Published Online on 28 September 2016

Proc Indian Natn Sci Acad **82** No. 4 September 2016 pp. 1237-1248

DOI: 10.16943/ptinsa/2016/48573

Review Article

Carrot Plant-A Potential Source of High Value Compounds and Biological Activities: A Review

DALVIR KATARIA*, KHUSHMINDER KAUR CHAHAL, PAVNEET KAUR and RAMANDEER KAUR
Department of Chemistry, Punjab Agricultural University Ludhiana, India

(Received on 23 November 2015; Revised on 04 March 2016; Accepted on 16 March 2016)

Essential oil of carrot is produced and accumulated in the secretary ducts known as vittae. Phytochemical studies have shown that the major chemical components of carrot plant are polyphenols, flavonols, glycosides, alkaloids, saponins, sesquiterpenoids and essential oil. Chemical constituents of carrot seed essential oil obtainedby hydrodistillation have been the subject of frequent researches. The composition of essential oil varies with plant parts. The carrot essential oil possesses biological activities like antimicrobial, antibacterial, antifungal, herbicidal, antioxidant, anticancer etc. The health benefits of carrot essential oil can be attributed to its antiseptic, disinfectant, detoxifying, antioxidant, anticarcinogenic, tonic, carminative, depurative, diuretic and stomachic properties.Major components present in different parts of carrot plant are listed along with their chemical composition. The morphological details of plant, its essential oil, chemicalconstituents and biological activities have been discussed in this review.

Keywords: Carrot; Seed Oil; Carotol, Daucol; Essential Oil; Hydrodistillation

Introduction

The genus *Daucus* comprises of about 60 weedy species widely distributed and commonly cultivated for their fleshy edible roots (Ahmed *et al*., 2004).The species *carota* originates from the word carotos. Carrot (*Daucus carota* L.), a flowering plantbelonging to family Apiaceae, is one of the popular root vegetables grown throughout the world having crisp texture when fresh, usually orange in colour, although purple, red, white, and yellow varieties also exist. It is one of the ten most economically important vegetables crops in the world (Simon, 2000). *D. carota* seeds are tiny, covered with a fleshy mericarp that must be removed prior to seeding. Seeds are formed from ovules present in the carpels. Seeds are tiny and covered with a spiny, hooked, and slightly curved mericarp. The mericarp contains characteristic oil which inhibits seed germination, requiring the removal of the mericarp before planting. Carrot seeds are not true seeds in a botanical sense but are dry fruits called schizocarps. The carrot is not a fruit in the common understanding, so there are no seeds inside or on the carrot.

Distribution

Carrot is native to Western or the near East Asia and is also found in the Mediterranean region, Southwest Asia, Tropical Africa, Australia and North and South America (Reed, 1976). It is considered as a serious weed in Afghanistan, Greece, Hungary and Poland, a principal weed in Jordan, Mauritius, Puerto Rico, Sweden, and Tunisia, a common weed in Austria, Canada, Egypt, England, Germany, Iran, Iraq, USA, USSR, and West Polynesia. Carrot inhabits dry fields and waste places at low altitudes throughout the northern United States from Vermont to Virginia west to Washington and California; and further north into Canada (Holm *et al*., 1979).

Habitat

Carrots develop within a great range of temperatures and are grown throughout the world with the exception of the very warmest area. The root growth is fastest at 15°C and 18°C. Seeds may germinate at low temperatures. Carrots are tolerant of long days but need low temperatures to induce flowering. Carrot

**Author for Correspondence: E-mail: katariadalvir@gmail.com*

normally does not occur on newly abandoned fields because seeds do not survive for more than two years (Gross and Werner 1982).

Morphology

The carrot is a herbaceous, biennial plant with height of 0.3 and 0.6 m; roughly hairy with a solid stem. In the first growing season, it shows a rosette of leavesduring the spring and summer, builds up the stout taproot to store large amounts of sugars and nutrients for the production of flowers and seeds in the second year (Elzer-Peters, 2014). Tap root is thick, swollen and red-orange or thin and light coloured having conical shape, although cylindrical and round cultivars are also available. Stem is furrowed, bristly-haired or compressed and the internodes are not distinct. The leaves are tri-pinnate, finely divided, stalked, lacy and overall triangular in shape. The inflorescence is a compound umbel, and each umbel contains several umbellets. A large primary umbel can contain up to 50 umbellets, each of which may have as many as 50 flowers. Flowers are small and white, sometimes with a light green or yellow tint and are arranged into a flat umbrella-like head or umbel. They consist of five petals, five stamens and calyx. The carrot fruits are oval and flattened from the sides, 2-4mm with short styles and hooked spines (McClintock and Fitter,1956).

