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Bunium persicum (Boiss.) B. Fedtsch: An overview on Phytochemistry, Therapeutic uses and its application in the food industry

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ABSTRACT

Bunium persicum (*Boiss.*) *B. Fedtsch* as a plant of the Apiaceae family grows in different regions of Asia such as Central Asia, Iran, Pakistan, Afghanistan, and India. This plant has significant medicinal, antimicrobial and antioxidant properties which indicate its high potential for use in the medicine and food industry. In traditional medicine, it is used to treat or improve some cases such as digestive and urinary disorders, diabetes, obesity and increasing breast milk. A comprehensive literature review was conducted by searching studies in all relevant authentic scientific databases. Databases were searched for the terms *Bunium persicu*, *Cuminum cyminum*, Black zire, black caraway, Carum carvi, Persian Cumin, Zire kuhi, Shah zira, Kala Zeera, Jira, Wild caraway and wild cumin without limitation up to 10 November 2017. According to researches, this plant and its derivatives are valuable compounds that have antimicrobial, antioxidant, anti-inflammatory, anti-diabetes, antihyperlipid and analgesic properties. *Bunium persicum* essential oil contains high levels of oxygenated monoterpenes, especially γ-Terpinene, cuminaldehyde, ρ-cymene and limonene, which has high antimicrobial and antioxidant effects. Due to the fact that *Bunium persicum* is widely used in people's diet as a flavoring agent, there is no major concern about the toxic effects of this plant.

INTRODUCTION

Bunium persicum (*Boiss.*) B. Fedtsch is a plant of Apiaceae family called wild caraway. It is a perennial aromatic plant with small white or pink flowers and small brown beans growing wild in areas with Mediterranean climate such as central and western Asia including Iran, Turkey, Syria, Pakistan, Tajikistan, Afghanistan, North India (Kashmir and Pamir), China, some parts of Europe, Northern Africa and South America (Aminzare *et al.*, 2017a; Miraj and Kiani, 2016; Salehi *et al.*, 2008). This plant is called with different names throughout the world as "Great pignut", "Black zire"," Black caraway", "Carum carvi", "Persian Cumin", "Zire kuhi", " Shah zira "," Kala Zeera", "Jira", "Wild caraway" and "wild cumin". *B. Persicum* (BP) has small (30 cm) to tall (80 cm) varieties which squeezed or expanded with large or small branches (Figure 1a) (Mandegari *et al.*, 2012; Sofi *et al.*, 2009). Seeds of the plant are brown or dark brown called *Zireh kuhi* in Iran meaning wild cumin (Figure 1b) (Iacobellis *et al.*, 2005). 1000 seeds of this plant weigh about 2 grams (Sofi *et al.*, 2009). Phytochemical profile of *Bunium persicum* (Boiss.) B. Fedtsch has shown flavonoids, phenolic acids, and aldehydes as well as a high content of mono-terpenes and sesquiterpenes contained in the essential oil and extracts of this plant (Chizzola *et al.*, 2014).

In recent years, application of natural compounds particularly medicinal plants has increased in food due to their potential to increase the food safety and shelf life (Iacobellis *et al.*, 2005). *B. persicum* (BP) is used for culinary intentions as a spice and flavoring agent in foods and beverages such as bread cooking, rice, yoghurt, cheese and in confectionery products. It has a strong earthy aroma is sharpened by frying and cooking it (Aminzare *et al.*, 2017a; Sharififar *et al.*, 2010; Sofi *et al.*, 2009). This plant is also used in the perfume and cosmetics (Salehi *et al.*, 2008).

There are several reports of therapeutic and functional properties of this plant. Seeds of this plant are mainly considered

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as a carminative and as well as an astringent for treating diarrhea (Sofi *et al.*, 2009). Several therapeutic effects are explained for this plant in traditional and modern medicine. *B. persicum* is used for treating gastrointestinal and urinary disorders such as stomatitis stimulant, flatulent indigestion, dyspeptic headache, relieve of heartburn, colic, and diarrhea as well as dyspepsia, hysteria and for improving liver function and obesity. It is used as an anticonvulsant, anti-diabetic, anti-asthma, antispasmodic, antiepileptic, anti-obstruction, diuretic and flow increaser of breast milk (Miraj and Kiani, 2016). It also exhibits good anti-inflammatory activity and anti-oxidative, free radicals scavenging, antimicrobial and anti-parasitic effects have been reported for this plant (Agah *et al.*, 2013; Mandegary *et al.*, 2012). This study was conducted to review and explain the biological and medicinal properties of BP and its effects on food preservation.

