Tagetes (Tagetes minuta) Oils

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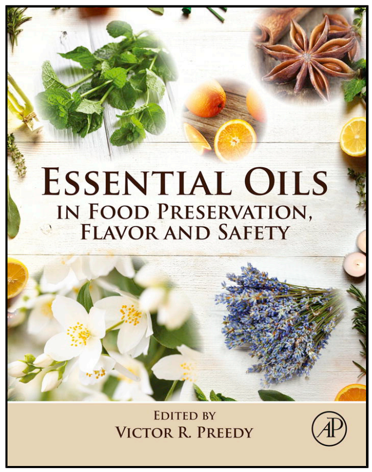

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Chapter 90

Tagetes (*Tagetes minuta*) Oils

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List of Abbreviations

$ Dollar of the United States of America
£ Sterlling Pound of the United Kingdom
BBT 5-(3-Buten-1-ynyl)-2,2′-bithienyl
BBTOAc 5-(4-Acetoxy-1-butynyl)-2,2′-bithienyl
CaRSV Carnation ring spot viruses
CAS Chemical Abstract Service
CaVMV Carnation vein mottle viruses
CBI Center for the Promotion of Imports from developing countries
E/Z *trans*/*cis*
EPAUS Environmental Protection Agency of the United States
GC Gas chromatography
GC-MS Gas chromatography–Mass Spectrometry
GFDL GNU Free Documentation License
ITC International Trade Center
IUPAC International Union of Pure and Applied Chemistry
Kg Kilograms
M^+ Molecular mass
NRCS Natural Resources Conservation Service
PUFA Polyunsaturated fatty acids
R South African Rand
UK United Kingdom
UNCOMTRADE The United Nations Commodity Trade Statistics Database
UNCTAD The United Nations Conference on Trade and Development
USA United States of America
USDA United States Department of Agriculture
w/w Weight per weight

INTRODUCTION

The plant *Tagetes minuta* L. is a worldwide species popularly known as wild marigold, a common English name prehistorically derived from "Mary's gold." It belongs to the sunflower family, Asteraceae, which comprises the largest family of vascular plants with more than 23,000 species. It is naturalized in a wide range of climatic conditions worldwide but is well known to be native to North and South America. It is now a naturalized species in Europe, Africa, Asia, Australia, New Zealand, United States, and Madagascar following its introduction during the Spanish colonization of South America (Babu and Kaul, 2007).

Tagetes minuta has a long history of human use as food, perfumes, medicines, ornamentals, and in ritual and sociocultural ethnopractices, depending on geographical location and ethnic background (Hamayun et al., 2006). For instance, in Chile and Argentina, the plant is popularly known for its traditional culinary use in stews as a highly prized flavoring agent. While in many parts of the world, *T. minuta* is commonly used to make a hot and cold refreshing beverage as well as herbal tea, a characteristic that has given it the potential to become a new crop for many of the drug-growing areas of the world

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(Chalchat et al., 1995). The essential oil of *T. minuta* is used in many ways, predominantly as flavoring and seasoning agent, and/or imparting aroma in a wide range of foodstuffs and beverages, depending on the essential oil's main constituents (Hamayun et al., 2006).

BOTANICAL ASPECTS OF *TAGETES MINUTA* L.

Morphology

Tagetes minuta is an erect, terrestrial, herbaceous annual and perennial plant, growing up to a height of 4.5 m (Figure 1) (Holm et al., 1997). The leaves are slightly glossy green and are pinnately dissected into four to six pairs of pinnae, while the leaf margins are finely serrate. The inflorescence heads on the plant are numerous, usually flat-topped cymes, 8–12 mm high, apex three to five toothed, ray florets usually three per head, rays 1–2 mm long, disk florets usually three to five per head, and corollas approxiamtely 2.5 mm long. The dark brown achenes of the plant are flattened, 6–8 mm long, and pappus scales 2–3 mm long (Wan and Chen, 2006). The under surface of the leaves bears a number of small, punctate, multicellular glands, orangish in color, which exude a licorice-like aroma when ruptured. Glands may also be found on the stems and involucre bracts. Four or five fused involucre bracts surround each head. The seeds have an unpleasant odor and can reduce the value of grain harvests when they are mixed and stored together (Wanzala et al., 2012).

The genus *Tagetes* consist of 56 species, 27 of which are annuals while 29 are perennials but mostly herbaceous plants (Soule, 1996). A considerable proportion of the species are commercially grown in respective agro-ecological regions worldwide as a multipurpose new crop. Of these species, *T. minuta*, *Tagetes erecta*, *Tagetes patula*, and *Tagetes tenuifolia* are most common with *T. minuta* being the most studied and widely grown species in several countries due to yielding high grade oil used in food, nutraceutical, perfumery, ornamental, pharmaceutical, agarbattis, and agricultural industries (Chalchat et al., 1995; Singh et al., 2003).

Ecology

Tagetes minuta is native to the temperate grasslands of southern South America (Holm et al., 1997). In the nonnative regions of this plant, it naturally grows in the wild and in the arable farming systems as a noxious weed (Holm et al., 1997). The high demand of the essential oil of this plant resulted into depletion of the wild resources, thus necessitating its systematic cultivation in subtropical and temperate agroclimatic zones worldwide, predominantly in the Indian subcontinent (Singh et al., 2003).

