, Sah AN, Meena H, Chander V, Singh R, et al. Phytochemical, antioxidant and antidepressant evaluation of *Ocimum basilicum*, *O. tenuiflorum*, *O. kilimandscharicum* grown in India. Journal of Biologically Active Products from Nature. 2015;5:120-131

[81] Omodamiro OD, Jimoh MA. Antioxidant and antibacterial activities of *Ocimum gratissimum*. American Journal of Phytomedicine and Clinical Therapeutics. 2015;3:010-019

[82] Venuprasad MP, Kandikattu HK, Razack S, Khanum F. Phytochemical analysis of *Ocimum gratissimum* by LC-ESI–MS/MS and its antioxidant and anxiolytic effects. South African Journal of Botany. 2014;92:151-158

[83] Tanuj J, Vijay J. Antioxidant activity of ethanolic extract of *Ocimum Kilimandscharicum* using hydroxyl radical scavenging method. Journal of Drug Delivery and Therapeutics. 2017;7:66-68

[84] Jamshidi N, Cohen MM. The clinical efficacy and safety of Tulsi in humans: A systematic review of the literature. Evidence-Based Complementary and Alternative Medicine. 2017;1:1-13

[85] Samak G, Rao MS, Kedlaya R, Vasudevan DM. Hypolipidemic efficacy of *Ocimum Sanctum* in the prevention of atherogenesis in male albino rabbits. Pharmacology. 2007;2:115-127

[86] Mirje MM, Zaman SU, Ramabhimaiyah S. Evaluation of the anti-inflammatory activity of *Ocimum sanctum* Linn (Tulsi) in albino rats. International Journal of Current Microbiology and Applied Sciences. 2014;3:198-205

[87] Güez CM, de Souza RO, Fischer P, de Moura Leão MF, Duarte JA, Boligon AA, et al. Evaluation of basil extract (*Ocimum basilicum* L.) on oxidative, antigenotoxic and anti-inflammatory effects in human leukocytes cell cultures exposed to challenging agents. Brazilian Journal of Pharmaceutical Sciences. 2017;53:e15098

[88] Eldin HME, Badawy AF. In vitro anti-*Trichomonas vaginalis* activity of *Pistacia lentiscus* mastic and *Ocimum basilicum* essential oil. Journal of Parasitic Diseases. 2015;39:465-473

[89] de Lima Silva L, Garlet QI, Koakoski G, de Abreu MS, Mallmann CA, Baldisserotto B, et al. Anesthetic activity of the essential oil of *Ocimum americanum* in *Rhamdia quelen* (Quoy & Gaimard, 1824) and its effects on stress parameters. Neotropical Ichthyology. 2015;13:715-722

[90] Caamal-Herrera SO, Carrillo-Cocom LM, Escalante-Réndiz DY, Aráiz-Hernández D, Azamar-Barrios JA. Antimicrobial and antiproliferative activity of essential oil, aqueous and ethanolic extracts of *Ocimum micranthum* Willd leaves. BMC Complementary and Alternative Medicine. 2018;18:55

[91] Dorman HJD, Deans SG. Antimicrobial agents from plants: Antibacterial activity of plant volatile oils. Journal of Applied Microbiology. 2000;88:308-316

[92] Burt S. Essential oils: Their antibacterial properties and potential applications in foods—A review.
International Journal of Food Microbiology. 2004;94:223-253

[93] Schmidt N, Mishra A, Lai GH, Wong GCL. Arginine-rich cell-penetrating peptides. FEBS Letter. 2010;584:1806-1813

[94] Londhe AM, Kulkarni AS, Lawand RV. In-vitro comparative study of antibacterial and antifungal activities: A case study of Ocimum kilimandscharicum, Ocimum tenuiflorum and Ocimum gratissimum. International Journal of Pharmacognosy and Phytochemical Research. 2015;7:104-110

[95] Miller AB, Cates RG, Lawrence M, Soria JAF, Espinoza LV, Martinez JV, et al. The antibacterial and antifungal activity of essential oils extracted from Guatemalan medicinal plants. Pharmaceutical Biology. 2014;53:548-554

[96] Pandey S. Antibacterial and antifungal activities of Ocimum gratissimum L. International Journal of Pharmacy and Pharmaceutical Sciences. 2017;9:26-31

[97] Wagura AG, Kimenju JW, Gichimu BM. Comparative antibacterial effects of raw and essential oils of Ocimum gratissimum L. against Ralstonia solanacearum (Smith). International Journal of Plant Pathology. 2011;2:144-152

[98] Chenni M, Abed DE, Rakotomanomana N, Fernandez X, 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

