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Review article

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LAVANDULA SPP. ESSENTIAL OILS – ITS USE, COMPOSITION AND GENETIC BASIS OF PRODUCTION

OLEJKI ETERYCZNE LAWENDY – ICH WYKORZYSTANIE ORAZ PODŁOŻE GENETYCZNE PRODUKCJI

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Streszczenie. Lawenda wykorzystywana jest głównie w medycynie, kosmetyce, aromaterapii, perfumiarstwie, a także jako przyprawa kulinarna. Niewątpliwe najczęściej uprawia się ją dla pozyskania olejków eterycznych, mających przyjemny zapach, a także bardzo dobre właściwości przeciwbakteryjne, przeciwgrzybiczne oraz antyoksydacyjne. Publikacja stanowi przegląd informacji dotyczących olejków eterycznych pozyskiwanych z tkanek roślin należących do rodzaju *Lavandula*, metod ich ekstrakcji oraz składu chemicznego, a także możliwości ich zastosowań. Skład chemiczny olejku roślinnego zależy od wielu parametrów, takich jak: uwarunkowania środowiskowe, okres wegetacyjny, w którym roślina została zebrana, sposób suszenia i przechowywania do czasu zasadniczej ekstrakcji olejku, sposób izolowania olejku, a także warunki prowadzenia analiz (kolumna, zaprogramowana temperatura), które są stosowane do identyfikacji związków.

Key words: *Lamiaceae*, secondary metabolites, antimicrobial and antioxidant properties, industrial use.
Słowa kluczowe: *Lamiaceae*, metabolity wtórne, właściwości antymikrobiologiczne i antyoksydacyjne, zastosowanie w przemyśle.

INTRODUCTION

The plants of the genus *Lavandula spp.* are native to the Mediterranean region (Miller 1985; Basch et al. 2004), the Arabian Peninsula, the Canary Islands and India (Upson and Andrews 2004). This plant naturally occurs in southern Europe and northern Africa. Indigenous species of this plant occur in northern, eastern and southern Africa, Bulgaria and Russia (Staicov et al. 1969).

The narrow-leaved lavender is one of the most useful aromatic-herbal plants used for medicinal purposes. The plant is particularly valued for its essential oils (Boelens 1995; Nobre 1996). The oils is a mixture of natural volatile compounds characterized by a strong fragrance and it is classified as plant secondary metabolite (Bakkali et al. 2008). The oils are

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extracted from plant material (flowers, buds, seeds, leaves, braches, bark, herbs, wood, fruit and roots) by means of expression, fermentation, *enfleurage* process or extraction. The most commonly applied method of obtaining oils on a commercial scale is steam distillation (Van de Braak and Leijten 1999).

The earliest records of distillation for the purpose of obtaining essential oils come from the region of Egypt and India, and date back to over 2,000 years ago (Guenther 1948). This method was improved in the 9th century by Arabs (Bauer et al. 2001). In the 13th century, the process of distillation was used by pharmacists and the pharmacological properties of essential oils were described in pharmacopoeia (Bauer et al. 2001). However, essential oils were widely used in Europe only from the 16th century (Crosthwaite 1998). According to French doctor – Du Chesne (Quercetanus), the practice of extracting essential oils was popular in the 17th century, and the pharmacies of the day offered 15–20 oils obtained from various plant species (Guenther 1948).

Due to rapid progress in molecular biology and natural sciences, the knowledge on essential oils, their synthesis and extraction continues to increase. There has been a growing interest in the potential application of the natural plant compounds, including lavender essential oils, in alternative medicine, clinical and medical microbiology, phytopathology, aromatheraphy, pharmacy and pharmacology (Daferera et al. 2000; Woronuk et al. 2011), as well as for preservation of food (Gómez-Estaca et al. 2010) and cosmetic products (Kunicka--Styczyńska et al. 2009; Dreger and Wielgus 2013).