Extraction of Oil from Carrot

Carrot seeds weresubjected to extraction using different solvents such as 1,1,2-trichloro-1,2,2-trifluoroethane, methylfuran, ethanol and dichloromethane. Quantitatively, the highest yields of concrete and essential oil were obtained using sylvan (4.79 and 0.47%) and ethanol (3.30 and 0.87%). These yields of essential oil were greater than those obtained by hydrodistillation (0.40%) (Jian *et al*., 1989). Extraction of essential oil fromcarrot fruitsby supercritical carbon dioxide method was investigated from the pretreatment of herbaceous matrix (Sandra *et al*., 2007).

Chemical Composition of Carrot Essential Oil

Fresh carrots contain 0.59% of essential oil (Alabran *et al*., 1975). The yield of essential oil from the leaves of carrot obtained by hydrodistillation in Iran was 0.2 % (v/w) (Mojab *et al*., 2008). At harvest time the plants had fully developed fruits and oil yields varied with parts of plant; 0.2, 0.1 -0.3 and 0.8-1.6 % (v/w) for roots, leaves, and fruits, respectively (Chizzola, 2009). The essential oil yield varied from 0.7 to 1.8% (v/w) during umbel ontogeny (Ram *et al*., 2013). Carrot seed oil contains petroselinic acid (70%) (Dutta and Appelqvist 1989). The hydrodistilled essential oil obtained from the aerial parts (stems and leaves, and umbels) of *D. carota* grown in Algeria analysed by GC and GC-MS showed the presence of monoterpenes (91.8 and 63.1%) which were more abundant than phenylpropanoids (0.2 and 13.7%) respectively (Hocine, 2012). Ozcan and Chalchat (2007) investigated the essential oil and edible oil composition of carrot seeds by GC and GC-MS. The oil yields of essential and edible oil from carrot seeds were found to be 0.83 and 7.84% respectively. The major constituents of seed essential oil were carotol (66.78%), daucene (8.74%), (*Z,Z*)-α-farnesene (5.86%), germacrene D (2.34%), trans-α-bergamotene (2.41%) and β-selinene (2.20%) whereas carotol (30.55%), daucol (12.60%) and copaenol (0.62%) were the important components of edible carrot seed oil. However, the dominant component of both the oils was carotol.

Nutritional Importance of Carrot

Carrot ranks tenth in nutritional value among various fruits and vegetables (Acharya *et al*., 2008). Carrots contain pro-vitamin A carotenes which maintain good eye health. Carrot is a good source of dietary fibre and of the trace mineral molybdenum, rarely found in many vegetables. Molybdenum aids in metabolism of fats and carbohydrates and is important for absorption of iron. It is also a good source of magnesium and manganese. Magnesium is needed for bone, protein, making new cells, activating B vitamins, relaxing nerves and muscles, clotting blood and energy production; secretion and functioning of insulin also require magnesiun (Guerrera *et al*., 2009; Bartletf *et al*., 2008; Kim *et al*., 2010).

Biological Potential of Carrot Seed-Essential Oil and Major Isolates

Carrot is cultivated almost all over the world as a useful vegetable and investigated since many decades for its biological activities. Many phytochemical studies were carried out on this plant and a large number of active ingredients were isolated that includes volatile