[99] Chouhan S, Sharma K, Guleria S. Antimicrobial activity of some essential oils-present status and future perspectives. Medicine. 2017;4:58

[100] Eswar P, Devaraj CG, Agarwal P. Anti-microbial activity of Tulsi (Ocimum Sanctum (Linn.) extract on a periodontal pathogen in human dental plaque: An in vitro study. Journal of Clinical and Diagnostic Research. 2016;10:ZC53-ZC56

[101] Mondal S. Antimicrobial and Immunomodulatory effects of Tulsi (Ocimum sanctum Linn) [thesis]. Faculty of All India Institute of Medical Sciences, New Delhi, India for the award of the degree of Doctor of Philosophy. 2010. pp. 1-141

[102] Carovic-Stanko K, Orlić S, Politeo O, Strikić F, Kolak I, Milos M, et al. Composition and antibacterial activities of essential oils of seven Ocimum taxa. Food Chemistry. 2010;119:196-201

[103] El-Soud NHA, Deabes M, El-Kassem LA, Khalil M. Chemical composition and antifungal activity of Ocimum basilicum L. essential oil. Open Access Macedonian Journal of Medical Science. 2015;3:374-379

[104] Warrier PK, Nambair VPK, Ramankutty C. Indian Medicinal Plants: A Compendium of 500 Species. Arya Vaidya Sala, Kottakal, Kerala: Orient Longman, India; 1995

[105] Behbahani M. Evaluation of in vitro anticancer activity of Ocimum basilicum, Alhagi maurorum, Calendula officinalis and their parasite Cuscuta campestris. PLoS One. 2014;9:e116049. DOI: 10.1371/journal.pone.0116049

[106] Mohammadi M, Majd A, Nejadssattari T, Hashemi M. Antioxidant and anticancer activities of Ocimum basilicum L. cv. Dark Opal (Lamiaceae). Pharmacognosy Communications. 2014;4:48-58
[107] Naidu JR, Gunjan M, Chen Y, Sasidharan S. Evaluation of in vitro cytotoxic activity of *Ocimum basilicum* and *Mentha spicata* extracts. Asian Journal of Pharmaceutical and Clinical Research. 2016;9:131-134

[108] Zarlah A, Kourkoumelis N, Stanojkovic TP, Kovała-Demertzí D. Cytotoxic activity of essential oil and extracts of *Ocimum basilicum* against human carcinoma cells. Molecular docking study of isoeugenol as a potent cox and lox inhibitor. Digest Journal of Nanomaterials and Biostructures. 2014;9:907-917

[109] Karthikeyan K, Gunasekaran P, Ramamurthy N, Govindasamy S. Anticancer activity of *Ocimum sanctum*. Pharmaceutical Biology. 1999;37:285-290

[110] Monga J, Sharma M, Tailor N, Ganesh N. Antimelanoma and radioprotective activity of alcoholic aqueous extract of different species of *Ocimum in C57BL* mice. Pharmaceutical Biology. 2011;49:428-436

[111] de Lima VT, Vieirab MC, Kassuyac CAL, Cardosos CAL, Alvesa JM, Foglioe MA, et al. Chemical composition and free radical-scavenging, anticancer and anti-inflammatory activities of the essential oil from *Ocimum kilimandscharicum*. Phytomedicine. 2014;21:1298-1302

[112] Goel HC, Roa AR. Radiosensitizing effect of camphor on transplantable mammary adenocarcinoma in mice. Cancer Letters. 1988;43:21-27

[113] Banerjee S, Welsh CW, Rao AR. Modulatory influence of camphor on the activities of hepatic carcinogen metabolizing enzymes and the levels of hepatic and extrahepatic reduced glutathione in mice. Cancer Letters. 1995;88:163-169

[114] Ghant VK, Hiramoto NS, Solvason HB, Tyring SK, Spector NH, Hiramoto RN. Conditioned enhancement of natural killer cell activity, but not interferon, with camphor or saccharin-LiCl conditioned stimulus. Journal of Neuroscience Research. 1987;18:10-15

[115] Samant SS, Dhar U. Diversity, endemism and economic potential of wild edible plants of Indian Himalaya. International Journal of Sustainable Development & World Ecology. 2002;4:179-191

[116] Muralidharan A, Dhananjayan R. Cardiac stimulant activity of *Ocimum basilicum* Linn. extracts. Indian Journal of Pharmacology. 2004;36:163-166

[117] Dupasquier CM, Dibrov E, Kneesh AL, Cheung PKM, Lee KGY, Alexander HK, et al. Dietary flaxseed inhibits atherosclerosis in the LDL receptor-deficient mouse in part through antiproliferative and anti-inflammatory actions. American Journal of Physiology-Heart and Circulatory Physiology. 2007;293:2394-2402