Fig. 1: *Bunium persicum* (Boiss.) B.Fedtsch plant (a) (Mandegari *et al.*, 2012) and seeds (b). (Seeds were collected after flowers blooming and browning of seeds indicates maturation).

MATERIAL AND METHODS

A comprehensive literature review was conducted to provide an in-depth insight into the medicinal plant BP and its related subspecies. All relevant authentic scientific databases including Science Direct, Wiley-Blackwell, Springer, Google Scholar, Scopus, PubMed and Scientific Information Database were searched for the terms "*Bunium persicum*", "*Cuminum cyminum*", ''Black zire'','' black caraway", ''*Carum carvi*'', ''Persian Cumin'', "Zire kuhi", " Shah zira "," Kala Zeera", "Jira", "Wild caraway" and "wild cumin" since last 20 years up to 10 November 2017. 6. Given to keywords, Totally 115 relative papers were obtained during 20 years period until Nov. 2017 which assessed the therapeutic effects of *B. persicum* and its application in the food industry.

RESULT AND DISCUSSION

Phytochemistry

Chemical compositions of the BP extract or essential oil are reported in several studies which have shown in Table 1. *B. persicum* essential oil (BPEO) or extract is recognized as a rich compound with a high amount of hydrocarbons and oxygenated monoterpenes in its composition (Ahmed, Soule *et al.*, 2000). According to the GC-MS data, the major volatiles constituents remained similar in different varieties of a plant from different sites, but their relative quantities differed among plants from different regions. Cuminaldehyde, γ-Terpinene, limonene, Carvone, ρ-cymene, and β-Pinene are the main constituents in the chemical composition of BP. Many factors can affect the characteristics and chemical composition of the extracts or EOs of plants including genetic diversity, ecotypes of plants, varieties of plants, application of fertilizers, geographical location, environment, seasonal changes, stress during growth, maturation, drying and post-harvesting conditions. In addition, different parts of the aromatic plant, a method of extracting and chemical compositions of them can also be effective on their biological properties (Raut and Karuppayil, 2014).

Other compounds

B. persicum also contains other compounds belonging to different classes of natural products such as Caryophyllene, β-Pinene, Eugenol, carvacrol , Safrole , 1,8-Cineole, S-3-Carene, cuminyl acetate, pinocarvyl acetate, α-methyl-benzene methanol, croweacin, Bornyl acetate, p-mentha-l,3-dien-7-al, p-mentha-l, 4-dien-7-al and p-menth-3-en-7-al, Sabinene, Myrcene, Caranone, α-Thujene, Camphene and Terpinolene. (Chizzola *et al.*, 2014; Shahsavari *et al.*, 2008; Thappa *et al.*, 1991).

Therapeutic uses

Several therapeutic effects have been reported in traditional medicine through the world including treatment of gastrointestinal disorders, urinary tract disorders and use as a diuretic, gynecologic, anticonvulsants, anti-helmentic, anti-asthma and dyspnea (Boskabady and Moghaddas, 2004) (Table 2). Also, the seeds of this plant have antispasmodic, carminative, emmenagogue, expectorant, galactagogue, stimulant, stomachic and tonic properties and are useful in diarrhea and dyspepsia (de Carvalho and da Fonseca, 2006; Pourmortazavi *et al.*, 2005).

Various studies showed that the aqueous extract and essential oil of caraway had anticonvulsant properties. This anticonvulsant activity may be due to the monoterpenic compounds present in the EOs (Mandegary *et al.*, 2012). However, the essential oil was more potent and effective than the aqueous extract as an anticonvulsant. Additionally, the anticonvulsant effect of caraway

was not due to a muscle relaxant activity. These findings support the acclaimed antiepileptic effect of caraway in folk medicine and propose its potential use in petit mal seizure in humans (Showraki *et al.*, 2016). In another study to investigate the effects of essential oil and methanolic extracts of cumin as an anticonvulsant, the results showed that the essential oil of this plant is effective to control severe seizures in the body (Mandegary *et al.*, 2012). Diuretic and antifertility activities of this plant in rats have also been reported (Thakur *et al.*, 2009). BPEO profoundly alters gastrointestinal smooth muscle contraction in a dose-dependent and tissue-specific manner (Jalilzadeh *et al.*, 2011) Anti-ulcerative and anti-diarrheal properties of essential oil of this plant on rat have been reported by Jalilzadeh and colleges (Jalilzadeh *et al.*, 2014; Jalilzadeh *et al.*, 2014).