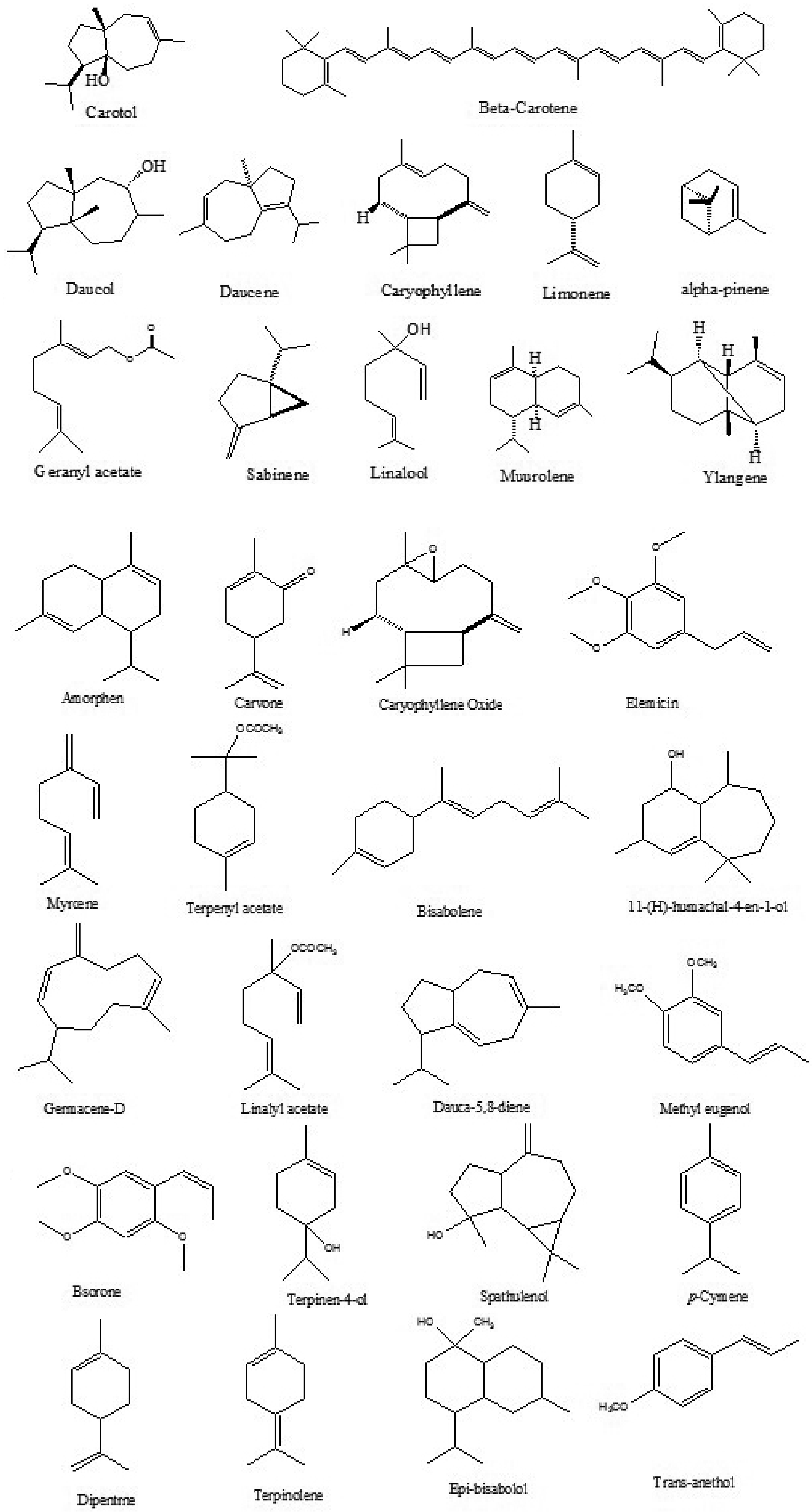

Fig. 1: Compounds present in carrot essential oil

Table 1: Percentage compostion of various compounds in different parts of carrot plant