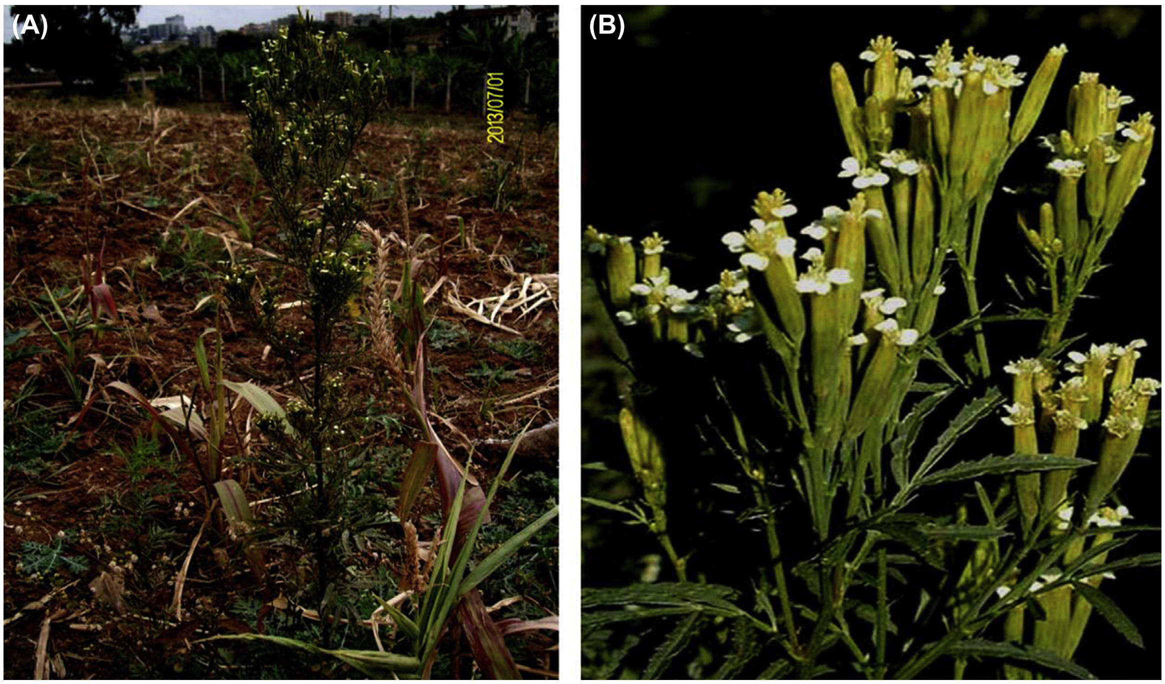


FIGURE 1 (A) A plant of *Tagetes minuta* L., 1753 in an arable farming system as a weed left in the farm after harvesting corn. (B) Theaerial parts of *T. minuta* that are harvested for extraction of essential oil. *Picture courtesy of Dr Wycliffe Wanzala.*

Tagetes minuta is now a widespread weed in Africa, South Europe, South Asia, Madagascar, and Australia (Chalchat et al., 1995). *Tagetes minuta* is rich at both high and low altitudes and in either high or low rainfall environments (Holm et al., 1997) and is often found growing in disturbed areas during early plant successional stages. The seeds cling to the hair of animals and human clothes once in contact and are therefore dispersed by humans, domesticated by wild animals. Toward the end of its growing season, the aerial parts of *T. minuta* dry up and may easily be destroyed by fire, but new colonies are formed rapidly in the following season from seeds deposited in the soil. *Tagetes minuta* tolerates a soil pH between 4.3 and 7.0. In South Africa, the marigold is a useful pioneer plant in the reclamation of disturbed land, while in many other countries, the plant is found spread on forested roadside, adjacent to forest margin and dominating arable land, particularly after crop harvest as the commonest weed (Figure 1(A)) (Wan and Chen, 2006).

USAGE AND APPLICATIONS OF TAGETES OIL IN FOOD SCIENCE

The usage and applications of the essential oil of *T. minuta* are deeply rooted in the diversity of useful secondary metabolites found in appropriately desired proportions, thus manifesting in a variety of biological properties (Table 1) (Sadia et al., 2013; Wanzala and Ogoma, 2013). Even from a traditional point of view, however, the nature of chemotypes and their composition affects the quantity and quality of oil, thereby impacting on the usage and applications of the oil, and thus the plant as a whole (Wanzala et al., 2012). Traditionally, the plant has a long history of interaction with humanity and henceforth, its applications to the pharmaceutical and nutraceutical industries, more particularly the preparation of teas and popular potato dish called *ocopa* in South America (Soule, 1996). Infusions, tinctures, and juice from aerial parts of *Tagetes* spp. have been used as traditional food additives worldwide. This traditional claim provided leads into research to help explain the underlying science and as a result. For example, an orange–yellow carotenoid lutein substance found in the florets of *T. erecta* and many other marigolds (*T. minuta* included) has been identified, isolated, and approved by the European Union (INS-Number E161b) for use as a food color and flavor in various foodstuffs, at a usage level in condiments and relishes such as pasta, vegetable oil, margarine, mayonnaise, salad dressing, baked goods, confectionery, dairy products, ice cream, yogurt, citrus juice, and mustard (Timberlake and Henry, 1986). Additionally, the orange pigment extracted from the petals of marigold is in great demand for poultry feed in food production systems, while, on the other hand, the plant is grown in arable farming systems to keep the nematode population in soil under control, hence often grown alongside valued food crops such as tomato, eggplant, chili pepper, tobacco, and potato plants to boost their production, thus ensuring food security. Tagetes oil is therefore a potential agent for protecting food crops on the farm and in storage, thereby increasing food security, particularly in undernourished communities of the world. The oil also provides an opportunity for developing an environmentally friendly and a nontoxic acaricide to enhance increased production of milk, beef, and hides/skin in the livestock industry (Wanzala, 2009; Nchu et al., 2012).