Table 1: The main components of different ecotypes of *Bunium persicum* (*Boiss.*) *FEDTCH* essential oil.

(a)

Main components	Part of plant (Extract or EO)	Part of plant	Origins of plant	References
Cuminaldehyde (27.8%), γ-terpinene (23%), c-Terpinen-7-al(19.2%), p-Cymene(13.5%), limonene (5.8%)	EO	fruit	Iran	(Chizzola *et al.*, 2014)
Carvone (23.3%), limonene (18.2%), germacrene D (16.2%), trans-dihydrocarvone (14.0%), carvacrol (6.7%)	EO	fruit	Italy	(Iacobellis *et al.*, 2005)
γ-terpinene (46.1%), cuminaldehyde (15%), ρ-cymene (6.7%), limonene (5.9%), α-Pinene(2.7%)	EO	seed	Kerman, Iran	(Kareshk *et al.*, 2015)
Carvone (78.8%), limonene (10.1%), cis-limonene oxide (1.8%), trans-carveol (1.3%), menthone (1.2%)	EO	fruit	Serbia	(Samojlik *et al.*, 2010)
γ-terpinene (44.2%), p-Cuminaldehyde (16.9%), γ-Terpinen-7-al (10.5%) p-cymene (8%), Bornyl acetate (2.9%)	EO	seed	Mashhad, Iran	(Oroojalian *et al.*, 2010)
Cuminaldehyde (11.4%), γ-terpinene (11.37%), α-Pinene (11.27%), α-Terpinene (11.13%), S-3-Carene (5.74%)	EO	seed	Kerman, iran	(Ehsani *et al.*, 2016)
Cuminaldehyde (22.37%), γ-terpinene (19.36%), γ-terpinene-7-al (11.85%), α-terpinene (7.3%), ρ-cymene (6.56%)	EO	seed	Iran	(Rabiey *et al.*, 2013)
Cuminaldehyde (22.08%), γ-terpinene (17.86%), γ-terpinene-7-al (15.41%), p-cymene (7.99%), β-Pinene (4.68%)	EO	seed	Iran	(Razzaghi-Abyaneh *et al.*, 2009)
Cuminaldehyde (23.04 %), γ-terpinene (14.48%), Trans-3-Caren-2-ol (12.51%), Acetic acid, 3-cyclohex-1-enyl-1-methylprop-2-ynyl ester (10.9%), Terpinolene (8.27%)	EO	seed	Iran	(Jalilzadeh *et al.*, 2011)
γ-terpinene (44.2%), cuminaldehyde (16.9%), ρ-cymene (8%), Bornyl acetate (2.9%), 1,8-Cineole (2.9%)	EO	seed	Mashhad, Iran	(Jamshidi *et al.*, 2014)
γ-terpinene (21.86%), cuminaldehyde (17.28%), ρ-cymene (6.21%), acetylphenylcarbinol (5.83%), 1-limonene (2.47%)	EO	seed	Yazd, Iran	(Haghirogsa-dat *et al.*, 2010)

(b)