[118] Amrania S, Harnafi H, Gadi D, Mekhfi H, Legssyer A, Aziz M, et al. Vasorelaxant and anti-platelet aggregation effects of aqueous *Ocimum basilicum* extract. Journal of Ethnopharmacology. 2009;125:157-162

[119] Janbaz KH, Hamid I, Gilani AH, Qadir MI. Spasmolytic, bronchodilator and vasodilator activities of Aqueousmethanolic extract of *Ocimum basilicum*. International Journal of Agriculture & Biology. 2014;16:321-327

[120] Packard RR, Maganto-Garcia E, Gotsman I, Tabas I, Libby P, Lichtman AH. CD11c(+) dendritic cells maintain antigen processing, presentation capabilities, and CD4(+) T-cell priming efficacy under hypercholesterolemic conditions
associated with atherosclerosis. Circulation Research. 2008;103:965-973

[121] Bravo E, Amrani S, Aziz M, Harnafi H, Napolitano M. Ocimum basilicum ethanolic extract decreases cholesterol synthesis and lipid accumulation in human macrophages. Fitoterapia. 2008;79:515-523

[122] Li H, Ge Y, Luo Z, Zhou Y, Zhang X, Zhang J, et al. Evaluation of the chemical composition, antioxidant and anti-inflammatory activities of distillate and residue fractions of sweet basil essential oil. Journal of Food Science and Technology. 2017;54:1882-1890

[123] Perretti M, D’Acquisto F. Annexin A1 and glucocorticoids as effectors of the resolution of inflammation. Nature Reviews. 2009;9:63-70

[124] D’Acquisto F, Maione F, Pederzoli-Ribeil M. From IL-15 to IL-33: The never-ending list of new players in inflammation. Is it time to forget the humble aspirin and move ahead? Biochemical Pharmacology. 2010;79:525-534

[125] Aye A, Jeon YD, Lee JH, Bang KS, Jin JS. Anti-inflammatory activity of ethanol extract of leaf and leaf callus of basil (Ocimum basilicum L.) on RAW 264.7 macrophage cells. Oriental Pharmacy and Experimental Medicine. 2019;19:217-226

[126] Kim HW, Roh DH, Yoon SY, Kang SY, Kwon YB, Han HJ, et al. The anti-inflammatory effects of low- and high-frequency electroacupuncture are mediated by peripheral opioids in a mouse air pouch inflammation model. Journal of Alternative and Complementary Medicine. 2006;12:39-44

[127] Son JK, Son MJ, Lee EK, Moon TC, Son KH, Kim CH, et al. Ginkgetin, a biflavone from Ginkgo biloba leaves, inhibits cyclooxygenases-2 and 5-lipoxygenase in mouse bone marrow-derived mast cells. Biological and Pharmaceutical Bulletin. 2005;28:2181-2184

[128] Happar M, Tursun A, Wen-ting Z, Lu-feng C, Tohti I, Reyim N, et al. Effect of extracts of Ocimum basilicum L. on mouse macrophage raw 264.7 and 5-lipoxygenase. Chinese Traditional Patent Medicine. 2013;35:1599-1604

[129] Benedec D, Pârvu AE, Oniga I, Toiu A, Tiperciuc B. Effects of Ocimum Basilicum L. extract on experimental acute inflammation. Revista Medico-chirurgicala a Societatii de Medici si Naturalisti din Iasi. 2007;111:1065-1069

[130] Selvakumar C, Gayathri B, Vinaykumar KS, Lakshmi BS, Balakrishnan A. Potential anti-inflammatory properties of crude alcoholic extract of Ocimum basilicum L. in human peripheral blood mononuclear cells. Journal of Health Science. 2007;53:500-505

[131] Murphy KM, Reiner SL. The lineage decisions of helper T cells. Nature Reviews Immunology. 2002;2:933-944

[132] Ranjan D, Chen C, Johnston TD, Jeon H, Nagabhushan M. Curcumin inhibits mitogen stimulated lymphocyte proliferation, NFkB activation, and IL-2 signaling. Journal of Surgical Research. 2004;121:171-177

[133] Van Den Brande JM, Peppelenbosch MP, Van Deventer SJ. Treating Crohn’s disease by inducing T lymphocyte apoptosis. Annals of the New York Academy of Sciences. 2002;973:166-180

[134] Złotek U, Szymanowska U, Karaś M,Świeca M. Antioxidative and anti-inflammatory potential of phenolics from purple basil (Ocimum basilicum L.) leaves induced by jasmonic, arachidonic
and β-aminobutyric acid elicitation. International Journal of Food Science and Technology. 2016;51:163-170

