JOURNAL OF NATURAL REMEDIES

An Overview on Ajwain (*Trachyspermum ammi*) Pharmacological Effects; Modern and Traditional

Mohammad M. Zarshenas[1,2], Mahmoodreza Moein[3,4*], Soliman Mohammadi Samani[5], Peyman Petramfar[6]

[1]Department of Traditional Pharmacy, School of Pharmacy, Shiraz University of Medical Sciences, Shiraz, Iran
[2]Essence of Parsiyan Wisdom Institute, Traditional Medicine and Medicinal Plant Incubator, Shiraz University of Medical Sciences, Shiraz, Iran
[3]Medicinal Plants Processing Research Centre, Shiraz University of Medical Sciences, Shiraz, Iran
[4]Department of Pharmaceutics, School of Pharmacy, Shiraz University of Medical Sciences, Shiraz, Iran
[5]Department of Pharmacognosy, School of Pharmacy, Shiraz University of Medical Sciences, Shiraz, Iran
[6]Department of Neurology, School of Medicine, Shiraz University of Medical Sciences, Shiraz, Iran

Abstract

Trachyspermum ammi (L.) Sprague or commonly Ajwain is a herbaceous herb belonging to the family Apiaceae and vastly grows in Egypt, Iran, Pakistan, Afghanistan, and India as well as European region. Known as *Zenyan* or *Nankhah* in medical and pharmaceutical manuscript of medieval Persia, seeds of Ajwain were highly administered by traditional healers and traditionally employed for different ailments. Due to its various chemical constituents, the herb seeds were also evaluated for its numerous pharmacological properties. Accordingly, current work was carried out to review the traditional and modern pharmacological properties of Ajwain regarding current and medieval reports. To this, respective databases were searched for the terms '*Trachyspermum ammi*', '*Carum copticum*', 'Ajwain' and 'Ajowan' without limitation up to early 2013. Information on the herb was gathered via electronic search using Pubmed, Scopus, Google scholar and SID (for articles in Persian language) as well as medical and pharmaceutical manuscripts of Persian medicine. Ajwain seeds revealed to possess antiseptic, stimulant, carminative, diuretic, anesthetic, antimicrobial, antiviral, nematicidal, antiulcer, antihypertensive, antitussive, bronchodilatory, antiplatelet and hepatoprotective as well as antihyperlipidemic effects, many of those were remarked by early Persian physicians. With reference to these pharmacological activities, Ajwain seeds can be a good candidate for to be applied in clinical practice. However, in spite of various experimental and animal studies, lack of comprehensive clinical trials aimed on regarded effects is still remained to reconfirm the traditional knowledge.

Keywords: Ajwain, *Trachyspermum ammi* (L.) Sprague, traditional medicine, herbal medicine

1. Introduction

Known as Ajwain, *Trachyspermum ammi* (L.) Sprague is an annual herbaceous plant belonging to the highly valued medicinally important family, Apiaceae [1]. It is said that the herb is widely grown in arid and semi-arid regions where the soil involve high amount of salts [2]. Ajwain has an erect and striate stem involving glabrous or minutely pubescent properties which may grow up to 90 cm tall [3]. Ajwain is widely distributed and cultivated in various regions such as Iran, Pakistan, Afghanistan, and India as well as Europe while it is indigenous to Egypt [4]. The herb is generally grown in October–November and should be harvested in May–June [5, 6]. Usually grayish brown seeds or fruits of Ajwain are considered for medical and nutritional purposes [5].

*Author for correspondence
Email: mrmoein@sums.ac.ir

A number of chemical constituents have been reported for the herb. Fiber (11.9%), carbohydrates (24.6%), tannins, glycosides, moisture (8.9%), protein (17.1%), fat (21.1%), saponins, flavones and other components (7.1%) involving calcium, phosphorous, iron, cobalt, copper, iodine, manganese, thiamine, riboflavin and nicotinic acid are of reported phytochemical constituents of Ajwain [6–8]. In the alcoholic extraction process, a large amount of saponin has been derived [6].