Main components	Part of plant (Extract or EO)	Part of plant	Origins of plant	References
Trans-anethole (93.9%), limonene (1.05%) and estragole (1.05%), Linalool (0.29%), 3-Carene (0.15%)	Ethanol/water, extract	Seed	India	(Padmashree *et al.*, 2007)
γ-terpinene (46.1%), cuminal (23.9%), p-cymene (15.9%), limonene (4.7%), 1,4-p-menthadien-7-al (4.5%)	EO, hydroalcoholic and polyphenolic extracts	Seed	Isfahan, Iran	(Hajhashemi *et al.*, 2011)
γ-Terpinene (14.4%), Limonene (4.42%), p-Cymene (4.31%), β-Pinene (2.94%), α-Pinene (2.37%)	Headspace vapor sample	Heads-pace	Iran	(Sekine *et al.*, 2007)
Γ-Terpinene (45.7%), Cuminaldehyde (12.7%), Limonene (10.6%), Cuminyl alcohol (6.4%), p-Cymene (5.6%)	Supercritical fluid extraction	seed	Mazandaran, Iran	(Pourmortaza-vi *et al.*, 2005)
Cuminaldehyde (22.34%), carvacrol (19.88%), anisole (15.19%), o-Cymene (12.04%), γ-Terpinene (9.77%), α-Propylbenzyl alcohol (8.99%), β-Pinene (2.34%), D-Limonene (2.14%)	EO	seed	Iran	(Aminzare *et al.*, 2017)
γ-Terpinene (46.1%), cuminaldehyde (15.5%), ρ-cymene (6.7%), limonene(5.9%), β-Pinene (2.5%)	EO	seed	Kerman, Iran	(Sharififar *et al.*, 2010)
Caryophyllene (27.81%), γ-terpinene (15.19%), cuminyl acetate (14.67%), cuminaldehyde (5.96%), p-cymene (5.25%)	EO	seed	Iran	(Shahsavari *et al.*, 2008)
Limonene (48.4%), carvone (31.1%), apiole (12.3%), Anethole (2.7%), cis-Dihydrocarvone (2%)	EO	seed	China	(Jiang *et al.*, 2011)
Carvone (46.62%), limonene (45.49%), Safrole (1.44%), cis-Dihydrocarvone (1.01%), Eugenol (0.66%)	EO	fruits	Serbia	(Simic *et al.*, 2008)
ρ-cymene (25.7%), γ-terpinene (23.9%), cuminaldehyde (22.6%), p-Mentha-l'3-dien-7-al and p-Mentha-1,4-dien-7-al (21.9%), β-Pinene (0.5%)	EO	seed	india	(Thappa *et al.*, 1991)

Table 2: Pharmacological and clinical studies of *Bunium persicum* (*Boiss.*) FEDTCH.

Reported activity	Type of preparation	Main finding	References
Diuretic activity	Aqueous extracts	The oral administration showed Diuretic activity in normal rats	(Lahlou *et al.*, 2007)
Antioxidant	EO	Elevated antioxidant properties (Plasma) total antioxidants, conjugated diene, lipid hydroperoxide and MDA content were diminished significantly by the treatment of Boerhaavia diffusa and Black Caraway Oil in respect to the infected group. In addition, daily use of dietary *B. diffusa* and Black Caraway oil will be efficacious, cost-effective, no side effects and a good source of antihypercholesterolemic, hypolipidemic/antiatherogenicantioxidant actions and anticarcinogenic.	(Khan *et al.*, 2012)
Apoptotic activities on human leukaemia cell lines	Ethanol extract	C. carvi had no apoptotic effect on human leukemia cell lines.	(Bogucka-Kocka *et al.*, 2008)
Anti breast Cancer	Thymoquinone, A Bioactive Component of Black Caraway Seeds	Thymoquinone could be useful in the management of Triple-negative breast cancers, even when functional p53 is absent	(Sutton *et al.*, 2014)
Bronchodilatory and anticholinergic effects	Aqueous extract , macerated extract, EO	It indicated that the bronchodilatory effect of *Carum carvi* is mainly due to the non-competitive antagonistic property on muscarinic receptors and The stimulatory effect and/or anti-histaminic effect of EO might be contributed to its non-competitive property	(Boskabady and Talebi, 1999)
Antinociceptive and anti-inflammatory	EO, hydroalcoholic extract and polyphenolic extract	Results showed the analgesic and anti-inflammatory effects of the plant fruits (IP injection in mice).	(Hajhashemi *et al.*, 2011)
Effect on serum lipid profile	Aqueous extract	*B. persicum* extract administration is very useful in improvement of lipid profile in hypercholesterolemic mice.	(Khaksari *et al.*, 2014)
Antihistaminic Effect	Aqueous and macerated extracts, EO	Results indicated a competitive antagonistic effect of *Bunium persicum* at histamine H1 receptors	(Boskabady and Moghaddas, 2004)
Antinociceptive	EO	Essential oil of *B. persicum*, administered i.p in mice (different dose), elicited antinociceptive effects in a dose-dependent manner. BP induced analgesia may be mediated via opioidergic and histamine H1 and H2 receptors.	(Zendehdel *et al.*, 2015)
Hypolipidemic effect	Aqueous extract	Oral administration of *Carum carvi* decrease lipid levels in diet-induced hyperlipidemic rats.	(Saghir *et al.*, 2012)
Anticonvulsant activity	EO, methanolic extract	The essential oil of the plant might be useful to control absence and grand mal seizures at dose 1 mL/kg (treated i.p). This activity might be due to its content of monoterpenes	(Mandegary *et al.*, 2012)
Antifertility	aqueous and ethanolic extract	The blockage of the estrus phase induced by treatment (oral) of an aqueous and ethanolic extract of both drug and showed a significant antifertility activity	(Thakur *et al.*, 2009)
Antidiabetic	EO	Oral administration of black caraway oil significantly lower the serum creatinine levels in the diabetic rats	(Ene *et al.*, 2006)
Antioxidant	EO	The results showed that oral administration of caraway seed oil can be effective in reducing oxidative stress in diabetes mellitus	(Erjaee *et al.*, 2015)
Effect on stomach ulcers	EO	Dietary use od BPEO was safe and protected in doses of 40 and 80 mg/kg body weight, which reduced the gastric ulcer and it was dose-dependent.	(Jalilzadeh *et al.*, 2014)
Inhibitory Effect on Castor-Oil Induced Diarrhea	EO	Results indicated that the plant may contain some biologically active constituents that may reveal antimotility and antidiarrheal effects and support the popular therapeutic use of *B. persicum* in traditional medicine for gastrointestinal disorders	(Jalilzadeh *et al.*, 2014)