METHODS OF ESSENTIAL OILS EXTRACTION

Essential oil of the *Lavandula spp.* genus is produced in the secretory glands (also known as secretory trichomes or essential oil glands) located between the fine hairs covering the flowers, leaves as well as stems. The oil can be isolated both from fresh as well as dry flowers, and the green parts of the lavender plant (leaves). The efficiency of the process is greater when it is performed with the use of flowers as raw material (13.9–15.3 mg $\cdot$ g^{-1} fresh weight). The oil obtained from this part of the plant is rich in linalool and linalool acetate, whereas the amount of oil obtained from lavender leaves, rich in camphor and borenol, ranges from 0.7–2.9 mg $\cdot$ g^{-1} of fresh weight (Falk et al. 2009).

The best quality oil is derived from *Lavandula angustifolia* and *Lavandula stoechas* even though its concentration in plant tissue is the lowest. The oil yield is estimated to be 40 kg per herctare (Lis-Balchin 2002). In turn, oil used for the production of cheaper perfumes is derived from *Lavandula latifolia* in the amount of 50 kg per hectare. Since 1920, lavender hybrids characterised by high amounts of essential oils in plant tissues (to 120 kg $\cdot$ ha^{-1}) have been cultivated on a commercial scale, despite the lower quality of the oils (Wyckoff and Sievers 1935). The most popular lavender hybrid is transgenic lavandula, produced by cross-breeding of *Lavandula latifolia* with *Lavandula angustifolia* (Cavanagh and Wilkinson 2002). The oil obtained from this hybrid is called lavandin oil and, due to high concentration of camphor, it is rarely used in the perfume industry or for therapeutic purposes. Due to its antiseptic, antifungal and antibacterial properties, the oil can be used for the purpose of preservation of products (Lis-Balchin 2002).

On a commercial scale, lavender oils are obtained by means of steam distillation (Zheljazkov et al. 2013) which produce higher ratio of alpha terpineol, linalool and linalyl acetate than supercritical fluid extraction (SFE method) (Hawthorne et al. 1993; Jin and Ha 2005). The research by Zheljakov et al. (2013) provides data on the influence of the duration of distillation on the obtained lavender oil yield and its composition. The distillation times under analysis were: 1.5; 3; 3.75; 7.5; 15; 30; 60; 90; 120; 150; 180 and 240 min. The highest efficiency of oil distillation in the range of 0.5–6.8% was found for distillation time 60 min. The concentration of cineol in the range of 6.4–35% and fenchol 1.7–2.9% was the highest for distillation time 1.5 min, and decreased with distillation time. The concentration of camphor in the range 6.6–9.2% reached maximum after 7.5–15 min, and the concentration of linalool acetate (15–38%) after 30 min. The results of this research show that there is no increase in the amount of obtained lavender essential oil after more than 60 min of distillation. However, according to Wesołowska et al. (2010), the maximum efficiency of the distillation process (2% essential oil *Lavandula angustifolia* Mill.) is achieved after 2 h, and the minimal oil yield (1%) is obtained after 40 min of distillation.

Extraction of oils by means of microwave radiation is also mentioned in the literature on the subject (Craveiro et al. 1989; Luque de Castro et al. 1999; Périno-Issartier et al. 2013). A method has been developed for obtaining lavender essential oils by microwave accelerated steam distillation (MASD). Dried lavender flowers were placed over the source of steam produced with the use of microwave heating. MASD method was compared with the classic steam distillation and both were used to obtain essential oils from narrow-leaved lavender. MASD method proved to be superior than the tradition method in terms of energy consumption, rate of the process (MASD – 10 min, steam distillation – 90 min), efficiency (MASD – 8.86%, steam distillation – 8.75%), purity and quality of the oils (Chemat et al. 2006).