Similar to the most species of the family Apiaceae, Ajwain is famous for its brownish essential oil. Apparently, presence of an Ajowan essential oil is responsible for its odor and taste. Hence fruits of Ajwain accumulate up to 5% essential oil in its compartments [9]. However, some investigation reported the yield of fruits essential oil up to 9% which may be considerable [10]. Usually, Thymol is the main Ajwain essential oil constituent and may be yielded from 35% to 60% [11, 12]. The non-thymol fraction (Thymene) contains Para-cymene, Gamma-terpinene, Alpha-pinene, Beta-pinene, α-terpinene, Styrene, Delta-3-carene, Beta-phyllanderene, terpinene-4-ol and Carvacrol [6, 13]. On the other hand, in an investigation, carvone (46.2%), limonene (38.1%) and dillapiole (8.9%) were introduced as principal oil constituents [14]. Also oleic, linoleic, palmitic, petroselinic acid, resin acids are isolated from fruits of Ajwain [7]. New glycosyl constituents such as 6-hydroxycarvacrol 2-O-β-D-Glucopyranoside and 3, 5-Dihydroxytoluene 3-O-β-D-Galactopyranoside are recently reported from fruits of Ajwain [15]. Also, a steroid like substance and a compound namely 6-O-β-Glucopyranosyloxythymol has been isolated from the fruits [16].

Water-soluble extract of Ajwain fruit revealed to involve many compounds such as a new Monoterpenoid, 3, 7-Dimethyloct-3(10)-ene-1, 2, 6, 7-tetrol; new Monoterpenoid Glucosides namely (2S, 6Z)-3, 7-Dimethyloct-3(10)-ene-1, 2, 6, 7-Tetrol 1-O-β-D-Glucopyranoside and 6-Hydroxythymol 3-O-β-D-Glucopyranoside; new aromatic compound glucosides as 2-Methyl-3-Buten-2-ol-β-D-Glucopyanoside Benzyl-β-D-Glucopyranoside and Glucide namely (3R)-2-Hydroxymethylbutane-1,2,3,4-tetrol [11, 17]. Other glucosides such as 1-Deoxy-L-Erythritol and 1-Deoxypentitol and also nucleosides as adenosine and uridine were isolated from Ajwain fruits [11].

Ajwain was vastly applied by medieval practitioners and it also exhibited different pharmacological effects regarding various chemical ingredients. Accordingly, current paper was aimed to review the clinical applications of the herb as well as most cited pharmacological properties in current medicine. To this, respective databases were searched for the terms "*Trachyspermum ammi*", "*Carum copticum*", "Ajwain" and "Ajowan" without limitation up to early 2013. Information on the herb was gathered via electronic search using Pubmed, Scopus, Google scholar and SID (for articles in Persian language) as well as medical and pharmaceutical manuscripts of Persian medicine.

2. Applications of Ajwain in Medieval and Traditional Persian Medicine

Ajwain has been commonly used in traditional medicine systems for a variety of medicinal and pharmacological aspects [18]. In Traditional Persian Medicine (TPM), Ajwain was well known from thousands of years. Persian practitioners usually used seeds of Ajwain as the most useful part of the herb [19]. According to its temperament, Ajwain is hot and dry in the third degree and also possesses some bitterness and acridity [20].

Oral application of seed was reported to be useful for paralysis, tremor and palsy as well as other neural disorders in the field of neurology [20]. Persian practitioners also applied the eye and ear drop formulated from seeds of Ajwain in order to control the infected conditions and correct the auditory weakness [21]. In the field of respiratory, Ajwain was said to be effective on cough, pleurisy and dysphonia [19]. Fruits were widely administered for liver spleen as well as gastrointestinal disorders such as nausea, vomiting, reflux, abdominal cramps and loss of appetite [20]. They were also said to be beneficial in stomach troubles and possess stimulant and carminative properties [21]. Ajwain was reported as an anthelmintic medicine and also antidote for various natural toxic agents [21]. It was also believed to be beneficial for dissolving the calculi and stones if taken with wine. Persian practitioners also considered the seeds as an aphrodisiac, galactagogue and diuretic agent [20].