Antibacterial properties

Plant-derived compounds especially essential oils (EOs) are well known as antibacterial agents due to their inhibitory properties against a wide range of pathogens, gram-positive and gram-negative bacteria (Raut and Karuppayil, 2014). It is demonstrated that most antibacterial activity of these compounds is related to their phenolic composition (Ghasemlou *et al.*, 2013). Making instability in the cell membrane is the main mechanism of action of these compounds. Due to the fact that EOs are lipophilic compounds, they can easily pass through the walls and membranes. Interactions between EO compounds with polysaccharides, fatty acids and phospholipids increase the permeability of the bacterial membrane and loss of ions and cellular content, resulting in cell death (Edris, 2007). Also, the effects on the activity of the proton pump, reduction of membrane clotting and leakage of cell contents can cause cells death (Di Pasqua *et al.*, 2007; Oussalah *et al.*, 2006). EOs can also cause them to die through denaturation of cytoplasmic proteins and inactivation of cellular enzymes (Gustafson, Liew *et al.*, 1998; Burt 2004).

Table 3: Summary of findings on the anti-bacterial effects of *Bunium persicum* (Boiss.).

Microorganisms	Fraction	MIC	MBC	Disk diffusion (mm)	Reference
S. aureus	EO	0.75 mg/ml	0.75 mg/ml		(Oroojalian *et al.*, 2010)
B. cereus		0.18 mg/ml	0.18 mg/ml		
L. monocytogenes		0.75 mg/ml	0.75 mg/ml		
E. coli O157:H7		1.50 mg/ml	1.50 mg/ml		
S. enteritidis		3.0 mg/ml	3.0 mg/ml		
Bacillus cereus	EO	300 µL/mL	400 µL/mL		(Begum *et al.*, 2008)
Bacillus cereus		200 µL/mL	300 µL/mL		
Bacillus megaterium		200 µL/mL	300 µL/mL		
S. aureus		300 µL/mL	400 µL/mL		
Escheriachia coli		200 µL/mL	300 µL/mL		
Pseudomonas sp		300 µL/mL	400 µL/mL		
Salmonella typhi		200 µL/mL	300 µL/mL		
Salmonella paratyphi		200 µL/mL	300 µL/mL		
Shigella dysenteriae		100 µL/mL	200 µL/mL		
Vibrio cholerae		200 µL/mL	200 µL/mL		
Bacillus cereus	EOs	0.5 µL/mL	—		(Simic *et al.*, 2008)
Escherichia coli		2.0 µL/mL			
Micrococcus luteus		1.0 µL/Ml			
Proteus mirabilis		2.0 µL/mL			
Pseudomonas tolaasii		4.0 µL/mL			
Salmonella enteritidis		0.25 µL/mL			
Staphylococcus aureus		0.1 µL/mL			
E. coli	EOs 80, 160, 240 µg			27, 36, 39 mm	(Thippeswamy *et al.*, 2013)
B. cereus				26, 31, 41 mm	
S. aureus				22, 36, 41 mm	
S. typhimurium				28, 33, 36 mm	
Shigella Flexneri		0.025 mg/ml	0.05 mg/ml		(Solimani *et al.*, 2010)
B. cereus		0.0125 mg/ml	0.025 mg/ml		
Bacillus subtilis		0.05 mg/ml	0.1 mg/ml		
E. coli		0.0015 mg/ml	0.0031 mg/ml		
S. aureus		0.0125 mg/ml	0.025 mg/ml		
H. pylori M22	Methanol extract	128 µg/mL		Metronidazole-sensitive and Metronidazole-resistant strain. = 19 mm	(Atapour *et al.*, 2009)
H. pylori M12		128 µg/mL			
H. pylori M31		256 µg/mL			
H. pylori M40		256 µg/mL			
H. pylori S22		128 µg/mL			
H. pylori S35		256 µg/mL			
H. pylori S42		256 µg/mL			
H. pylori S45		128 µg/mL			
H. pylori R19		512 µg/mL			
H. pylori R14		256 µg/mL			
H. pylori R42		128 µg/mL			
H. pylori R55		256 µg/mL			
Lactococcus garvieae.	Ethanol extract	8 µl/ml			(Goudarzi *et al.*, 2011)

