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Review

Acinos species: Chemical composition, antimicrobial and antioxidative activity

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Published papers considering composition, antimicrobial and antioxidant activity of *Acinos* Miller species were reviewed. Main volatile constituents are pulegone, menthone and germacrene D. Alcoholic and water extracts contain a number of flavonoids. Reported chemical composition suggest potential use of *Acinos* species as phyto-therapeutic and food preservative agents. The investigation of biological activity of *Acinos* species has rarely been reported so further research should be carried out to determine whether the extract components posses activity both, *in vitro* and *in vivo* and ultimately are safe for human consumption.

Key words: *Acinos*, Lamiaceae, essential oil, antibacterial activity, antioxidant activity, composition.

INTRODUCTION

Acinos Miller is one of the smaller genera of the Lamia-ceae family native to Europe, Mediterranean, central Asia, northern Africa and North America. The name Acinos comes from the Greek word *akinos* meaning a small aromatic plant. *Acinos* species are annual and short-lived evergreen perennial woody plants. They are small, tufted, bushy or spreading plants growing to 10 - 45 cm tall which propagate by division, softwood cuttings or from seed in spring (Bonnier, 1927; Bown, 1995). Among botanists there is no agreement about the list of accepted species. According to The International Orga-nization for Plant Information (IOPI), genus *Acinos* Miller comprises 11 species (names and synonyms from different sources are given in Table 1). Even small *Acinos* is important genus within the Lamiaceae family from the economic point of view. A number of *Acinos* species are being traded in the herbal market, as the herbs of “mint” group, mainly in the Mediterranean countries (Table 2). Traditional applications of *Acinos* species in folk medicine has not been justified enough through biochemical researches. This review presents published results of chemical composition, antibacterial and antioxidant acti-vity of *Acinos* species in order to point out which species could be considered as possible phyto-therapeutics.

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Reviewing the available literature (SciFinder), 47 references were found concerning *Acinos* species. Majority of the papers dealt with essential oil composition. There are only two papers devoted to the antibacterial activity, one to antioxidant properties and one to fatty acids. *A. suaveolens* is the most examined species and also has the greatest number of uses in traditional medicine while some of the species weren’t examined at all.

CHEMICAL COMPOSITION

Published data of chemical composition of A*cinos* species are summarized in the Table 3. Presented results (Table 3) suggest a number of observations:

1. According to essential oil yield and composition two group of *Acinos* species could be recognized: one which produce essential oil in great quantity than other exa-mined Acinos species (2.3 - 0.64) with monoterpenes as main constituents, pulegone, menthone and isomenthone (Figure 1): *A. majoranifolius* and *A. suaveolens* and the other group which was characterize with low yield of oil (0.01 - 0.08) and sesquiterpenes as dominant consti-tuents. There is one exception: for *A. arvensis* oil from Greece was reported that it consist of pulegone, menthone and isomenthone, (Souleles et al. (1988). Misidentification of the species may be hypothesized.

Table 1. Names and synonyms of A*cinos* species from different literature sources.