As a cosmetic agent, local administration of Ajwain as a paint results in yellowish complexion on the skin. It was also incorporated in medicine prepared for pityriasis and leukoderma and plastered with honey in cases of all types of ecchymosis [19, 20]. Persian practitioners also used the seeds in the form of fumigation for the female genital disorders. In the field of toxicology, it was reported that bathing the affected part with the decoction of Ajwain seeds alleviates the pain caused by scorpion's bite [19]. Also it was used for the reduction of undesired effects related to the opioid withdrawal. Ajwain was also introduced as a potent analgesic and anti-inflammatory agent. Therefore it was applied on the affected area solely of in combination with egg white or honey. Persian practitioners used Ajwain in chronic fevers and gripes [20, 21].

Hydrosol and oil extracted from the seeds of Ajwain was also used for medical purposes. Of those, management of paralysis, palsy, tremor and neurological disorders such as neuropathic pain as well as chronic pains are cited in Persian medical and pharmaceutical manuscripts [20, 22]. The Ajwain hydrosol combining with Borage and Cinnamon was highly recommended as a great enlivening medicine [20, 23].

3. Current Pharmacological Findings

3.1 Analgesic and Antinociceptive Effects

In order to evaluate the analgesic and antinociceptive activity of Ajwain, an *In vivo* investigation was carried out using a Tail-flick Analgesiometer Device [24]. The study revealed that the ethanolic extract significantly increase in Tail-Flick Latency (TFL) within 2 hours post-drug administration. An experimental trial study has also been carried out to compare the antinociceptive effect of the hydroalcoholic extract of Ajwain with morphine sulphate using formalin test. Findings revealed that Ajwain extract exhibited antinociceptive effect on both early and late phases [25]. Similar study has been done on the Ajwain total essential oil which was significantly effective on the late phase of formalin test [26] and it may be due to the presence of thymol in essential oil.

In addition, under a randomized controlled placebo control clinical trial, the herb essential oil was assayed for the analgesic effect in neuropathic feet burn. Results revealed that Ajwain essential oil significantly reduced the feet burn compared to placebo [27].

3.2 Antibacterial and Antifungal Activities

To assay the antibacterial efficacy of Ajwain, acetone and aqueous extracts were tested against *Enterococcus faecalis*, *Escherichia coli*, *Klebsiella pneumonia*, *Pseudomonas aeruginosa*, *Salmonella typhi*, *Salmonella typhimurium*, *Shigella flexneri*, and *Staphylococcus aureus* using agar diffusion assay [28]. The study showed that acetone extract shows more activity compared to the aqueous extract. In another study, ethanolic extract of Ajwain possessed antibacterial activity against eight strains of *Helicobacter pylori* [29]. Also methanolic extract of Ajwain exhibited bactericidal activity against 11 species at 2mg/well in agar well-diffusion method. It was measured by Diameter of Inhibition Zones (DIZ). DIZ was over 15mm against *Staphylococcus aureus* and *Staphylococcus epidermidis*; 10–14 mm against *Pseudomonas aeruginosa* and *Bacillus pumilus*; 7–9 mm against *Escherichia coli*, *Klebsiella pneumonia* as well as *Bordetella bronchiseptica*. On the other hand, no activity was reported against *Pseudomonas fluorescens* and *Micrococcus luteus* [30]. As Ajwain may have large amounts of Thymol or Carvacrol in its total essential oil, mentioned phenolic compounds are reported to be either bactericidal or bacteriostatic agents depending on the concentration [31].

In order to assess the antifungal activity of Ajwain, total essential oil extracted from seeds was subjected for fungicidal effect and showed proper effect on *Aspergillus niger* and *Curvularia ovoidea* at 5000 ppm as minimum inhibitory concentration [32].

3.3 Insecticidal Assessment

It is reported that the essential oil extracted from the seeds of Ajwain can exhibit insecticidal activity in the oviposition step as well as egg hatching and developmental inhibitory activities against *Callosobruchus chinensis* [33, 34].