[135] Gawlik-Dziki U, Świeca M, Sugier D. Enhancement of antioxidant abilities and the lipoxygenase and xanthine oxidase inhibitory activity of broccoli sprouts of biotic elicitors. Acta Scientiarum Polonorum, Hortorum Cultus. 2012;11:13-25

[136] Raina P, Deepak M, Chandrasekaran CV, Agarwal A, Wagh N, Kaul-Ghanekar R. Comparative analysis of anti-inflammatory activity of aqueous and methanolic extracts of Ocimum basilicum in RAW264.7, SW1353 and human primary chondrocytes. Journal of Herbal Medicine. 2016;6:28-36

[137] Rodrigues LB, Martins AOBPB, Ceśario FRAS, Castro FF, Albuquerque TR, Fernandes MNM, et al. Anti-inflammatory and antiedematogenic activity of the Ocimum basilicum essential oil and its main compound estragole: In vivo mouse models. Chemico-Biological Interactions. 2016;257:14-25

[138] Coelho CF, Vieira RP, Lopes-Martins PSL, Aparecida S, Teixeira AUB, Gouvea IM, et al. The effect of inhaled nitric oxide on the carrageenan-induced paw edema. Histology and Histopathology. 2015;30:117-124

[139] Boyle JP, Honeycutt AA, Venkat Narayan KM, Hoerger TJ, Geiss LS, Chen H, et al. Projection of Diabetes Burden Through 2050: Impact of changing demography and disease prevalence in the U.S. Diabetes Care. 2001;24:1936-1940

[140] Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: Estimates for the year 2000 and projections for 2030. Diabetes Care. 2004;27:1047-1053

[141] Mousavi L, Salleh RM, Murugaiyah V, Asmawi MZ. Hypoglycemic and anti-hyperglycemic study of Ocimum tenuiflorum L. leaves extract in normal and streptozotocin-induced diabetic rats. Asian Pacific Journal of Tropical Biomedicine. 2016;6:1029-1036

[142] El-Beshbishy HA, Bahashwan SA. Hypoglycemic effect of basil (Ocimum basilicum) aqueous extract is mediated through inhibition of α-glucosidase and α-amylase activities: An in vitro study. Toxicology and Industrial Health. 2012;28:42-50

[143] Lean ME, Noroozi M, Kell L, Burns J, Talwar D, Sattar N, et al. Dietary flavonols protect diabetic human lymphocytes against oxidative damage to DNA. Diabetes. 1999;48:176-181

[144] Bihari CG, Manaswini B, Keshari PS, Kumar TS. Phytochemical investigation & evaluation for antidiabetic activity of leafy extracts of various Ocimum (Tulsi) species by alloxan induced diabetic model. Journal of Pharmacy Research. 2011;4:28-29

[145] Parasuraman S, Balamurugan S, Christopher PV, Petchi RR, Yeng WY, Sujithra J, et al. Evaluation of antidiabetic and antiglycemic effects of hydroalcoholic extract of leaves of Ocimum tenuiflorum (Lamiaceae) and prediction of biological activity of its Phytoconstituents. Pharmacognosy Research. 2015;7:156-165

[146] Egesie UG, Ibu ABAJO, Egesie OJ. Safety and hypoglycaemic properties of aqueous leaf extract of Ocimum Gratissimum in Streptozotocin induced diabetic rats. Nigerian Journal of Physiological Sciences. 2006;21:31-35

[147] Ezeani C, Ezenyi I, Okoye T, Okoli C. Ocimum basilicum extract exhibits antidiabetic effects via inhibition of hepatic glucose mobilization and carbohydrate
metabolizing enzymes. Journal of Intercultural Ethnopharmacology. 2017;6:22-28

[148] Okoduwa SIR, Umar IA, James DB, Inuwa HM. Anti-diabetic potential of Ocimum gratissimum leaf fractions in fortified diet-fed Streptozotocin treated rat model of Type-2 diabetes. Medicine. 2017;4:1-21

[149] Hannan JML, Marenah L, Ali L, Rokeya B, Flatt PR, Abdel-Wahab YHA. Ocimum sanctum leaf extracts stimulate insulin secretion from perfused pancreas, isolated islets and clonal pancreatic β-cells. Journal of Endocrinology. 2006;189:127-136

[150] WHO. Overview—Preventing chronic diseases: A vital investment. 2005

[151] Franz C, Baser KHC, Windisch W. Essential oils and aromatic plants in animal feeding—A European perspective. A review. Flavour and Fragrance Journal. 2010;25:327-340