S.No.	Compound	%age	Plant part	References
1	Carotol	0.7-66.7	Unripe and ripe fruits, seeds, leaves, stem, root, flowering umbels.	Ozcan and Chalchat 2007; Benecke *et al*., 1987; Perineau *et al*., 1991; Ram *et al*.,2013; Jasicka *et al*.,2004; Seifert and Buttery 1978; Flamini *et al*., 2007; Rossi *et al*., 2007; Maxia *et al*., 2009; Marzouki *et al*., 2010; Glisic *et al*., 2007; Wu *et al*., 2006; Khanna *et al*., 1989; Ashraf *et al*., 1979; Hilal *et al*., 1977; Talwar*et al*., 1963; Stahl 1964; Sokovic *et al*., 2009; Toulemonde *et al*., 1987; Nigam and Radhakrishnan 1963, Meshcheryuk *et al*., 1983; Smigielski *et al*., 2014; Kula *et al*., 2006.
2	β-Carotene	39.6-11.2	Root	Suman and Kumari 2002; Naseem *et al*., 2011; Simon and Wolff 1987.
3	Daucol	4.3-7.35	Fruits, seeds	Benecke *et al*.,1987; Perineau *et al*., 1991; Pinilla *et al*., 1995; Jasicka-Misiak *et al*., 2004; Wu *et al*., 2006; Ashraf *et al*., 1979; Talwar *et al*., 1963; Stahl 1964; Toulemonde *et al*., 1987; Nigam and Radhakrishnan 1963; Meshcheryuk *et al*., 1983, Smigielski *et al*., 2014; Kula *et al*., 2006.
4	Daucene	0.39-8.7	Leaves, seeds	Ozcan and Chalchat 2007; Pinilla *et al*.,1 995; Sokovic *et al*., 2009.
5	α-caryophyllene	4.6-47.0	Umbels, seeds, ripe fruits	Alabran *et al*., 1975; Jasicka-Misiak *et al*., 2004; Sokovic *et al*., 2009; Kula *et al*., 2006; Schaller and Schnitzler 2000.
6	Limonene	2.3-12.7	Seeds, fruits, stem, leaves, flowers	Staniszewska *et al*., 2005; Chizzola 2009; Ram *et al*., 2013; Schaller and Schnitzler 2000; Mockute and Nivinskiene 2004; Meliani *et al*., 2013; Halim *et al*., 1988; Saad *et al*., 1995; Flamini *et al*., 2014.
7	α-pinene	7-51.2	Fruits, seeds, roots, leaves, unripe and ripe fruits, flowers, stem, blooming umbels	Gonny *et al*., 2004; Staniszewska *et al*., 2005; Chizzola 2009; Ram *et al*.,2013; Jasicka-Misiak *et al*., 2004; Rossi*et al*., 2007; Maxia*et al*.,2009; Wu *et al*., 2006; Sokovic *et al*., 2009; Smigielski *et al*., 2014; Schaller and Schnitzler 2000; Mockute and Nivinskiene 2004; Meliani *et al*.,2013; Flamini *et al*., 2007; Marzouki *et al*., 2010.
8	Geranyl acetate	51.7-77.0	Fruits, seeds	Benecke *et al*., 1987; Perineau *et al*., 1991; Pinilla *et al*., 1995; Chizzola 2009; Rossi *et al*., 2007; Maxia *et al*., 2009; Ashraf *et al*., 1979; Hilal *et al*., 1977; Talwar *et al*., 1963; Stahl 1964; Toulemonde *et al*., 1987; Nigam and Radhakrishnan 1963, Meshcheryuk *et al*., 1983; Flamini *et al*., 2014, Marzouki *et al*., 2010; Pigulevskii and Kovaleva 1955a, Pigulevskii and Kovaleva 1955b, Pigulevskii *et al*., 1965.
9	Sabinene	1.5-60.0	Fruits, leaves, seeds, blooming umbels, unripe and ripe fruits, stem	Staniszewska *et al*., 2005; Chizzola 2009; Ram *et al*., 2013; Jasicka *et al*., 2004; Rossi *et al*., 2007; Maxia *et al*., 2009; Khanna *et al*., 1989; Sokovic *et al*., 2004; Smigielski *et al*., 2014; Mockute and Nivinskiene 2004; Meliani *et al*., 2013; Flamini *et al*., 2007; Marzouki *et al*., 2010; Tavares *et al*., 2008.
10	Linalool	37.6-38.0	Seeds, leaves	Alabran *et al*., 1975; Khanna *et al*., 1989.
11	α-muurolene	8.2-10.9	Ripe and unripe fruits	Sokovic *et al*.,2009
12	α-ylangene	4.8-5.2	Unripe and ripe fruits	Sokovic *et al*., 2009
13	α-amorphen	7.5	Unripe fruits	Sokovic *et al*., 2009
14	Carvone	0.03	Leaves	Khanna *et al*., 1989
15	Caryophyllene–oxide	4.3-7.7	Seeds, unripe fruits	Jasicka *et al*., 2004; Sokovic *et al*., 2009; Meliani *et al*., 2013.
16	Elimicin	11.4-35.0 fruits	Ripe, umbels (seeds),	Gonny *et al*., 2004; Rossi *et al*., 2007; Maxia*et al*., 2009; Marzouki *et al*., 2010; Tavares *et al*., 2008.
17	Myrcene	12.0-24.0	Seeds, leaves, roots	Chizzola 2009; Schaller and Schnitzler 2000; Mockute and Nivinskiene 2004.
18	Terpinyl acetate	0.70-5.03	Fruits	Benecke *et al*., 1987; Ashraf *et al*., 1979.
19	â-bisabolene	17.6-51.0	Flowering and mature umbels	Maxia*et al*., 2009