3.4 Anthelmintic Activity

Antifilarial activity assessment of the Ajwain methanolic extract was done as an *in vitro* assay against adult bovine

filarial *Setaria digitata* worms. In that investigation, a bioassay-guided fractionation was prepared by introducing the crude extract to flash chromatography. HPLC analysis was done for both crude extract and active fraction [35]. Active fraction and also crude extract exhibited significant activity against adult *S. digitata* by both worm motility and MTT [3-(4, 5-dimethylthiazol-2-yl)-2, 5-diphenyltetrazolium bromide] reduction assays. The isolated active principle which was identified as a phenolic monoterpene was structurally characterized by IR, H-NMR and MS analysis. The compound was then evaluated for in vivo antifilarial activity against the human filarial worm *Brugia malayi*. Results revealed *in vivo* macrofilaricidal activity and female worm sterility against *B. malayi* [35].

Antihelmintic activity of Ajwain was carried out by considering the *Haemonchus contortus* in sheep and *Ascaris lumbricoides* in humans. Results were due to loss of energy reserves by interference with the energy metabolism of parasites through potentiating the ATPase activity. Ajwain has also been reported to exhibit cholinergic activity with peristaltic movements of gut. Hence this fact may help in expulsion of intestinal parasites and be a contributory factor to its anthelmintic activity [36, 37].

Ajwain was also evaluated for its nematicidal activity. A survey was done on the total essential oil components of Ajwain that showed significant nematicidal activity against pinewood nematode, *Bursaphelenchus xylophilus*. Nematicidal activity of Ajwain essential oils LC_{50} values was measured as 0.431mg/ml [38] and it was mainly attributed to the activity of Thymol and Carvacrol [39].

3.5 Antiplatelet Activity

Antiplatelet activity has been done on the dried ethereal extract of Ajwain. Therefore, in an *in vitro* study with human blood samples, Ajwain seeds inhibited the platelet aggregation induced by arachidonic acid, collagen and epinephrine [40].

3.6 Anti-inflammatory Effects

Ajwain was also evaluated for exhibiting anti–inflammatory effect. Accordingly, both total alcoholic extract and total aqueous extract possess *in vivo* significant anti–inflammatory effect [41].

3.7 Antitussive and Bronchodilatory Effects

Antitussive effect of Ajwain has been reported in traditional medical manuscripts. In this regard, in a study the mentioned clinical effect of aerosols related to two different concentrations of aqueous and macerated extracts of Ajwain seeds as well as Carvacrol, codeine, and saline were evaluated by counting the number of coughs produced. According to the results, both concentrations of Ajwain seeds revealed significant reduction of cough number which may be a result of its potent antitussive effect [42]. Relative studies showed the inhibitory effect of both Ajwain extract and essential oil on Histamine (H1) receptors of isolated guinea-pig tracheal chains [43]. In another study, in the field of respiratory, bronchodilatory effects of different fractions of Ajwain essential were examined. Results showed that the relaxant and bronchodilatory effect of essential oil fractions may be due to the amount of Carvacrol [44]. The bronchodilatory effect of decocted extract of Ajwain on the asthmatic patients' airways was examined in a subsequent trial study. According to the results, the extract has a relatively bronchodilatory effect on asthmatic airways compared to the effect of Theophylline at concentrations used [45].

3.8 Diuretic and Anti-lithiasis Activity

Ajwain was attributed to have diuretic and anti-lithiasis activity in ethnopharmacological reports. Accordingly, a human study was performed and in which, seeds of Ajwain were decocted in milk and given orally to volunteers suffering from urinary stone for a nine days period. The results were reported satisfactory against pure ca-oxalate stone [46].

3.9 Antihyperlipidemic Properties

Another activity which has been proved for Ajwain is the antihyperlipidemic property. An *in vivo* study revealed that Ajwain seeds powder is extensively effective on lipid profile and can decrease total cholesterol, LDL-cholesterol, triglycerides and total lipids. Moreover, organic extract of seeds reduced atherogenic index and increased the level of HDL-cholesterol in albino rabbits [47].