Several studies have shown the anti-microbial activity of BP EO and extract. Phenolic compounds have an antimicrobial activity such as carvacrol, thymol, γ-terpinene and ρ-cymene (Burt, 2004). The antibacterial effects of BP were studied on different strains of bacteria. Many studies showed that EO of BP has a greater inhibitory effect on gram-positive bacteria than gram-negative bacteria (Oroojalian *et al.*, 2010; Simic *et al.*, 2008; Thippeswamy *et al.*, 2013). The extract of this plant has a high antimicrobial effect on *Escherichia coli* (Gupta *et al.*, 2011). Great inhibitory effects of BPEO on several pathogens such as *Staphylococcus aureus* (ATCC 25923, ATCC 6538), Bacillus cereus (ATCC 11778), *Listeria monocytogenes* (ATCC 19112, ATCC 19118, ATCC 7644), *Escherichia coli* O157: H7 (ATCC 43894), *Salmonella spp.* (ATCC 13311; ATCC 14028) has been reported (Abdalaziz *et al.*, 2017; Ehsani *et al.*, 2016; Fallahi *et al.*, 2010; Ghderi *et al.*, 2014; Jamshidi *et al.*, 2014; Noori *et al.*, 2014; Oroojalian *et al.*, 2010; Rabiey *et al.*, 2013). Findings of other related studies have been summarized in Table 3.

Anti-fungal properties

Spices and herbs show antimicrobial and anti-fungal properties due to the ingredients in their essential oils. Antifungal effects of herbal essential oils have been evaluated in several studies. Cuminaldehyde is the main antifungal component among the compounds of derived EO of BP (Sekine *et al.*, 2007). BPEO has shown significant anti-fungal properties against all types of food spoilage and pathogen fungi (Simic *et al.*, 2008). In a study by Soliman and Badeaa (2002), the antifungal effect of BPEO on the growth of different species of pathogenic Aspergillus (*A. flavus*, *A. parasiticus,* and *A. ochraceus*) was studied and their obtained results indicated that this plant had significant inhibitory effects on growth and mycotoxin production of these fungi. Skrinjar *et al.* (2009) showed that different concentrations of EO have an inhibitory effect on *A. fumigatus*, *A. flavus,* and *A. ochraceus* species. *Carum carvi* EO also has significant inhibitory effects on *Candida albicans* growth (Skrobonja *et al.*, 2013). In another study, it was showed that EO of *C. carvi* in addition to

inhibiting *A. parasiticus* growth also effectively inhibits aflatoxin production by this mold (Razzaghi-Abyaneh *et al.*, 2009). High concentration of BP extracts exhibited great antimicrobial activity against *A. niger* (Gupta *et al.*, 2011).