Greuter et al. (1984, 1986)	**Czerepanov (2007)**	**Database of European Plants (ESFEDS). Edinburgh (http://www.helsinki.fi/kmus/botflor.html)**
Acinos alpinus (L.) Moench Synonims: *Satureja alpina* (L.) Scheele	*Acinos alpinus* (L.) Moench Synonims: *Acinos baumgartenii* (Simonk.) Klokov, *Melissa baumgartenii* Simonk., *Acinos alpinus* subsp. baumgartenii (Simonk.) Pawl>l.	A*cinos alpinus* (L.) Moench Synonims: *Calamintha alpina* (L.) Lam., *Clinopodium alpinum* (L.) Merino, *Satureja alpina* (L.) Scheele, *Calamintha alpina* (L.) Lam. subsp. alpina
Acinos arvensis (Lam.) Dandy Synonims: *Satureja acinos* (L.) Scheele	*Acinos arvensis* (Lam.) Dandy Synonims: *Acinos schizodontus* Klokov, *Acinos thymoides* Moench	*Acinos arvensis* (Lam.) Dandy Synonims: *Acinos thymoides* Moench, *Calamintha acinos* (L.) Clairv., *Satureja acinos* (L.) Scheele
Acinos corsicus (Pers.) Getliffe Synonims: *Satureja corsica* (Pers.) Caruel	-	*Acinos corsicus* (Pers.) Getliffe Synonims: *Calamintha corsica* (Pers.) Bentham, *Satureja corsica* (Pers.) Caruel, *Thymus corsicus* Pers.
Acinos graveolens Synonims: *Satureja graveolens* (MB.) Caruel	*Acinos graveolens* (M. Bieb.) Synonims: *Acinos rotundifolius* Jim.Perss.	*Acinos graveolens* (Bieb.) Link **Synonyms:** Synonims: *Acinos rotundifolius* Pers.
Acinos hungaricus (Simonkai) Synonims: *Satureja hungarica* (Simonkai) Hayek	-	-
Acinos majoranifolius (Miller) Synonims: *Satureja majoranifolia* (Miller) K. Mal'y	-	-
Acinos orontius (K. Mal'y) Synonims: *Satureja orontia* K. Mal'y	-	-
Acinos rotundifolius Pers. Synonyms: *Satureja rotundifolia* (Pers.).	*Acinos rotundifolius* Jim.Perss. Synonyms: *Acinos fominii* Des.-Shost., *Acinos graveolens* (M.Bieb.), *Acinos infectus* Klokov, *Acinos subcrispus*, Klokov *Acinos thubcrispus* Klokov	*Acinos rotundifolius* Pers. Synonyms: *Acinos fominii* Roussine *Acinos graveolens* (Bieb.) Link, *Calamintha exigua* (Sibth. & Sm.) Hayek, *Calamintha graveolens* (Bieb.) Bentham, *Calamintha maritima* Bentham, *Calamintha rotundifolia* (Pers.) Bentham, *Satureja rotundifolia* (Pers.) Briq.

Table 1. Contd.

Acinos suaveolens (Sm.) Synonyms: *Satureja suaveolens* (Sm.) Watzl-Zeman	-	*Acinos suaveolens* (Sibth. & Sm.) G. Don fil. Synonyms: *Calamintha suaveolens* (Sibth. & Sm.) Boiss.
Acinos troodi (Post) Leblebici Synonyms: Satureja troodi (Post) Holmboe	-	-
-	-	*Acinos villosus* Jim.Perss. Synonyms: *Acinos eglandulosus* Klokov, *Acinos arvensis* subsp. eglandulosus (Klokov) Tzvelev, *Acinos arvensis* subsp. villosus (Pers.) Soják

Table 2. Reported medicinal uses of *Acinos* Miller species.

Species	Medicinal use	References
A. alpinus Folk names: Rock thyme, mint	Antiemetic, anti-inflammatory, diuretic, for cholesterol, diarrhea, digestion, obesity and respiratory ailments	Karousou et al. (2007)
A. arvensis Folk name: Basil Thyme	Antiseptic, stimulanttonic, for shortness of breath, improving digestion, to treat bruises, toothache, Sciatica and neuralgia	Bown (1995)
A. suaveolens Folk name: mint	Anticplvusive, antiseptic, aphrodisiac, blood purification, dizziness-nausia-sea sickness, dysmenorrhoea, fever gall disorders, headache-migraine influenza mouth and throat hygiene, rheumatisms, sedative, spazmolytic, tonic-stimulant, tonsilitis, diabetes, stomach ailments.	Karousou et al. (2007)

2. Germacrene D is widespread main sesqiuterpene among examined *Acinos* species. However, there are two exceptions: Jovanovi et al. (2002) reported caryophyllene oxide as the dominant constituent for *A. hungaricus oil* and Skaltsa et al. (1999) found germacrene A as major compound in *A. alpinus* oil. Possible reason could be the cause of the existence of different chemotypes or wrong constituent identification.

3. There is the variability in quantity and composition of essential oils among populations of the same species suggesting different chemical types within it (Kaya et al.1999a,b,c).

4. Linolenic acid is the main constituent in *A. alpinus* and *A. hungaricus* chloroform-methanolic extract (Jovanovi et al. (2008). Studies have found evidence that -linolenic acid, an *n*−3 essential fatty acid, is related to a lower risk of cardiovascular disease (Kris-Etherton et al., 2002). Research has also suggested a major neuroprotective effect of -linolenic acid in in-vivo models of both global ischemia and epilepsy (Lauritzen et al., 2000).

