Contents lists available at ScienceDirect

Food and Bioproducts Processing

journal homepage: www.elsevier.com/locate/fbp

Extraction of biologically active compounds from *Sideritis* ssp. L.

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ABSTRACT

In this study extraction of polyphenols and flavonoids from cultivated hybrid *Sideritis scardica* × *Sideritis syriaca*, known for its rich content of phenolics and flavonoids with antioxidant activity, was investigated. Extractions have been done by ethanol and water–ethanol, respectively. High equilibrium values of the extracted species were obtained—17.55 mg/(g solid) total phenolics and 5.7 mg/(g solid) total flavonoids with ethanol as solvent. The influence of the solvent on the total yield and the content of biologically active compounds were studied. Maximum polyphenolics and flavonoids extraction was observed for water–ethanol solvent ratio 20/80. Increase of the content of ethanol in the solvents led to lower total yield of extracts but higher percentage of polyphenolics. The extraction kinetics showed that 90% of the phenolic compounds were extracted during the first 2.5 h. The experimental kinetics was described by a constant effective diffusion coefficient $D_e = 1.5 \times 10^{-12}$ m^2/s in the solid, accounting for the actual particle size distribution.

Keywords: Solid–liquid extraction; Extraction kinetics; Diffusion coefficient; *Sideritis* L.

1. Introduction

In the recent years, there has been a global trend toward the use of phytochemicals present in natural resources, such as vegetables, fruits, oilseeds and herbs, as antioxidants and functional ingredients (Elliott, 1999; Kaur and Kapoor, 2001; Xu et al., 2005; Huntley, 2009). Flavonoids are becoming very popular because they have many health promoting effects. Some of the activities attributed to flavonoids include: anti-allergic, anti-cancer, antioxidant, anti-inflammatory and anti-viral. The flavonoid quercetin is known for its ability to relieve high fever, sinusitis and asthma (Min et al., 2007; Boots et al., 2008). Epidemiological studies have illustrated that heart diseases are inversely related to flavonoid intake. Studies have shown that flavonoids prevent the oxidation of low-density lipoprotein thereby reducing the risk for the development of atherosclerosis (Londoño-Londoño et al., 2010; Aviram, 2004; Medeiros et al., 2008).

The genus *Sideritis* L. comprises more than 150 species occurring mainly in the Mediterranean area and the Balkan Peninsula (Obon de Castro and Nunez, 1994). Several new species form the Mediterranean region were described (Duman et al., 1995; Rios et al., 2001). *Sideritis scardica* Griseb. is endemic for the Balkan peninsula and in Bulgaria is known under the name "Pirin mountain tea" or "Mursalitza tea". It is widely used in the folk medicine due to its anti-inflammatory and anti-rheumatic properties. The study of the chemical composition of the extracts from *Sideritis* spp. has proved the significance of the high content of flavonoids and phenolics for its biological activity (Koleva et al., 2003; Ozkan et al., 2005; Gabrieli et al., 2005). Part of the reported investigations with *Sideritis* spp. are focused on the chemical composition of the extracts in relation to their antioxidant activity (Nakiboglu et al., 2007; Sagdic et al., 2008).

As can be seen from Table 1, the cited antioxidant activity is mainly attributed to the flavonoid content of this plant. Koleva (2007) found that the total methanol extracts from *S. scardica*, *Sideritis syriaca* and *Sideritis montana* show a strong radical scavenging activity against DPPH•, close to that of rosmarinic acid. The antioxidant activity of *Sideritis* extracts was

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Received 29 March 2010; Received in revised form 4 October 2010; Accepted 11 October 2010

doi:10.1016/j.fbp.2010.10.004

Table 1 – Summary of the studies, dealing with the antioxidant activity (AA) of different extracts from *Sideritis*.

Sideritis species	Solvent	Antioxidant activity (AA) evaluated by	Compounds, that correlate with AA	Reference
Sideritis mugronenis	Chloroform	DPPH[a]	Flavonoids (hypolaetin 8-glucoside)	Barberan et al. (1987)
Sideritis javalambrensis	–	$FeSO_4$/cysteine-induced microsomal lipid peroxidation	Flavonoids	Rios et al. (1992) and De Las Heras et al. (1994)
Sideritis raeseri (Greece)	Methanol, n-BuOH, (1) phenolic fraction, (2) fraction 5,8-dihydroxy-flavone-7-oallosylglucosides	CL[b], DPPH[a]	Flavonoids	Gabrieli et al. (2005)
Sideritis sipylea (Turkey)	Water, methanol, ethanol, acetone	DPPH	Phenolic hydroxyl groups (but not necessarily only with the high amounts of phenolics)	Nakiboglu et al. (2007)
Sideritis ozturkii *Sideritis caesarea* (Turkey)	Methanol	DPPH	Phenolics and flavanols. Negative correlation with the content of flavonols	Sagdic et al. (2008)
Sideritis syriaca *Lamiaceae* (Greece)	Methanol, petroleum ether dichloromethane	DPPH, CL	Phenolic content (apigenin and phenyl-propanoids)	Armata et al. (2008)
Sideritis (Labiatae), Bulgaria *Sideritis syriaca* *Sideritis scardica* *Sideritis montana*	Methanol	DPPH	Flavonoids 5,8-Dihydroxy-flavone-7-oallosylglucosides	Koleva et al. (2003)
Sideritis euboea	*n*-Butanol *n*-hexane, methanol, diethyl ether, ethyl acetate	DPPH	Highest reported values 3,5,7,4′-Tetrahydroxy flavones Extracted residues	Tsaknis and Lalas (2005)
Sideritis condensata and *Sideritis eryhrantha*	Methanol	PM[c], DPPH	Total phenolics	Ozkan et al. (2005)
Sideritis italica	Acetone	ABTS[d], DMPD[e], CL	Essential oils	Basile et al. (2006)

[a] 2,2-Diphenyl-1-picrylhydrazyl (DPPH•) radical scavenging method.
[b] Co(II)/EDTA-induced luminol chemiluminescence (CL) method.
[c] Phosphomolybdenum method.
[d] 2,2-Azinobis(3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS) cell free colorimetric methods.
[e] N,N-dymethyl-*p*-phenylenediamine dihydrochloride (DMPD) cell free colorimetric method.

attributed to the presence of flavonoids and phenylpropanoid glycosides. For the extracts from *S. syriaca* with polar solvents, Armata et al. (2008) related this characteristic to their phenolic content and attributed it to the presence of apigenin and phenylpropanoids. On the other hand, diterpenoid content of *Sideritis* species correlated with their antibacterial effect (Topçu and Gören, 2007), antifeedant and insectidal activities (Topçu and Gören, 2007; Kilic et al., 2009).

The important role of *S. scardica* as traditional remedies tea and its conservation has required its cultivation. The selected hybrids *S. scardica* × *S. syriaca* have been cultivated since 10 years (Evstatieva, 2006). The influence of the cultivation on the chemical composition and the influence of the extraction method on the yield of flavonoids and phenolics, as well as on the profile of the major flavonoids found in cultivated hybrid *S. scardica* × *S. syriaca* is studied (Kostadinova et al., 2008; Alipieva