3.10 Detoxification Activity

Detoxification of aflatoxins by seed extract of Ajwain can support the related traditional reports. Hence in an

experimental study, Ajwain seed extract exhibited the maximum degradation of aflatoxin G1 [48].

3.11 Antioxidant Properties

The antioxidant and ameliorative property of Ajwain extract has been evaluated on hexachlorocyclohexane induced oxidative stress and toxicity in an *in vivo* investigation. Accordingly, results revealed that the dietary Ajwain extract would reduce the toxicity resulted from hepatic free radical stress [49].

3.12 Antiviral Effects

For the evaluation of Ajwain antiviral activity, an *in vitro* assay was carried out on the methanolic extract of the herb which showed significant inhibitory effects on Hepatitis C Virus (HCV) protease [50].

3.13 Spermicidal Activity

Spermicidal activities of Ajwain essential oil was determined via an *in vitro* study where it was revealed that the volatile oil possessed potent spermicidal action [51]. Therefore, the oil may be considered as a natural contraceptive agent.

3.14 Hepatoprotective Effects

Along with the potent antioxidant activity, the Ajwain methanolic extract revealed to exhibit *in vivo* hepatoprotective activity with eighty percent protection against a normally-lethal dose of paracetamol in mice. The extract also possessed preventive effects against CCl_4-induced prolongation of pentobarbital sleeping time as well as equilibrating the level of hepatic enzymes, Alkaline Phosphatase (ALP) and Aminotransferases (AST and ALT) during liver damage [52].

3.15 Antiulcer Activity

Using different ulcer models, Ajwain ethanolic extract resulted in significant ulcer index decrease in animal pre-treated with and also exhibited ulcer protection in all models. Overall, the extract reduced the ulcerative lesions compared to control group of animal model [53].

3.16 Antihypertensive and Antispasmodic Activity

Ajwain was evaluated for the potentiality of antihypertensive and antispasmodic activity. In the related investigation, the aqueous-methanolic extract of the seeds caused a dose dependent decrease in arterial blood pressure in anaesthetized animal models. Furthermore, inhibitory effect on the K^+-induced contractions was seen in isolated rabbit aorta and jejunum preparations during the application of Ajwain extract. These findings prove the potential antihypertensive and antispasmodic activity of Ajwain [52].

3.17 Digestive Stimulant Activity

Traditional practitioners recommended the herb as a digestive stimulant medicine [20]. It is now proved that Ajwain can increase the secretion of gastric acid, bile acids and activity of digestive enzymes. It may also reduce the food transient time [54, 55]. As the enzyme modulatory activity, Ajwain reinforced the pancreatic lipase and amylase effectiveness, which may support the digestive stimulant activity [56].

3.18 Estrogenic Activity

The total phytoestrogen content of dry Ajwain seed was determined as 473 ppm. In this regard, the herb is the second highest in the list of plants tested for total phytoestrogen content [57]. It should be noted that the herb has been traditionally used as a galactagogue [20].

3.19 Toxicity and Tratogenicity

It was reported that Ajwain showed teratogenicity in rat fetuses. Therefore it may be harmful to be intake during pregnancy [58].

4. Conclusion

With reference to the mentioned pharmacological activities, Ajwain seeds can be used for clinical applications. However, in spite of various experimental and animal studies, lack of comprehensive clinical trials aimed on regarded effects still remains to reconfirm the traditional knowledge.

References

1. Gersbach PV, Reddy N. Non-invasive localization of thymol accumulation in *Carum copticum* (Apiaceae) fruits by chemical shift selective magnetic resonance imaging. Ann Bot. 2002; 90(2):253–57.