5. Plenty of flavonoids and flavonoids glycosides were isolated from *A. alpinus*, *A. suaveolens* and *A. hungaricus* (Figures 2 and 3). Flavones (apigenin, luteolin, chrysoeriol) and their glycosides (luteolin-7-*O*-rutinoside, cynaroside, linarin, fortunalin) are the most frequent flavonoids in methanol extracts of examined *Acinos species*. Flavonols such as kaempferol and quercetin are less frequent Glycosidic form of flavanones (narirutin, hesperidin, neoponcirin, paucerin, portsirin) also occur in the *Acinos* species. Majority of flavonoids are linked with sugars in position 7. The most frequent monoglycoside is *O*-glucosides. Among diglycosides it is true for rutinosides. Both, flavonoids and their glycosides, have been used as a nutritional supplement due to positive effects in combating or helping to prevent cancer, prostatitis, heart disease, cataracts, allergies/inflammations, and respiretory diseases such as bronchitis and asthma. In an eight year long study it was found that the presence of three flavonols (kaempferol, quercetin, and myricetin) in a diet

Table 3. Chemical composition of *Acinos* species

Acinos species	Essential oil main constituents* (%)	Other constituents**	References
A. alpinus	Germacrene D (3.5-39.8), hexadecanoic acid (3.7-24.3), thymol (10.9-15.3)	-	Kaya et al. (1999a)
	germacrene A (32.3), epi-bicyclosesquiphellandrene (15.8), β-elemene (12.5) and β-caryophyllene (12.2)	-	Skaltsa et al. (1999)
	Germacrene D (56.8; 43.2), β-caryophyllene (6.2; 15.4), bicyclogermacrene (5.9; 11.7)	-	Velasco-Negueruela et al. (1993)
	-	Aurapin, naringenin, taxifolin, neoponcirin	Venturella et al. (1980)
	-	Linolenic acid 35.2% palmitic acid 23.0%; linoleic acid 15.1%	Jovanovi et al. (2008)
A. arvensis	Germacrene D (47.0) β-bourbonene (7.7)	-	Jovanovi et al. (2005)
	Germacrene D (14.3) hexadecanoic acid (14.0) β-bourbonene (7.0)	-	Kaya et al. (1999b)
	Germacrene D (51.4) β-caryophyllene (7.9) β-bourbonene (4.8)	-	Kaya et al. (1999b)
	pulegone (51.3) izomenthone (18.1)	-	Souleles et al. (1988)
		Linarin (acacetin 7-O-rutinoside)	Marin et al. (2001)
	-	phytol (0.04-0.1%), β-sitosterol (0.06-0.08%), ursolic acid (0.4-1.4%), betulin (0.05%)	Popa and Pasechnik (1974)
	-	Atsinoside (didymine, neoponcirin)	Wagner et al. (1974)
	-	Fortunallin (acacetin 7-(2-O- -L-rhamnopyranosyl - -D -glucopyranoside)	Sergienko et al. (1968)
	-	paucerin (5-hydroxy-4-methoxyflavanone 7 -D-glucopyranoside-2- -L-rhamnopyranoside)	Sergienko et al. (1967)

Table 3. Contd.

	-	Portsirin (5,7-dihydroxy-4'-methoxyflavanone 7- (-D-glucopyranosyl-2- -L-rhamnopyranoside), atsinoside (didymine, neoponcirin)	Sergienko et al. (1966)
A. hungaricus	germacrene D (46.7), β-bourbonene (6.6)	-	Chalchat et al. (2004)
	caryophyllene oxide (16.8), geraniol (9.7), β-bourbonene (5.7), globulol (5.6)	-	Jovanovi et al. (2002)
		linolenic acid 26.7% palmitic acid 21.8%; linoleic acid 11.7%;	Jovanovi et al. (2008)
		Linarin (acacetin 7-O-rutinoside)	Marin et al. (2001)
A. majoranifolius	pulegone (97), menthone (3)	-	Pavlovi et al. (1984b)
A. rotundifolius	germacrene-D (14.4-73.1), hexadecanoic acid (17.5-30.2)	-	Kaya et al. (1999b)
A. suaveolens	pulegone (67.7; 77.7), isomenthone (4.9; 6.8)	-	Couladis et al. (2002)
	pulegone (23.2-80.7), isomenthone (1.1-54.1)	-	Kaya et al. (1999b)
	isomenthone (50.86), pulegone (33.22)	-	Tumen (1991)
	pulegone (69.04), isomenthone (17.04)	-	Kokkalou (1988a)
	pulegone (96.9)		Pavlovi et al. (1984a)
	-	apigenin, kaempferol, chrysoeriol, luteolin, quercetin, didymin, narirutin, cosmosiin, cynaroside, isoquercitrin, hesperidine, luteolin-7-O-rutinoside	Kokkalou and Kapetanidis (1988b)
A. troodi	hexadecanoic acid (7.5-18.2 and 15.2-22.3), germacrene D (10.2-14.5 and 14.1-29.7)	-	Kaya et al. (1999c)