S.No.	Compound	%age	Plant part	References
20	11-α-(H)-himachal 4-en-1-β-ol	-9.0–21.6	Flowering and mature umbels	Maxia*et al*., 2009
21	Germacrene-D	2.34	Seeds	Ozcan and Chalchat 2007
22	Linayl acetate	3.01	Leaves	Khanna *et al*., 1989
23	Dauca-5,8-diene	0.04	Seed	Mazzoni *et al*., 1999
24	Trans-methyl-isoeugenol	0.5.-7.6	Fruits, stem, Leaves	Gonny *et al*., 2004; Saad *et al*., 1995
25	Basarone	0.3-1.0	Fruits, stem and leaves	Saad *et al*., 1995
26	Methyl-Eugenol	7.39	Fruits	Kameoka *et al*., 1989
27	Terpinene-4-ol	2.4-7.5	Umbels	Staniszewska *et al*., 2005; Mockute and Nivinskiene 2004; Meliani *et al*., 2013
28	Spathulenol	0.6-4.3	Umbels	Meliani *et al*., 2013
29	p-cymene	3.3-2.2	Umbels	Meliani *et al*., 2013
30	Isopathulenol	0.2-3.8	Seed	Alabran *et al*., 1975; Meliani *et al*., 2013
31	Dipentene	15.0	Seed	Alabran *et al*., 1975
32	α-terpinolene	2.0-21.0	Seed, root	Alabran *et al*., 1975; Chizzola 2009
33	Epi-bisabolol	4.5	Fruits	Flamini *et al*., 2007
34	Trans-anethole	23.5	Leaves	Nigam and Radhakrishnan 1963

oils, steroids, triterpenes, carbohydrates, glycerides, tannins, flavonoids, amino acids, flavonoids, carotene and hydrocarotene (Mazzoni *et al.*, 1999).

Antimicrobial

The antimicrobial action wasdue to the lipophilic character of hydrocarbon skeleton and hydrophilic character of functional group in *D. carota* essential oil (Bendiabdellah *et al*., 2012). The essential oil of *D. carota* var. *gummifer* was more active than the *D. carota* var. *carota* essential oil against six bacterial strains, with minimum inhibitory concentration (MIC) values ranging from 2.5 to 5 mg/ml. The most prominent inhibitory action of this essential oil was observed against three gram-positive bacteria (*L. monocytogenes*, *B. cereus* and *S. aureus*) and one gram-positive bacterium (*E. coli*) at 2.5 mg/ml (Meliani *et al*., 2013). The flowering umbel, and mature umbel oils from carrot in Poland, previously tested for inhibitory effect on microorganisms (*S. aureus*, *B. subtilis* and *C. albicans*) were dominated by α-pinene (17-42%) and sabinene (19-40%). The essential oil obtained from aerial parts of growing wild carrot in Corsica, at the end of flowering stage constituted of (E)-methylisoeugenol (21.8%), β-bisabolene (21.3%), elemicin (16.3%) and α-pinene (15.9%) and acted as antimicrobial agent against the human enteropathogen *Campylo bacter* (*C. jejuni*, *C. bacter coli*, and *C. bacter lari*) (Rossi *et al.*, 2007). Antimicrobial properties of the oils obtained from herb, flowering and mature umbels of wild carrot in Poland were compared using four species of bacteria. The oils obtained from cultivated carrot seed were more effective against all tested organisms. The strongest overall activity was demonstrated by the commercial oil of cultivated carrot seeds (Flamini *et al.*, 2007). Sabinene and undecan-2-one isolated from the carrot seed oil possessed antimicrobial activity (Gillani *et al*., 2000). Stronger antimicrobial activity of the essential oil may be due to the investigated strain sensitivity to α-pinene, sabinene and the other lighter components present in essential oil only. In the case of *B. subtilis*, essential oil had a stronger antimicrobial effect. Stronger antimicrobial effect of supercritical fluid extracts might be due to greater sensitivity of strains to carotol or to the synergistic activity of carotol and other heavier molecular weight compounds present (Dorman and Deans, 2000). Essential oil from different parts of *D. carota* was screened for antimicrobial activity against 12 bacterial strains (Glisic *et al*., 2007). The diethyl ether extract of *D. carota* inhibited the growth of the yeast *C. albicans* at 25 mg/ml (Radulovic *et al.*, 2011). The antimicrobial activity of the compounds (four sesquiterpenes daucane esters, one polyacetylene, one sesquiterpene coumarin and sitosterol glucoside) obtained from roots of the wild carrot showed that these compounds possessed low antibacterial activities against four gram positive (*Staphylococcus aureus*, *Streptomyces scabies*, *B. subtilus*, *B. cereus*) and two gram negative species (*Pseudomonas aeruginosa*, *Escherichia coli*) (Ahmed *et al*., 2004). Antibacterial activity of the oils from the ripe fruits, unripe fruits, flowers, root, leaves, and stem of wild *D. carota* collected from Serbia against eight bacterial and eight fungal strains, by a microdilution technique was investigated. The most prominent biological activity was observed in isolated essential oils of ripe and unripe fruits of *D. carota* (Sokovic *et al*., 2009). The essential oils of *D. carota* was tested against the standard strains showed significant inhibitory action against all the tested strains (Syed *et al.*, 1986). Ethyl acetate extract of *D.carota* seeds was effective on West Nile Virus with an IC50 of 0.008 mg/ml (Miladi2012). Carrot oil showed no antibacterial characteristics against the bacteria *Listeria monocytogenes*, *Yersiniaenterolitica*, *Pseudomonas aeruginosa* and *Lactobacillus plantarum* (Elgayyar *et al*., 2001).