2. Joshi S. Medicinal plants. 1st ed. Delhi: Oxford and IBH Publisher; 2000.
3. Chatterjee ASC. The treatise of Indian medicinal plants. 2nd ed. New Delhi: Publication and Information Directorate CSIR; 1995.
4. Shojaaddini M, Moharramipour S, Sahaf B. Fumigant toxicity of essential oil from Carum copticum against Indian meal moth, *Plodia interpunctella*. J Plant Prot Res. 2008; 48(4):411–19.
5. Chauhan B, Kumar G, Ali M. A Review on phytochemical constituents and activities of *Trachyspermum ammi* (L.) sprague fruits. AJPTR. 2012; 2(4):329–40.
6. Ranjan B, Manmohan S, Singh SR, Singh RB. Medicinal uses of *Trachyspermum ammi*: a review. Pharmacogn Rev. 2012; 6(11): 56–60.
7. Qureshi AA, Kumar KE. Phytochemical constituents and pharmacological activities of *Trachyspermum ammi*. Plant Archives. 2010; 10(2):955–59.
8. Duke J. Handbook of phytochemical constituents of GRAS herbs and other economic plants. 1st ed. Boca Raton: CRC Press; 1992.
9. Minija J, Thoppil JE. Essential oil composition of trachyspermum ammi (l.) sprague from South India. Indian J Pharmaceut Sci. 2002; 64(3):250–51.
10. Balbaa SI, Hilal SH, Haggag MY. The volatile oil from the herb and fruits of *Carum copticum* at different stages of growth. Planta Med. 1973; 23(4):312–20.
11. Ishikawa T, Sega Y, Kitajima J. Water-soluble constituents of Ajowan. Chem Pharmaceut Bull. 2001; 49(7):840–44.
12. Zarshenas MM, Petramfar P, Semani SM, Moein M. Analysis of the essential oil components from different *Carum copticum* L. samples from Iran. Pharmacognosy Res. 2014. [Ahead of Print].
13. Mohagheghzadeh A, Faridi P, Ghasemi Y. *Carum copticum* Benth. & Hook., essential oil chemotypes. Food Chem. 2007; 100(3):1217–19. doi:10.1016/j.foodchem.2005.12.002
14. Choudhury S, Ahmed R, Kanjilal PB, Leclercq PA. Composition of the seed oil of *Trachyspermum ammi* (L.) Sprague from Northeast India. J Essent Oil Res: JEOR. 1998; 10(5):588–90.
15. Gang SK, Sharma ND, Gupta SR. A phenolic glucoside from the seeds of *Carum copticum*. Phytochemistry 1980; 9(10):2215–16.
16. Garg S. A new glucoside from *Trachyspermum ammi*. Fitoterapia. 1998; 69(6):511–12.
17. González AG, Barrera BJ, Diaz JG, López AL, De Paz PP. Distribution of secondary metabolites in two subspecies of *Todaroa aurea*. Biochem Systemat Ecol. 1988; 16 (7–8):641–45.
18. Lateef M, Iqbal Z, Akhtar MS, Jabbar A, Khan MN, Gilani AH. Preliminary screening of *Trachyspermum ammi* (L.) seed for anthelmintic activity in sheep. Trop Anim Health Prod. 2006; 38(6):491–96.
19. Avicenna. Al Qanun Fil Tibb [Hameed HA trans]. 1st ed. New Delhi: Jamia Hamdard Printing Press; (1998).
20. Aghili-Shirazi S. Makhzan ol Advieh. 1st ed. Tehran: Intisharat va Amoozesh enghelab Islami Press; 1992.
21. Tonekaboni H. Tohfat ol momenin. 1st ed. Tehran: Nashre shahr Press; 2007.
22. Heravi MG. Qarabadin-e-salehi. 1st ed. Tehran: Dar-ol-khalafeh; 1765.
23. Shirazi SA. Qarabadin-e-Kabir. 1st ed. Tehran: Ostad Allah Qoli khan Qajar; 1855.
24. Dashti-Rahmatabadi MH, Hejazian SH, Morshedi A, Rafati A. The analgesic effect of *Carum copticum* extract and morphine on phasic pain in mice. J Ethnopharmacol. 2007; 109(2):226–28. [Epub 2006 Aug 1].
25. Hejazian SH, Mosaddegh MH, Dashti Rahmatabadi HM. Antinociceptive effects of *Carum copticum* extract in mice using formalin test. World Appl Sci J. 2008; 3(2):215–19.
26. Hejazian S. Analgesic effect of Essential Oil (EO) from *Carum Copticum* in mice. World Appl Sci J. 2006; 1(2):95–99.
27. Petramfar P, Moein M, Semani S, Zarshenas MM. Ajwain 10% o/w cream versus placebo in feet burning; a randomized, double-blind, placebo-controlled trial. Iranian Journal of Neurology. 2013; 12(1):61.
28. Kaur GJ, Arora DS. In vitro antibacterial activity of three plants belonging to the family Umbelliferae. Int J Antimicrob Agents. 2008; 31(4):393–95. [Epub 2008 Jan 10]
29. Zaidi SF, Yamada K, Kadowaki M, Usmanghani K, Sugiyama T. Bactericidal activity of medicinal plants, employed for the treatment of gastrointestinal ailments, against *Helicobacter pylori*. J Ethnopharmacol. 2009; 121(2):286–91. [Epub 2008 Nov 8]
30. Shahidi B. Evaluation of antibacterial properties of some medicinal plants used in Iran. J Ethnopharmacol. 2004; 94(2–3):301–05.
31. Caccioni DR, Guizzardi M, Biondi DM, Renda A, Ruberto G. Relationship between volatile components of citrus fruit essential oils and antimicrobial action on *Penicillium digitatum* and *Penicillium italicum*. Int J Food Microbiol. 1998; 43(1–2):73–79.