*Essential oils obtained by hydrodistillation using a Clevenger-type apparatus.
**Maceration in methanol was used as extraction method in references: Venturela et al. (1980), Wagner et al. (1974), Sergienko et al. (1967, 1968 and 1966), and Kokkalou and Kapetanidis (1988b). Popa and Pasechnik (1974) used acetone as solvent for extraction. Marin et al. (2001) extracted plant material by aqua's methanol (H_2O:CH_3OH, 20:80). Fatty acids were extracted by maceration in chloroform: methanol, 2:1.

were associated with a reduced risk of pancreatic cancer in current tobacco smokers (Nöthlings et al., 2007).

ANTIOXIDANT AND ANTIMICROBIAL ACTIVITIES

There is only one paper that stated the antioxidant activity of water extract of *A. suaveolens* (Triantaphyllou et al., 2001). Results of this work indicate that water extract of A. suaveolens (mint) have a protective effect against lipid oxidation but it is less active than the water extract of sage (Salvia officinalis).

A. arvensis essential oil is active against *Escherichia coli*, *Staphylococcus aureus* and *Klebsiella pneumonia* but not against *Pseudomonas aeruginosa* (Jovanovi et al. (2005). Couladis et al. (2002) found that *E. coli*, *S. aureus, S. epidermidis, S. hominis* and *K. pneumonia* were susceptible to the *A. suaveolens* oil.

CONCLUSION

Activity of the plant extracts would be expected to relate to their composition, the structural configuration of the components, their functional groups and possible synergistic or antagonistic interactions between components. There are a lot of papers that connect particular extract component with observed extract bioactivity (Misra, 2009). It is known that *p*-menthane ketones are effective towards a number of microorganisms (Dorman, 2000). Pulegone exhibited high antimicrobial activity, especially on S*almonella typhimurium* and *S. aureus* (Duru, 2004). β-Caryophyllene have moderate antimicrobial activity (Blagojevi , 2006). One may conclude that the composi-