Herbicidal

Carrot seed essential oil exhibited herbicidal properties (Jasicka-Misiak *et al*., 2005; Dudai *et al*., 1999). Whereas the water extracts from the carrot seed exhibited plant growth inhibitory properties against cress, cucumber, onion and carrot due to the action of low-and high-molecular components of the extract. Crotonic acid ((*E*)-2-butenoic acid), low-molecular component with high level in seeds was also available after release to soil, might be considered as an allelopathic and autotoxic factor in the seeds (Jasicka-Misiak *et al*., 2005).

Antifungal

Essential oil isolated from seeds of *D. carota* exhibited antifungal activity against the test fungus *Aspergillus flavus* (Diwedi and Dubey, 1993) and the oil from the roots of *D. carota* var. *hispanicus* inhibited the aflatoxin production (Jasicka-Misiak *et al*., 2004; Bendiadellah *et al*., 2014). Carotol, β-caryophyllene, daucol from the carrot oil produced strong inhibitory effects on mycelium radial growth of *Alternaria alternata*. Although, it was observed that sesquiterpene β-caryophyllene failed to have any effect. The activity of carotol was nearly as strong as the commercially available fungicide funaben T (85%) (Jasicka-Misiak *et al*., 2004). The carrot seed oil inhibited growth of *Aspergillus paraiticus*and no aflatoxin was produced. Carrot seed oil, limonene and terpinene reduced the growth rate, measured by the incorporation of [^{3}H] amino acids into trichloracetic acid (TCA) insoluble protein (Batt *et al*., 1983). *D.carota* oil showed no cytotoxicity in mouse skin dendritic cells (Tavares *et al*., 2008). Limited antifungal activity of wild carrot was documented against only one (*Botrytis cinerea*) out of nine fungi tested. Fungicidal activity of two biocidal peptides isolated from carrot seeds, towards the pathogenic fungus *Verticilliu mdahlia was effective* (Yilli *et al*., 2006). Antifungal activity of oils obtained from flowering and ripe umbels was evaluated against yeasts, *Aspergillus*and dermatophyte strains. Dermatophyte strains showed more sensitivity to these oils as compared to yeasts and other filamentous fungi. The essential oil from ripe umbels with high amounts of elicimin proved to be more active (Rossi *et al*., 2007).

Antioxidant

The methanolic extract of carrot seeds showed antioxidant activity and increased the carbohydrate metabolism and morphology of pancreas in type I diabetic male rats (Ranjbar, 2010), whereas the ethanolic extract of *D. carota* seeds showed the antioxidant potential by the reduction of oxidative stress and lipid levels in experimental rats (Pranita, 2010). The oil from the aerial parts of Algerian *D. carota* possessed antioxidant activity (Hocine, 2012). The alkenes present in the essential oil of flowers, stems, roots and leaves of *D. carota* were easily oxidized due to presence of unsaturation and showed an activity of the antiformation of free radicals to some extent (Wu *et al*., 2006). *In vivo* antioxidant and hepatoprotective activity of methanolic extracts of *D. carota* seeds induced in rats by thioacetamide 100 mg/kg, in four groups of rats (two test, standard and toxic control). On the 8th day animals were sacrificed and liver enzyme like serum glutamic pyruvic transaminase (SGPT), serum glutamic-oxaloacetic transaminase (SGOT) and alkaline phosphatase (ALP) were estimated in blood serum and antioxidant enzyme like superoxide dismutase (SOD), catalase

(CAT), glutathione reductase (GRD), glutathione peroxidase (GPX), glutathione-S-transferase (GST) and lipid peroxidation (LPO) were estimated in liver homogenate. It was found that carrot seed oil contributed to the reduction of oxidative stress and the protection of liver in experimental rats (Kamlesh *et al*., 2012).