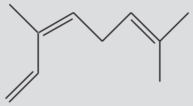
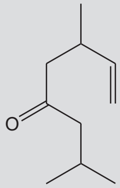
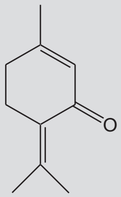
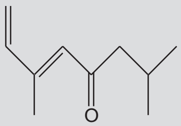
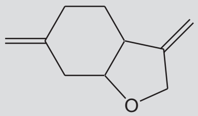
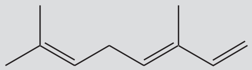
Chemotypes of the Essential Oil of *Tagetes minuta* L.

Tagetes minuta essential oil has a strong, sweet, wild, fruity, and slight citrus-like aroma. It has a yellow to reddish–amber coloration with an intermediate viscosity, which may well turn thick and even gel-like upon exposure to air at length (Figure 2) due to easy polymerization. The oil is rich in secondary metabolites, including acyclic, monocyclic and bicyclic monoterpenes, sesquiterpenes, flavonoids, carotenoids, and thiophenes (Wanzala and Ogoma, 2013).

The usage and applications of the essential oils of *Tagetes* spp. are rooted in the composition of secondary metabolites in the oil. Previous reports have shown significant differences in their compositions, thus having different biological properties and impacting on the nature of their usage and applications (Wanzala, 2009). Furthermore, the *Tagetes* species can be unambiguously differentiated taxonomically by the chemical composition of their essential oils (Singh et al., 2003). Gas chromatography (GC) and gas chromatography–mass spectrometry (GC-MS) analysis of *T. minuta* oils indicated that the geographical location of plants (Chalchat et al., 1995; Singh et al., 2003), stage of growth of harvested plants, plant parts harvested (Chalchat et al., 1995), soil type and its nutrient status (Singh et al., 2003), nature of chemotypes (Gil et al., 2000), plant parts, climate, sunlight, methods of plant harvesting, and oil extraction method (Wanzala, 2009) equally affects the quantity and quality of oil.

In Argentina, dihydrotagetone, α-phellandrene, limonene, o-cymene, as well as the isomers of β-ocimene, tagetone, and tagetenone were the major constituents of *T. minuta* essential oil (Gil et al., 2000). In Saudi Arabia, GC and GC-MS analysis confirmed the presence of tagetone (11.52%), 5-octyn-4-one,2,7-dimethyl (11.52%), propanedinitrile, dicyclohexyl-(10.45%), and 2-pinen-4-one (8.03%) to be the main components with lesser amounts of 1-acetoxy-*p*-menth-3-one (0.17%) and 9-octacenamide(Z) (0.48%) (EL-Deeb et al., 2004). In India, the freshly distilled *T. minuta* oil contained ocimene 54.97%, and dihydrotegetone 32.58% as major constituents (Singh et al., 2003), while in other studies (Z)-tagetone,

TABLE 1 Some of the Major Chemical Components Evaluated in the Essential Oil of *Tagetes minuta* (Sample Plants were Collected from the Southern Slopes of Mount Elgon in Western Kenya) and Some of Their Corresponding Industrial Applications in Food and Agriculture

Chemical Name	IUPAC Name	Chemical Structure	Molecular Formula	Molecular Mass (g/mol)	Density (g/cm³)	CAS Number	Uses
Tagetes minuta essential oil	Tagetes oil	Not applicable	Not applicable	Not applicable	Variable (0.850–0.922)	91770-75-1 (Replacing 8016-84-0)	Multipurpose (in food, agriculture and perfumery/ fragrance industries)
cis-Ocimene	3,7-Dimethyl-1,3, 7-octatriene		$C_{10}H_{16}$	136.24	0.800	3338-55-4	Agriculture (insecticides)/ perfumery
Dihydrotagetone	2,6-Dimethyloct-7-en-4-one		$C_{10}H_{18}O$	154.25	0.826	1879-00-1	Flavory in food industry/ perfumery
Piperitenone	2-Methyl-6-propan-2-ylidenecyclohex-2-en-1-one		$C_{10}H_{14}O$	150.22	0.977	491-09-8	Fragrance and flavor concentrates of all types.
trans-Tagetone	(5E)-2,6-Dimethylocta-5, 7-dien-4-one		$C_{10}H_{16}O$	152.23	0.847	6752-80-3	Livestock tick repellant/ perfumery
3,9-Epoxy-*p*-mentha-1,8(10)-diene	3,6-Dimethylidene-4,5,7,7a-tetrahydro-3aH-1-benzofuran		$C_{10}H_{14}O$	150.22	0.967	494-90-6	Peppermint oil formulations
β-Ocimene	(3E)-3,7-Dimethylocta-1,3, 6-triene		$C_{10}H_{16}$	136.23	0.776	3779-61-1	Perfumery