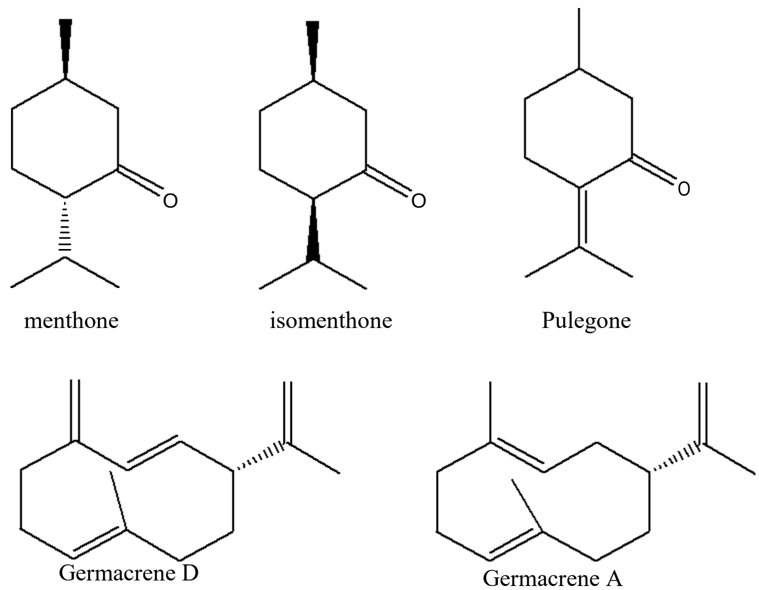
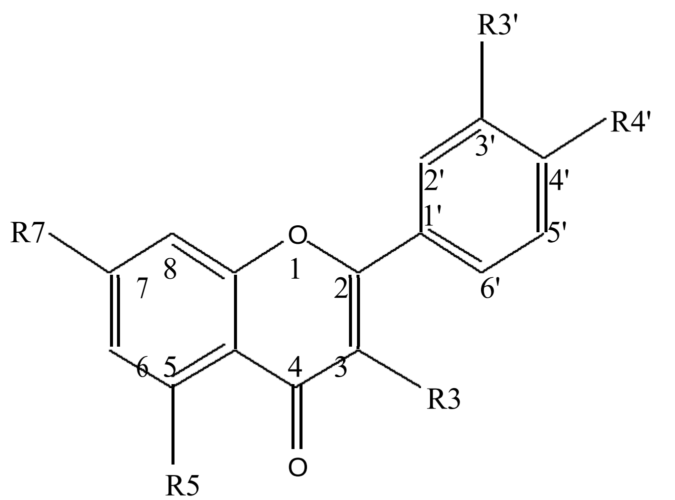
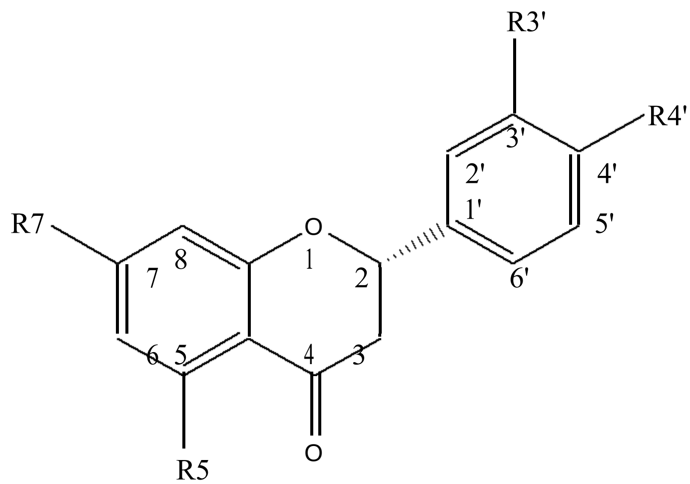


Figure 1. Main constituents of *Acinos* species essential oils.



Compound	R3	R5	R7	R3′	R4′
Apigenin	H	OH	OH	H	OH
Luteolin	H	OH	OH	OH	OH
Kaempferol	OH	OH	OH	H	OH
Quercetin	OH	OH	OH	OH	OH
Chrysoeriol	H	OH	OH	OCH_3	OH
Cosmosiin (apigetrin)	H	OH	*O*-glucoside	H	OH
Isoquecitrin	*O*-glucoside	OH	OH	OH	OH
Luteolin-7-O-rutinoside	H	OH	*O*-rutinoside	OH	OH
Cynaroside	H	OH	*O*-glucoside	OH	OH
Linarin	H	OH	*O*- rutinoside	H	OCH_3
fFortunalin	H	OH	*O*-(2-*O*- -L-rhamnopyranosyl - -D – glucopyranoside)	H	OCH_3

Figure 2. Common flavones, flavonols and their glycosides of *Acinos* species



Compound	R5	R7	R3′	R4′
Narirutin	OH	O-rutinoside	H	OH
Hesperidin	OH	O-rutinoside	OH	OCH_3
Didymin (neoponcirin, atsinoside)	OH	O-rutinoside	H	OCH_3

Figure 3. Common flavanone glycosides of *Acinos* species

tion of essential oils of *Acinos* species promises exploitable *in vitro* antimicrobial activity.

In addition, *Acinos* species are promising source of natural antioxidants because of high content of flavonoids and linolenic acid in their extracts (Table 3). Flavonoids are known as high-level antioxidants because of their ability to scavenge free radicals and reactive oxygen species such as singlet oxygen, superoxide anion radical and hydroxyl radicals.

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