USE OF ESSENTIAL OILS

Essential oils are used in a wide range of specialised industries and production of lavender essential oils is one of the highest in the world. For centuries, it has been used for therapeutic purposes (Cavanagh and Wilkinson 2002) and in aromatherapy (Welsh 1997; Moss et al. 2003; Lehrner et al. 2005; Setzer 2009). The oils derived from *Lavandula stoechas* and *Lavandula dentata* have spasmolytic properties and are used in folk medicine (Khalil et al. 1979; Gilani et al. 2000). Lavender oils are used in the treatment of illness of the digestive system and thanks to content of cumarin, herniarin and acidic triterpenoids it alleviates flatulence, colic symptoms as well as has relaxant effects on ileum and smooth muscles (Lis-Balchin and Hart 1997, 1999). *In vitro* studies showed that lavender oil has analgesic properties (Skoglund and Jorkjed 1991), and testing in rabbits confirmed its anaesthetizing effects (Ghelardini et al. 1999).

Fragments of *Lavandula angustifolia* plants, used as dried product as well as extracts and plant hydrolates, are widely used in Europe and in the United States for treatment of mild anxiety and stress (Bradley et al. 2007). It has been demonstrated that the plant has soothing properties on airways, both in people and in animals (Lis-Balchin and Hart 1999). Hydrolates contain numerous valuable water-soluble substances as well as slight amounts of oil – from 0.02% to 0.5%. Therefore, hydrolates, including lavender hydrolate, have sedative as well as refreshing effects and are used in the treatment of insomnia and headache. Moreover, lavender hydrolate has beneficial effects on skin and is used in the treatment of diseases of the skin and burns (Stanojević et al. 2011). However, some ingredients of the lavender essential oil obtained from *Lavandula* may trigger allergic reactions. It is believed that D-limonene, geraniol, linalool and linalyl acetate are potentially allergenic compounds (Jin and Ha 2005) which have strong anti-microbiological effects and can irritate the skin (Pattnaik et al. 1997; Arputhabibiana et al. 2012).

It has been known for centuries that essential oils derived from herbal plants have some antimicrobial properties, yet the efficiency of oils was scientifically proven only relatively recently (Deans and Ritchie 1987; Janssen et al. 1987). The ingredients of essential oils of narrow-leaved lavender such as linalool, linalyl acetate, α-terpineol, geranyl acetate and cumarin (Kreis and Mosandl 1992; Figueiredo et al. 1995; Flores et al. 2005) exhibit strong antbacterial properties (Cole 1992; Adam et al. 1998; Mayaud et al. 2008; De Rapper et al. 2013), antifungal (D'Auria et al. 2005; De Rapper et al. 2013) and antioxidant effects (Spiridon et al. 2011; Hamad et al. 2013).

The activity of lavender oil on microorganisms present on human skin was thoroughly examined and its high activity against these pathogens was confirmed (Farag et al. 1989, Paster et al. 1990; Adam et al. 1998; Smith-Palmer et al. 1998). Adaszyńska et al. (2013) demonstrated astrong effect of oils isolated from ‘Blue River’ and ‘Munstead’ cultivars of narrow-leaved lavender against *Staphylococcus aureus* and *Pseudomonas aeruginosa* bacteria. The activity of lavender oils on these bacteria was confirmed by Kunicka--Styczyńska et al. (2011). Antibacterial properties of essential oils isolated from narrow--leaved lavender were demonstrated also against *Micrococcus ascoformans, Proteus vulgaris* (Hui et al. 2010) and *Escherichia coli* (Mayaud et al. 2008). Moreover, essential oils inhibit bacterial growth of *Salmonella enteritidis*, *Klebsiella pneumoniae* as well as fungi – *Candidia albicans* and *Aspergillus niger* (Hammer et al. 1999). Essential oils derived from *Lavandula angustifolia* and *Lavandula x intermedia* show strong anti-parasitic properties against human pathogens – *Giardia duodenalis* and *Trichomas vaginalis* protozoa, and *Hexamita inflate* in fish (Moon et al. 2006).