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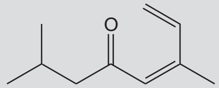
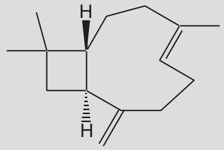
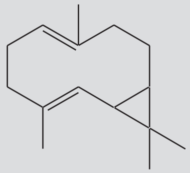
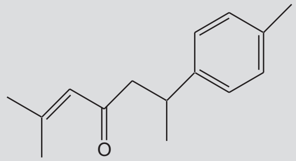
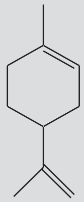
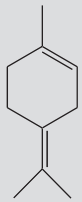
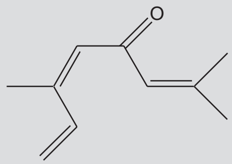
cis-Tagetone	(Z)-2,6-Dimethylocta-5, 7-dien-4-one		$C_{10}H_{16}O$	152.23	0.847	3588-18-9	Treatment of wounds, skin infections, bee stings, warts, cancer, mosquito repellant
(*trans*)-β-Caryophyllene	4,11,11-Trimethyl-8-methylene-bicyclo[7.2.0] undec-4-ene		$C_{15}H_{24}$	204.36	0.905	87-44-5	Antileishmanial
Bicyclogermacrene	(1R, 4E,8E, 10S)-4,8,11,11-Tetramethyl-bicyclo[8.1.0] undeca-4,8-diene		$C_{15}H_{24}$	204.35	0.861	67650-90-2	Terpene with no recorded uses
Ar-Turmerone	(6S)-2-Methyl-6-(4-methylphenyl)hept-2-en-4-one		$C_{15}H_{20}O$	216.32	0.945	532-65-0	Insecticidal activity/Fungicidal activity/ Antidermatophytic property/ antiphenom activity
Lemonene	1-Methyl-4-(1-methylethenyl)-cyclohexene		$C_{10}H_{16}$	136.24	0.841	5889-27-5	Agriculture (insecticides)/ Cosmetic products
α-Terpinolene	Cyclohexene,1-methyl-4-(1-methylethylidene		$C_{10}H_{16}$	136.24	0.861	586-62-9	Flavors and fragrance
(Z)-Ocimenone	2,5,7-Octa-trien-4-one, 2,6-dimethyl-		$C_{10}H_{14}O$	150.22	0.847	33746-71-3	Flavors and fragrance

Continued

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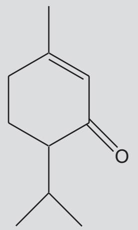
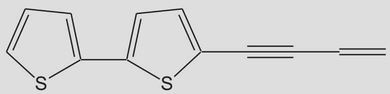
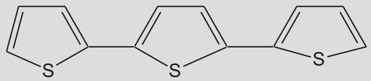
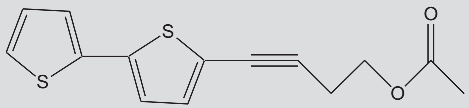
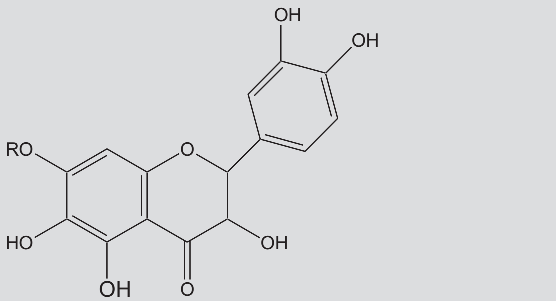
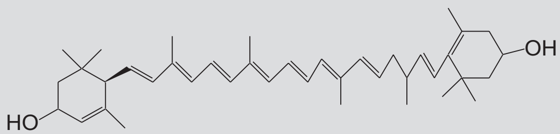
TABLE 1 Some of the Major Chemical Components Evaluated in the Essential Oil of *Tagetes minuta* (Sample Plants were Collected from the Southern Slopes of Mount Elgon in Western Kenya) and Some of Their Corresponding Industrial Applications in Food and Agriculture—cont'd