32. Dwivedi SK, Singh KP. Fungitoxicity of some higher plant products against *Macrophomina phaseolina* (Tassi) Goid. Flavour and Fragrance Journal. 1998; 13(6): 397–99.
33. Chaubey MK. Fumigant toxicity of essential oils from some common spices against pulse beetle, *Callosobruchus chinensis* (Coleoptera: Bruchidae). J Oleo Sci. 2008; 57(3):171–79.
34. Kostyukovsky M, Rafaeli A, Gileadi C, Demchenko N, Shaaya E. Activation of octopaminergic receptors by essential oil constituents isolated from aromatic plants: possible mode of action against insect pests. Pest Manag Sci. 2002; 58(11):1101–06.
35. Mathew N, Misra-Bhattacharya S, Perumal V, Muthuswamy K. Antifilarial lead molecules isolated from *Trachyspermum ammi*. Molecules. 2008; 13(9): 2156–68.
36. Tamura T, Iwamoto H. Thymol: a classical small-molecule compound that has a dual effect (potentiating and inhibitory) on myosin. Biochem Biophys Res Commun. 2004; 318(3):786–91.
37. Jabbar A, Khan M, Iqbal Z. In vitro anthelmintic activity of *Trachyspermum ammi* seeds. Phcog Mag. 2006; 2(6):126–29.
38. Park IK, Kim J, Lee SG, Shin SC. Nematicidal activity of plant essential oils and components from Ajowan (*Trachyspermum ammi*), Allspice (*Pimenta dioica*) and Litsea (*Litsea cubeba*) essential oils against pine wood nematode (*Bursaphelenchus Xylophilus*). J Nematol. 2007; 39(3):275–79.
39. Wright DJ. Nematicides: mode of action and new approaches to chemical control. New York: Zukerman & Rhode Publisher; 1981.
40. Srivastava KC. Extract of a spice–omum (*Trachyspermum ammi*) shows antiaggregatory effects and alters arachidonic acid metabolism in human platelets. Prostaglandins Leukot Essent Fatty Acids. 1988; 33(1):1–6.
41. Thangam C, Dhananjayan R. Anti-inflammatory potential of the seeds of *Carum Copticum* Linn. Indian J Pharmacol. 2003 Nov 1; 35(6):388–91.
42. Boskabady MH, Jandaghi P, Kiani S, Hasanzadeh L. Antitussive effect of *Carum copticum* in guinea pigs. J Ethnopharmacol. 2005; 97(1):79–82. doi:10.1016/j.jep.2004.10.016
43. Boskabady MH, Shaikhi J. Inhibitory effect of *Carum copticum* on Histamine (H1) receptors of isolated guinea-pig tracheal chains. J Ethnopharmacol. 2000; 69(3):217–27. doi:10.1016/S0378-8741(99)00116-6
44. Boskabady MH, Ramazani M, Tabei T. Relaxant effects of different fractions of essential oil from *Carum copticum* on guinea pig tracheal chains. Phytother Res. 2003; 17(10):1145–49.
45. Boskabady MH, Alizadeh M, Jahanbin B. Bronchodilatory effect of *Carum copticum* in airways of asthmatic patients. Therapie. 2007; 62(1):23–29. [Epub 2007 Mar 21]