Antioxidative properties

Many studies have been carried out in the field of antioxidant properties of extracts and essential oil of black Caraway which all indicated high antioxidant effects and scavenging ability of free radicals for this plant (Abdalaziz *et al.*, 2017; Bamdad *et al.*, 2006; Chizzola *et al.*, 2014; Haghirogsadat *et al.*, 2010; Samojlik *et al.*, 2010). Essential oil and phenolic extract of black caraway show a good antioxidant and DPPH scavenging properties compared to BHT and BHA (Kapoor *et al.*, 2010; Thippeswamy *et al.*, 2013). Caraway has high antioxidant activity due to monoterpene alcohols, linalool, carvacrol, carvone, limonene, anethole, estragol, flavonoids and other polyphenolic compounds (Agrahari and Singh, 2014). It was reported that daily use of BP in diet will be efficacious, cost-effective as a good antioxidant with no side effects (Khan *et al.*, 2012). The results of peroxide value (PV) and tiobarbituric acid (TBA) tests showed that BP could be used as a natural alternative instead of synthetic antioxidants (Zangiabadi *et al.*, 2012). BP seed extract can prevent hemolysis of human erythrocytes that can be due to the presence of bioactive compounds which has a radical-scavenging activity (Atrooz, 2013). Caraway supplementation had a modulatory role in tissue lipid peroxidation, antioxidant profile and prevented 1,2-dimethylhydrazine-induced histopathological lesions in colon cancer of rats (Kamaleeswari and Nalini, 2006).

Anticarcinogenic/Antimutagenic effects

Colon cancer is one of the most common cancers around the world. It has been observed that diets containing cumin prevent colon cancer in rats and reduce the histopathologic lesions resulting from 1,2-dimethylhydrazine (DMH). It also reduces aberrant crypt foci expansion, the amount of fecal bile acid, neutral sterols and alkaline phosphatase activity (Deeptha *et al.*, 2006; Kamaleeswari and Nalini, 2006). Monoterpenes like anethofuran, carvone and limonene which are present in the essential oil of the cumin have prominent anticarcinogenic properties (Agrahari and Singh, 2014). Compounds present in seed extract of caraway reversed 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) that induced mutagenicity. It inhibited TCDD induced CYP 1 A2 and CYP 1 A1 activities and expression in rat hepatoma cells in a dose-dependent manner (Naderi-Kalali *et al.*, 2005).

Hypoglycemic and Hypolipidemic effects

Seed extract of BP seems can cause insulin-dependent hypoglycemia. Hypoglycemic activity of these plants may result from inhibiting glucose production or stimulating the use of glucose in peripheral tissues especially in muscle and fat tissues (Eddouks *et al.*, 2003). Extract of this herb can also act as inhibitors of glucose reabsorption in renal tubes (Maghrani *et al.*, 2003). A survey on diabetic rats showed that ethanolic extract of BP seed in different concentrations decreased glucose and insulin levels significantly in diabetic rats, in compare with healthy rats (Eidi *et al.*, 2010). Oral administration of cumin extract significantly reduced the glucose level of diabetic rats with no changes in plasma insulin concentrations which indicates that the mechanism of drug activity of this extract is independent with insulin secretion (Eddouks *et al.*, 2004). Aqueous extract of Black zeera compounds, especially flavonoids and carvone have a strong antioxidant activity, which provides renoprotection against diabetes and its complications. Water extract of BP has shown protective effects on diabetes-induced renal damage in rats (Sadiq *et al.*, 2010). Various studies on animals have shown that black Zeera has significant hypolipidemic effects (Khaksari *et al.*, 2014; Saghir *et al.*, 2012). Oral administration of *C. carvi* aqueous extract exhibits a potent lipid-lowering activity in diabetic and healthy rats (Lemhadri *et al.*, 2006).

Antiparasitic effects

Some studies showed that the EO or extract of BP has antiparasitic effects. The evaluations show that BP may have significant antitoxoplasmosis effects. The results of a study on mice with acute toxoplasmosis showed that the oral administration of BP essential oil can be as a natural source to produce new prophylactic agent and use in toxoplasmosis (Kareshk *et al.*, 2015). Findings of Mahmoudvand *et al.* (2016) demonstrated the potent scolicidal activity of BP with no significant toxicity, which might be used as a natural scolicidal agent in hydatid cyst surgery.