Chemical Name	IUPAC Name	Chemical Structure	Molecular Formula	Molecular Mass (g/mol)	Density (g/cm³)	CAS Number	Uses
Piperitone	6-Isopropyl-3-methyl-1-cyclohex-2-enone		$C_{10}H_{16}O$	152.23	0.933	89-81-6	Production of synthetic menthol and thymol for pharmaceuti cals
BBT	5-(3-Buten-1-ynyl)-2,2′-bithienyl		$C_{12}H_8S_2$	216.	–		Antifungal, nematocidal, antibacterial
α-Terthienyl (α-terthiophene)	2,5-Di(thiophen-2-yl)thiophene		$C_{12}H_8S_3$	248.38	–	1081-34-1	Antifungal, nematocidal, antibacterial
BBTOAc	5-(4-Acetoxy-1-butynyl)-2,2′-bithienyl		$C_{14}H_{13}S_2O_2$	276	–	–	Antifungal, nematocidal, antibacterial
Quercetagetin-7-arabinosyl-galactoside	–	 R=arabinose-galactose	$C_{26}H_{31}O_{17}$	616	–	–	Antimicrobial activity
Lutein	(3R,3′R,6′R)-β,ε-Carotene-3,3′-diol		$C_{40}H_{56}O_2$	568.88	–	127-40-2	Food colorant

IUPAC, International Union of Pure and Applied Chemistry; CAS, Chemical Abstract Service.

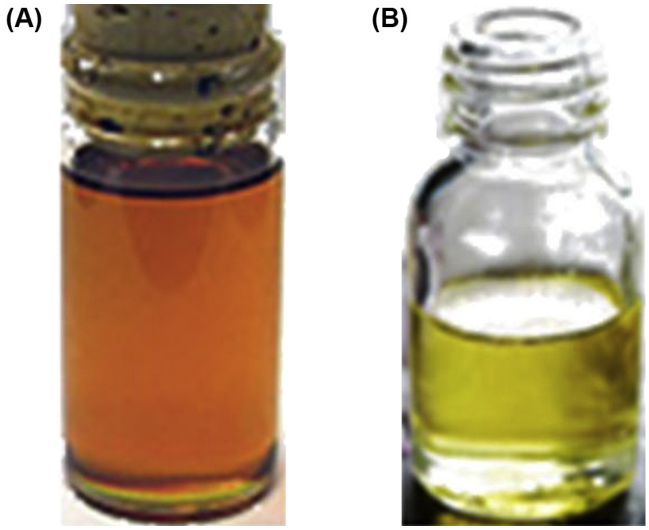


FIGURE 2 Samples of the color of the essential oil of *Tagetes minuta* L., 1753 (reddish–amber–light yellowish fluid liquid (A) and yellowish (B)). The color of the essential oil produced on industrial large-scale form for commercial use (A) and the color of the essential oil produced in the laboratory on small-scale for studies (B). When sample (B) is left exposed to air for some time, its color changes to that of sample (A) due to oil oxidation.

(Z)-β-ocimene, dihydrotagetone, (Z)- and (E)-ocimenone were found as major constituents (Chalchat et al., 1995). In Egypt, the main components of the *T. minuta* essential oil were monoterpenes of which *trans*- and *cis*-tagetone were present in 52.3–64.2% (Mohamed et al., 2002). In Iran, GC and GC-MS analysis revealed the main components to be α-terpineol (20.8%), (Z)-β-ocimene (17.7%), dihydrotagetone (13.7%), (E)-ocimenone (13.3%), (Z)-tagetone (8.4%), and (Z)-ocimenone (6.1%) (Moghaddam et al., 2007). In Madagascar, the main components in the essential oil of *T. minuta* were limonene (3.6–11%), (Z)-β-ocimene (1.0–17.1%), (E)-β-ocimene (0.5–14.6%), *p*-cymene (0.3–20.4%), β-caryophyllene (1.1–12.7%), (Z)-tagetenone (26.7%), (E)-tagetenone (31.3%), α-muurolene (36.5%), and verbenone (1.4–15.4%) (Wanzala and Ogoma, 2013). In Kenya, characterization of the essential oil showed that *T. minuta* oil comprised mainly *cis*-ocimene (43.78%), dihydrotagetone (16.71%), piperitenone (10.15%), *trans*-tagetone (8.67%), 3,9-epoxy-*p*-metha-1,8(10) diene (6.47%), β-ocimene (3.25%), and *cis*-tagetone (1.95%) (Wanzala and Ogoma, 2013). In other studies, out of 104 chemical components, the major constituents of *T. minuta* essential oil were tagetone, E/Z-ocimenone, E/Z-ocimene, germacrene, limonene, *trans*-anethole, and dihydrotegetone. Some of the major chemical components in the essential oil of *T. minuta* and their applications in industry are listed in Table 1.