Insecticidal

Compounds isolated from the bioactive hexane extract of carrot seeds i.e. 2,4,5-trimethoxy benzaldehyde, oleic acid, trans-asarone, and geraniol were evaluated for their mosquitocidal activity (Sharma *et al*., 1994). Trans-asarone caused complete mortality of fourth-instar mosquito larvae, *Aedes aegyptii*at 200 µg/ml whereas carrot extract showed larvicidal activity against *A. aegypti* and *Culex quinquefasciatus* (Lee, 2006). Vapours of trans-2-nonenal, the aldehyde in the essential oil of carrotkilled the carrot fly larva *Psilarosae* (Guerin and Ryan, 1980). Acetone, ethanol, hexane, and methanol extracts of carrotwere found to be insecticidal against 4th instars of *C. annulirostris* (Shaalan *et al*., 2006). The essential oil from the flowers of carrot possessed fumigant activity against third instar larvae of *Spodoptera littoralis* (Salaheddine *et al*., 2013). Larvicidal activity of the essential oil and the constituents from carrot plant was reported against *C. pipienspallens* and *D. magna*. It was found that active components of carrot essential oil could be developed as control agents against mosquito larvae. Among the tested compounds, carotol was the most toxic to *D. magna*. The insecticidal activities of carrot oil were stronger than carotol, indicating that other constituents of carrot oil act synergistically (Park and Park, 2012). Carrot leaves were found to act as ecofriendly insecticide against certain insects causing damage to cucumber leaves resulting in lower yields (Azad *et al*., 2006).

Anticancer

Carrots had been used for treatment of leukaemia in traditional medicine. Polyacetylenes rather than beta-carotene or lutein were the bioactive components found in *D. carota* and could be useful in the development of new leukemic therapies (Ziani *et al*., 2012). Significant cytotoxicity of 2-epilaserine against HL-60 cells was observed, which implied that phenylpropanoids were cytotoxic compounds in carrot (Yang *et al*., 2008). *D. carota* oil extract exhibited anticancer activity against human breast adenocarcinoma cell lines MDA-MB-231 and MCF-7 (Shababey *et al*., 2014). Compounds from carrot seed oil and their hydroindene-derivatives examined for their ability to inhibit the growth of myeloid leukaemia (HL-60) cancer cell lines. All compounds showed significant activity, which was comparable to the most active volatile organic compounds, such as *trans–trans*-farnesol, citral and nerolidol (Radoslaw *et al*., 2012).

Antifertility

The use of carrot seed for contraception and abortion was recorded throughout European history, with contemporary reports from India and the United States (Jansen and Wohlmuth, 2014). *In vivo* and *ex vivo* studies suggested that several modes of action may have contributed to the anti-fertility effect, including an effect on the oestrous cycle and anti-progestogenic activity (Jansen and Wohlmuth, 2014; Dhar, 1990; Bhatnagar, 1995). Significant antifertility activity (60%) in rats was reported for wild carrot extract (Majumdar *et al*., 1998). In contrast, insignificant antifertility activity was observed in pregnant rats. Petroleum, aqueous and alcoholic extracts exhibited 10, 20 and 40% activities respectively. Seed extracts showed anti-implantation activity and weak oestrogenic activitiesin rats (Prakash, 1984; Sharma, 1976; Garg *et al*., 1978; Kant, 1986). The postcoital antifertility effect of alcoholic extract of carrot seed was related to its inherent estrogenicity (Sharma *et al*., 1976). Kamboj and Dhawan (1982) at CDRI, Lucknow, however found no antifertility activity in the red and black varieties of carrot seeds (). The petroleum ether extract and fatty acids of carrot seeds arrested the normal estrus cycle of adult mouse and reduced the weight of ovaries significantly. The cholesterol and ascorbic acid content in ovaries were significantly elevated due to the treatment with extract and fatty acids of carrot seeds. It was found that the fatty acids present in carrot seeds acts as an antisteroidogenic agents (Majumder *et al*., 1997).