46. Sabar AG. Lithotripsy of different urinary tract stones by using seeds of *Carum copticum*. Iraqi Journal of Pharmaceutical Sciences. 2010; 19(2):38–41.
47. Javed I, Iqbal Z, Rahman ZU, Khan FH, Muhammad F, Aslam B, et al. Comparative anti-hyperlipidaemic efficacy of *Trachyspermum ammi* extracts in albino rabbits. Pakistan Vet J. 2006; 26(1):23–29.
48. Velazhahan R, Vijayanandraj S, Vijayasamundeeswari A, Paranidharan V, Samiyappan R, Iwamoto T, et al. Detoxification of aflatoxins by seed extracts of the medicinal plant, *Trachyspermum ammi* (L.) Sprague ex Turrill – structural analysis and biological toxicity of degradation product of aflatoxin G1. Food Contr. 2010; 21(5):719–25. doi:10.1016/j.foodcont.2009.10.014
49. Anilakumar KR, Saritha V, Khanum F, Bawa AS. Ameliorative effect of Ajwain extract on hexachlorocyclohexane-induced lipid peroxidation in rat liver. Food Chem Toxicol. 2009; 47(2):279–82. doi:10.1016/j.fct.2008.09.061
50. Hussein G, Miyashiro H, Nakamura N, Hattori M, Kakiuchi N, Shimotohno K. Inhibitory effects of Sudanese medicinal plant extracts on Hepatitis C Virus (HCV) protease. Phytother Res. 2000; 14(7):510–16.
51. Buch JG, Dikshit RK, Mansuri SM. Effect of certain volatile oils on ejaculated human spermatozoa. Indian J Med Res. 1988 Apr; 87:361–63.
52. Gilani AH, Jabeen Q, Ghayur MN, Janbaz KH, Akhtar MS. Studies on the antihypertensive, antispasmodic, bronchodilator and hepatoprotective activities of the Carum copticum seed extract. J Ethnopharmacol. 2005; 98(1–2):127–35.
53. Ramaswamy S, Sengottuvelu S, Haja Sherief S, Jaikumar S, Saravanan R, Prasadkumar C, et al. Gastroprotective activity of ethanolic extract of *Trachyspermum Ammi* Fruit. International Journal of Pharma and BioSciences. 2010; 1(1):1–15.
54. Vasudevan K, Vembar S, Veeraraghavan K, Haranath PS. Influence of intragastric perfusion of aqueous spice extracts on acid secretion in anesthetized albino rats. Indian J Gastroenterol. 2000; 19(2):53–56.

55. Platel K, Srinivasan K. Studies on the influence of dietary spices on food transit time in experimental rats. Nutr Res. 2001; 21(9):1309–14.

56. Ramakrishna Rao R, Platel K, Srinivasan K. In vitro influence of spices and spice-active principles on digestive enzymes of rat pancreas and small intestine. Nahrung. 2003; 47(6):408–12.

57. Harjit K. Estrogenic activity of some herbal galactogogue constituents. Indian J Anim Nutr. 1998; 15(3): 232–34.

58. Nath D, Sethi N, Srivastava S, Jain AK, Srivastava R. Survey on indigenous medicinal plants used for abortion in some districts of Uttar Pradesh. Fitoterapia. 1997; 68(3):223–25.