General Biological Properties of *Tagetes minuta* L. and Its Essential Oil

Validation of some of the folkloric claims about *T. minuta* through evaluation of its essential oil has shown the plant to contain compounds and/or blends that have a wide range of bioactive and therapeutic properties (particularly in aromatherapy) such as antihelminthic, carminative, arthropod repellency, sedative, weedicidal, antiseptic, diaphoretic, spasmolytic, germicides, stomachic, antispasmodic, antiprotozoal, bactericidal, emmenagogue, nematocidal, insecticidal, fungicidal, antiviral, and other microbicidal properties (Sadia et al., 2013). Also, the essential oil of *T. minuta* has been shown to possess bronchodilatory, tranquilizing, hypotensive, and antiinflammatory bioactivities (Singh et al., 2003). There is empirical evidence that the secondary compounds in *Tagetes* species are effective deterrents of numerous organisms, including fungi (Chan et al., 1975), pathogens, bacteria (Grover and Rao, 1978), trematodes, nematodes (Graham et al., 1980), and numerous insect pests through several different mechanisms (Maradufu et al., 1978). It has been reported that Z-β-ocimene and dihydrotagetone, which are constituent compounds of the essential oil of *T. minuta*, were found to be antiviral, active against carnation ring spot and carnation vein mottle viruses. The essential oil of *T. minuta* generally affects a variety of microbial organisms (Senatore et al., 2004). Allelopathic activities of *Tagetes* spp., particularly those against nematodes, have been reviewed (Sadia et al., 2013). Nematocidal activity of *T. minuta* roots is attributed to thienyls, which provide inhibitory effects to parasitic root nematodes and other microbes affecting roots of plants in arable farming systems (Soule, 1996) while the biocidal effects of the essential oil from *T. minuta* flowers and leaves are generally due to a wide range of terpenoids (Singh et al., 2003). Dihydrotagetone and Z-β-ocimene isolated from *T. minuta* oil showed strong nematicidal activity against eggs and juveniles of a root-knot nematode, *Meloidogyne incognita* (Kofoid and White, 1919) with dihydrotagetone showing a higher level of toxicity than Z-β-ocimene (Adekunle et al., 2007).

Ethnobotanic Usage and Applications of *T. minuta* L. in Food Science

Tagetes minuta has a long history of human interest and is used as beverage, condiment, ornamental, medicinal decoction, and in ritual/religious practices (Soule, 1996). In southern South America where the plant is native, its leaves, stems, and flowers are used as a culinary herb in Peru, Ecuador, and parts of Chile and Bolivia, where it is called by the Incan term, *huacatay*. The *huacatay* paste is used to make the popular potato dish called *ocop*a. In Peru, since the ancient Inca civilization, *T. minuta* is made into puree and seasoning that give local dishes a unique herbal flavor which is thought to taste like a mixture of mint, coriander, and basil oils. The plant is also popular in making ethnomedicinal teas in some areas (Soule, 1996). Farmers, who do not practice industrialized agriculture leave plants of *T. minuta* in their arable farming fields. This second crop is beneficial in several ways such as the rapid growth of *T. minuta* quickly shades out other plant species that may be of less use to the farmer and it can be harvested for personal use or for sale in city markets; as well, it has been reported to aid in the retention of humidity in the arable farming fields (Jimenez-Osornio, 1991). In Nepal, marigold garlands are used almost in every household especially during the *Tihar* festival and in Portugal, as well as in India, the plants are used for daily worships and rituals particularly in the Day of the Dead celebrations as the plant was regarded as the flower of the dead in prehispanic Mexico. In Ukraine, related plants of marigold, traditionally known as *Chornobryvtsi* are regarded as one of the national symbols and are often mentioned in songs, poems, and tales. There has been increasing interest in the use of *T. minuta* by indigenous people in India due to increased demand of the essential oil, which is widely used in daily lives while the plant's flowers are used to decorate Hindu temples (Anjaria, 1989). More importantly, an orange pigment extracted from petals of marigold is in great demand for poultry feed in food production systems, while, on the other hand, the plant is grown in arable farming systems to keep the nematode population in soil under control, is often grown alongside valued food crops such as tomato, eggplant, chili pepper, tobacco, and potato plants to boost their production (Wanzala and Ogoma, 2013). Due to the plant's antinematicidal activity, it is used as an intercrop in rotation arable farming systems to protect crops from damage (Singh et al., 2003). In addition, marigold produces antibacterial thiophenes as exudates by the roots in the arable farming soils thereby reducing risks of arable farmers contracting infections while in contact with affected and infected soils (Soule, 1996). This therefore implies that the tagetes (marigold oil) producing plants should not be planted near any nitrogen-fixing leguminous plants whose bacterial activity increases soil fertility, otherwise arable farming productivity and food security for thiophenes may kill the useful bacteria. Dried leaf powder of *T. minuta* was used as a mulch to suppress the growth of two rice paddy weeds, *Echinochloa crus-galli* and *Cyperus rotundus*, thus increasing rice yield and enhancing food security (Singh et al., 2003).

In many regions of the world, the plant is popularly used as anthelmintic, diuretic, antispasmodic, and to treat stomach and intestinal diseases and relief stomach upsets following a meal. The plant's decoction and/or tea preparations may be consumed either warm or cooled and may be sweetened to individual's taste. *Tagetes minuta* is popularly used in rice dishes and as flavoring agent in stews in Chile and Argentina since antiquity. For instance, in northern Chile, *suico* (a tradition preparation of *T. minuta* that enhances flavor of food) is so highly prized that many people have made a traditional habit of collecting wild plants to dry a sufficient supply to last the winter season in their respective homesteads (Soule, 1996). Leaf infusions and extracts from *Tagetes* spp. have been used in folk medicines to treat intestinal and stomach diseases, which have been also suspected of causing food poisoning and some of them have been found to have bioactivity against Gram-positive and Gram-negative bacteria (Tereschuk et al., 1997).

In Kenya, an infusion of *T. minuta* is used for the treatment of snake bites in the Luo and Kamba communities and aerial parts of the plant used for protection against mosquito bites in the tribes of western Kenya and its scent (essential oil) used as antitick agent in the livestock industry (Wanzala, 2009).