Application in food systems

Due to good antimicrobial and antioxidant properties, BP has a high potential for use in foods to prevent microbial and chemical degradation of food and as well as food-borne diseases. In this regard, several studies were conducted to increase foods shelf life. *B. Persicum* essential oil can be used not only as a natural flavor but also as a preservative against microbial contamination in foods such as Gouda cheese, and also plays an important role in consumer health (Taherkhani *et al.*, 2015). The essential oil of this plant can be used as a natural preservative in the food industry due to the high antioxidant effect is shown in the starch film (Aminzare *et al.*, 2017a). Also, biodegradable starchy films containing BPEO have a good inhibitory effect on food pathogens and can be used as an active ingredient in the food industry to enhance safety and to prolong foods' shelf life (Aminzare *et al.*, 2017b). It was shown that addition of BP extract can have significant effects on the extending shelf life of fresh silver carp fish in refrigerated storage condition for 6-9 days (Eskandari *et al.*, 2015). Also, in another study, it was shown that combination of BPEO, smoking, NaCl and low temperature as a Hurdle system has noticeable inhibition on *L. monocytogenes* growth in fish model systems (Rabiey *et al.*, 2013). *B. persicum* essential oil has shown good inhibitory effects on food pathogens during the production, ripening, and storage of Iranian white Cheese, and also has shown a significant impact on the improvement of the color, odor, flavor, texture and general acceptability of this product (Ehsani *et al.*, 2016). Addition of different concentrations of BP essential oil to chicken meat has shown the deterrent effect on the causative agents of chemical and microbial spoilage (Kamkar *et al.*, 2017). Talebi *et al.* (2017) indicated that polylactic acid films containing BPEO may be useful for packaging of foods in order to increase their shelf life and safety. Studies in the field of maintenance and oxidative stability of various types of edible oils such as olive, Linseed and soybean oil have confirmed that BP essential oil can be used as

food additive and a natural antioxidant compound to increase the shelf life and oxidative stability of oils (Keramat and Golmakani, 2016; Shahsavari *et al.*, 2008; Zangiabadi *et al.*, 2013).

Toxicity

Poisonous properties of essential oils and plant extracts were investigated in several studies. Due to the fact that BP is widely used in people's diet for its flavoring properties, there is no major concern about the toxic effects of this plant. Mandegary *et al.* (2012) assessed the toxicity of BP essential oil and extract on mice by Intaperitoneal (I.P) injection of essential oil (at doses of 0.75, 1, 1.25 and 1.75 ml/kg) and extract (at doses of 4 and 5 g/kg) and determined mortality and morbidity after 24 hours. Results showed that extract exhibited no mortality at a dose of 4 g/kg, but 16% mortality occurred at a dose of 5 g/kg and the EO showed no mortality up to the dose of 2.5 ml/kg. In another study, the toxicity of aqueous extract and essential oil of BP was investigated on rats by IP injection at different doses of aqueous extract (1600, 3200, 3600, 4000 and 5000 mg/kg) and essential oil (200, 400, 600, 800 and 1200 mg/kg). Maximum non-lethal concentrations of aqueous extract and EO were 3200 mg/kg and 400 mg/kg, respectively (Showraki *et al.*, 2016). An acute toxicity effect of BPEO was evaluated in another study on mice. The LD50 value of IP injection of the BPEO was 1.96 mL/kg body weight, and the maximum nonfatal doses were 1.28 mL/kg body wt. (Mahmoudvand *et al.*, 2016).

Future perspectives

In traditional medicine, BP is used to treat gastrointestinal and urinary disorders, bloating and dyspepsia. Caraway mixture is used as a cumin formulation for the treatment of dyspepsia and bloating in children. According to researches, BP is a valuable drug that has antimicrobial, antioxidant, anti-inflammatory and lipid and glucose-lowering effects.

The most noticeable effects of BP herb are anti-microbial and antioxidant properties. Researches have shown that the essential oil of this plant has a good inhibitory effect on bacteria such as *S. aureus*, *B. cereus*, *L. monocytogenes*, *E. coli*, *Salmonella* and *fungi* such as *Aspergillus* and *Candida*. It seems that in the future, we will see the plant's extensive use in the food industry alone or in combination with other preserving agents and it can be used in food industry due to increased shelf-life of food and food safety. It was showed that BP and its derivatives (essential oil or extracts) alone or in combination with other food preservatives and or in composition of edible films or coating can be used to control spoilage and pathogens microorganisms as well as to prevent chemical spoilage in foods such as all types of oils, cheeses, fish, poultry and meat products. BP is widely used in people's diet due to its flavoring properties and there is no major concern about the toxic effects of this plant. However, the study on the acute and chronic toxicity of the compounds of this plant seems necessary for use as auxiliary treatment and application in food industry. Also, according to studies done on the anti-carcinogenic and anti-mutagenic properties of this plant, it seems that BP has the potential for use as an adjunct therapy in the treatment and prevention of seizure and cancer.

Given to the differences reported in the essential oil composition of this plant, it is recommended that future research is performed on the various effects and the role of each of its compounds and using a standard essential oil with specific compounds.

CONFLICT OF INTEREST

Authors declare there is no conflict of interest.

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