Memory Improvement

A study on the effects of carrot seeds on memory in rats revealed that, the ethanolic extract was administered orally in three doses (100, 200 and 400 mg/kg) for seven successive days to different groups of young and aged rats. Extracts (200 and 400 mg/

kg) showed significant improvement in memory of young and aged rats. Carrotextract also reversed the amnesia induced by scopolamine (0.4 mg/kg) and diazepam (1 mg/kg) (Vasudevan *et al*., 2010).

Anti-inflammatory

The polyacetylene compounds falcarindiol, falcarindiol 3-acetate, and falcarinol and reduced nitric oxide production in macrophage cells by about 65% without cytotoxicity. Thus polyacetylenes, not anthocyanins, in purple carrots were responsible for anti-inflammatory bioactivity (Metzger *et al*., 2008). Polyacetylenes are cytotoxic to certain fungi, microorganisms, and protective against various cancer cells *in vitro* and *in vivo* studies (Metzger and Barnes, 2009). Polyacetylenes possess bioactive properties which include the inhibition of lipid transport enzymes, induction of liver phase II detoxification enzymes, and anti-inflammatory activity. The essential oils from the flowers, roots and stem were evaluated on the basis of characteristics of the yield, color and chemical structure from the three parts as well as the components of multi fragrances these oils, which showed the activities of antibiosis and antiinflammation (Wu *et al.*, 2006). The oil demonstrated a strong anti-inflammatory activity by inhibiting nitric oxide (NO) production in both lipopolysaccharide (LPS)-triggered macrophages and microglia cells (Valente *et al*., 2014).

Wound Healing

Wound-healing property of ethanolic extract (topical application) of *D. carota* root was due to the various phytoconstituents like flavonoids and phenolic derivatives present in the root and the quicker process of wound healing could be a function of either its antioxidant or antimicrobial potential (Patil *et al.*, 2012).

Diuretic

Terpinen-4-ol, component of the carrot seed oil and juniper was considered to be the diuretic principle exerting its effect by causing renal irritation. The traditional use of wild carrot was as a diuretic and ethanolic extract of carrot produced an increased urine flow in dogs (Stanic *et al*., 1998).

Antiulcer

The antiulcer activity of fresh juice extract of the roots of carrot was assessed by the parameters i.e. volume of gastric section, pH, free acidity, total acidity, mucus content and ulcer index. The *Daucus carota* extract possesses gastroprotective property and the results supported traditional use of the roots of this plant in the treatment of gastric ulcer and acidity (Nayeem *et al*., 2010).

Muscle Relaxant and Lowering of Blood Pressure

Ethanolic extract of *D. carota* exhibited Ca^{2+} channel blocking-like direct relaxant action on cardiac and smooth muscle preparations and lowered the blood pressure due to presence of two cumarin glycosides in aerial parts (Gilani *et al*., 1994). The seed oil obtained from *D. carota*var *sativa* was reported to elicit CNS hypnotic effects in the rat, hypotension, direct depressant effect on cardiac muscle in the dog (Gambhir, 1966; Bhargava, 1967), leading to respiratory depression at higher doses, anticonvulsant activity in the frog, *in vitro* smooth muscle relaxant activity.

Conclusions

Although many studies have been carried out on carrot essential oil, its biological models, clinical studies demonstrated that essential oil showed various uses in pharmaceutical aromatherapy andfound effective in the treatment of various diseased conditions. The study explored one of the promising and effective medicinal sources of carrot essential oil. The reviews on Chemistry and biological activities of carrot plant and carrot seed essential oils have not been reported. Screening of literature on carrot showed that hydrodistillation method was commonly used method for isolation of essential oils. Carrot essential oil is rich in sesquiterpenes, major component was carotol while daucol anddaucene were minor compounds present. Due to their wide spectrum of biological activity, isolation of major and minor compounds, their quantification, derivatization and structural elucidation is still a crucial matter. The carrot seed oil and its constituents possessed wide spectrum of biological activities like antifungal, antimicrobial, insecticidal, anti-inflammatory, anticancer, antifertility, antiulcer, antioxidant, herbicidal, diuretic, muscle relaxant etc. Thus essential oil of carrot plant is very useful and its chemistry needs to be further explored.

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