Value Addition Usage and Applications of *T. minuta* L. in Food Science

Identification of essential oil of *Tagetes minuta* with a wide range of biological activity such as anthelminthic, carminative, repellent property, weedicidal, diaphoretic, spasmolytic, germicides, stomachic, antispasmodic, antiprotozoal, bactericidal, emmenagogue, nematocidal, insecticidal, fungicidal, antiviral, and other microbicidal activity (Tereschuk et al., 1997), and its application in food science became inevitable (Chatchal et al., 1995; Saha et al., 2012). For a long time in the history of humanity, infusions, tinctures, and juice from aerial parts of *Tagetes* spp. have been used as traditional food additives worldwide. This provided leads into research for underlying science and as a result, for instance, an orange–yellow, carotenoid lutein substance in the florets of *T. erecta* and many other marigolds (*T. minuta* included) has been identified and approved by the European Union (INS-Number E161b) for use as a food color and flavor in various foodstuffs, at a usage level in condiments and relishes such as pasta, vegetable oil, margarine, mayonnaise, salad dressing, baked goods, confectionery, dairy products, ice cream, yogurt, citrus juice and mustard (Timberlake and Henry, 1986).

In such applications, the European Union approved a maximum level of 0.05% of the essential oil of *T. minuta* in cosmetic products and a level in the consumer product not exceeding 0.01%. In the United States, however, the powders and extracts from marigolds are only approved as colorants in poultry feed. In Europe, Asia, Africa, and America, where a variety of insects at various stages of their developments, are used for food and feed security, marigolds have been recorded as a potential food plant for some of these insects such as Lepidoptera caterpillars including the dot moth and as a nectar source for butterflies (Soule, 1996). Conversely, dried leaves of Mexican marigold are used in cooking to give an apple-like aroma to foodstuffs such as soup, meat dishes, and vegetables. In addition to marigold's use in food additives as coloring and flavoring agent, it is innovatively used as fodder in animal food, principally the dried flowers meal and extract used as supplement for poultry feed (Saha et al., 2012). In South America, India and many parts of Asia, essential oil of *T. minuta* is used for flavoring milk, cheese, bakery products, jams, confectionery, and soft drinks (Mohamed et al., 2002) and for spraying in food stores, green houses, and tissue culture laboratories to stop fungal growth and other destructive microbial agents. In parts of Peru, *T. minuta* is used as a vegetable called *huacatay*, which is among the vegetables with the highest levels of vitamin C (Holm et al., 1997). *Huacatay* paste is used to make the popular Peruvian potato dish called *ocopa* (a traditional dish of Arequipa, Peru).

Usage and Applications of Essential Oil of *Tagetes minuta* in Agriculture

Arable Farming System: Plants

In arable farming system, wild marigold is sometimes an alternative host for *Sclerotinia sclerotiorum* ((Lib.) de Bary, 1884), a fungal pathogen that can infect a variety of crops (Soule, 1996), thus showing its agricultural economic importance in arable farming systems used for food production worldwide. The essential oil of *T. minuta* has been found to be effective against three species of common grain pests of fungus, namely, *Tribolium castaneum* (Herbst, 1797), *Rhyzopertha dominica* (Fabricius, 1792), *Callosobruchus analis* (Fabricius, 1781)(Wanzala, 2009) thus can be used to protect grains in storage. While working on a biopesticides registration action document for tagetes oil (PC Code: 176,602), the United States Environmental Protection Agency found this oil to be useful as an insecticide/acaricide for the control of mites, whiteflies, aphids, thrips, mealybugs, scales, and pyslla on a variety of food crops. The essential oil is thus a potential agent for protecting food crops on farm and in storage, thereby increasing food security, particularly in undernourished communities of the world.

Livestock Farming System

Tagetes minuta essential oil has over 95% efficacy against *Rhipicephalus* (*Boophilus*) *microplus* (Canestrini, 1888), *Rhipicephalus sanguineus* (Latreille, 1806), *Amblyomma cajennense*(Fabricius, 1787), and *Argas miniatus* (Koch, 1844) at a concentration of 20%. The oil has the potential to control *Rhipicephalus appendiculatus* (Neumann, 1901), *Amblyomma* spp. etc. (Wanzala, 2009) and other livestock tick species (such as *Hyalomma rufipes*(Koch, 1844)) (Nchu et al., 2012) that cause socioeconomic losses to farmers. The essential oil therefore provides an opportunity for developing an environmentally friendly and a nontoxic acaricide to milk, beef, and hides/skin production in livestock industry. The oil also has repellent effect against blowflies and effectively used for blowfly dressing in livestock industry (Jacobson, 1983).

Production and Market Value of Essential Oil of *Tagetes minuta* L.

The essential oil of *T. minuta* is isolated from the aerial parts of the plant picked when the seeds are just starting to form. Worldwide, production of the essential oil of *T. minuta* was around 1.5 tonnes per annum in 1984 (Lawrence, 1985) and is currently estimated at between 8 and 15 tonnes per annum and priced at $50 per kg on an upward trend. However, for unknown reasons, world records of production and market value of the essential oil of *T. minuta* are not easy to access in the literature (Table 2). Nevertheless, some organizations such as Floracopeia Aromatic Treasures in India price their essential oil at US $1.07 per mL while Mountain Rose Herbs company in the USA that rates South Africa and France as the largest producing countries in the world, sell ½ oz *T. minuta* essential oil at US $11.75. Hermitage soil, a leading supplier of specialist oils in the United Kingdom since 1979, sells *T. minuta* essential oil at £8.20. The International Trade Center (ITC) identifies Egypt and Zimbabwe as the major world producers of *T. minuta* essential oil. Other countries contributing to the international production and marketing of the *T. minuta* essential oil include: Nepal, India, Brazil, Madagascar, Australia, Ukraine, Chile, Bolivia, Peru, Ecuador, Paraguay, Morocco, Kenya, China, United States of America, Argentina, and Madagascar (Craveiro et al., 1988) (Table 2). In 1996, *T. minuta* was on the list of aromatic plants cultivated on a large-scale rating for

TABLE 2 Annual Global Production of *Tagetes minuta* Essential Oil in Some Countries and/or Regions

Country and/or Region	Quantity Produced (tonnes)	Quality Rating	Level of Production	Source Government Agencies, Institutions, and/or Trading Companies Transacting the Essential Oil Business
[b]South Africa	6.5	High quality	Large-scale farming	CBI market information database. www.cbi.eu
India	4.0	Low quality	Large-scale farming	CBI market information database. www.cbi.eu
[b]Zimbabwe	2.0	High quality	Small-scale wild collections	CBI market information database. www.cbi.eu International Trade Center (ITC)
Europe	[a]Negligible	High quality	Small-scale farming	CBI market information database. www.cbi.eu
[b]Madagascar	– (Price: US $155/kg)	High quality with 42–47% *cis*-β-ocimene	Both large-/small-scale farming and wild collections	International Trade Center (ITC) Biolandes http://www.biolandes.com/ouverturepdf.php?file=F2959.pdf&lg=en Natural Extracts Limited http://www.naturalextracts.com/ne/price_sheet.php
China	–	Low quality	Large-scale farming	CBI market information database. www.cbi.eu
[b]Egypt	100–250 kg	High quality	Both large-/small-scale farming	Cairo Aromatic Limited www.cairoaromatic.com
[a]France	183.3–458.2 kg (Approximated from related existing figures)	High quality	–	International Trade Center (ITC) UNCTAD COMTRADE database, United Nations Statistics Division, 2002
Morocco	63.9–159.7 kg (Approximated from related existing figures)	High quality	Both large- and small-scale farming	UNCTAD COMTRADE database, United Nations Statistics Division, 2002

Note: Exact information was not available and/or difficult to access in literature; CBI, Center for the Promotion of Imports from developing countries; UNCTAD, The United Nations Conference on Trade and Development; COMTRADE, The United Nations Commodity Trade Statistics Database.
[a]*European countries are mainly importers of the* Tagetes minuta *essential oil.*
[b]*Leading countries in the production of* Tagetes minuta *essential oil, worldwide.*

industrial processing in Asia, with Nepal taking the lead, just a head of South Africa, which was producing 6000–7000 kg per annum as per 2003 international records of evaluation of market value of essential oil industry at a price ranging from R400 to R1000 per kg. However, this market value is determined by sustainable supply of considerably sufficient volumes and a high quality of the oil. In turn, the quality is determined by the composition and, for instance, oils containing 40–55% *cis*-β-ocimene are highly rated and valued at the international market by the consumers while the biocidal activity is determined by the presence of tagetenone in the composition.

The rate of isolation of the essential oil from *T. minuta* by steam distillation is normally 0.1–0.4 w/w (Wanzala and Ogoma, 2013). However, at a farm level, the production of essential oil from *T. minuta* ranges from 12.5 to 75 kg per hectare (Panda, 2004). Nevertheless, in European countries the market value of *T. minuta* essential oil is potentially increasing as food manufacturers are increasingly preferring to use this oil in a wide range of foodstuffs (such as frozen deserts) and beverages (such as alcoholic beverages and soft drinks) because of its complex and unique flavors such as that of an apple, banana and mixture of sweet basil, tarragon, mint, and citrus. Further, the oil also has preservative properties.

SUMMARY POINTS

- *Tagetes minuta* has a wide range of bioactivity, thus presenting itself as an excellent preventive measure agent and as a food preservative for a wide range of foodstuffs and beverages.
- The presence of antifungal acetylinic thiophenes from *T. minuta*, presents the plant as a potential on-farm biopesticide agent in arable farming systems.
- The wide range of microbicidal activity of the essential oil of *T. minuta* against virus, bacteria, fungi, arboviruses, protozoa, and helminths presents the oil as a potentially agent to relief food poisoning.
- The essential oil of *T. minuta* has the potential to be developed as a weedicide and anthelminthic to help increasing productivity in arable farming systems thereby increasing food productivity as the plant is grown to suppress a wide range of perennial weeds and to protect crops against nematodes and slugs.
- *Tagetes minuta* is a potential food storage agent and an environmentally friendly and nontoxic acaricide.
- There is a need for validation of traditionally claimed usages and applications of the essential oil of *T. minuta* in the food industry.

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