Lavender essential oils can be widely used in agriculture. The oils are used for the purpose of combating plant pathogens such as *Botryris cinerea* (Thanassoulopoulos and Laidou 1997; Reddy et al. 1998; Pavela 2005) or *Rhizopus stolonifer* (Reddy et al. 1998).

Moreover, oils also have herbicidal properties and the essential oil of *Lavandula angustifolia* offers an alternative to synthetic herbicide as it inhibits germination of *Xantium strumarium* L., *Avena sterilis* L. and *Phalaris brachystachys* L. (Uremis 2009). Haig et al. (2009) argue that the ingredients of lavender oils such as cumarin and 7-metoxycumarin show strong phytotoxic effects on annual ryegrass (*Loliumrigidum*).

Also, there is a growing interest in perillyl alcohol – monoterpene produced in trace quantities by *Lavandula angustifolia*, which shows chemotherapeutic properties (Perrucci et al. 1994; Schulz et al. 1994; Hohl 1996). It was found that lavender extract can inhibit growth of tumour cells (Stanojević et al. 2011).

Lavender oil is used in food industry for the purpose of aromatisation of beverages, ice cream, sweets, pastries and chewing gum (Kim and Lee 2002). Lavender extracts are used for the same purpose due to their nutraceutical properties which additionally have beneficial effects on health. Aqueous extracts of *Lavandula angustifolia* and *Lavandula stoechas* contain a strong tyrosinase inhibitor and can be used as a food bleaching agent (Hsu et al. 2007). Additionally, oils have inhibitory effects on microorganisms and prevent food spoilage (Thompson 1989; Basilico and Basilico 1999). Lavender oil shows strong antioxidant activity against lipid peroxidation in a model system of linoleic acid (Hui et al. 2010). The most common method for determining antioxidant activity is DPPH method. Oils obtained from *Lavandula angustifolia* shows strong antioxidant properties which suggests that lavender oils can be used as an efficient antioxidant compound (Hamad et al. 2013). Addition of *Lavandula vera* extract to minced chicken meat decreases lipid oxidation and loss of α-tocopherol during storage of cooked meat (Kovatcheva-Apostolova et al. 2008).

COMPOSITION OF LAVENDER OILS

Plant essential oils of *Lavandula sp.* are volatile and aromatic oily substances composed of mixtures of volatile components synthesized by plants, including primarily two groups of biosynthetically related compounds such as terperns C10-C15 – derivatives of isoprene, aromatic terpenoids and aliphatic compounds with low molecular weight (Cosentino et al. 1999; Daferera et al. 2000; Landmann et al. 2007; Da Porto et al. 2009; Bertoli et al. 2011). There can be from 20 to even as much as 100 components present in oils in various concentrations. One characteristic aspect is that two or three of the components may be present in high concentration, whereas the others are present only in trace quantities.

The characteristic lavender aroma of essential oils is attributed to monoterpenes of low molecular weight (C10). The essential oils obtained from *Lavandula angustifolia* characterised by high concentration of linalool/linalyl acetate and low of camphor are considered to have the most beautiful fragrance and are the most desired oils used in aromatherapy and cosmetic industry. Oils obtained from other species of lavender contain high concentrations of terpens, including high content of camphor, which results in less pleasant fragrance (Lynam and Smith 2009).

Researchers found various concentrations and number of compounds in different species of lavender. With the use of GC-MS method Hussain et al. (2011) found 56 compounds in *Lavandula angustifolia* essential oil. According to Wesołowska et al. (2010), oils of *Lavandula angustifolia* Mill. have the highest content of linalool (28.78–30.68%), linalyl acetate (12.35–17.67%) and α-terpineol (7.57–11.49%) among the indentified compounds (from 43 to 47).

Adaszyńska et al. (2011, 2013) conducted GC-MS analysis of essential oils isolated from lavender cultivars: 'Munstead', 'Munstead Strain', 'Lavender Lady', 'Ellegance Purple', 'Blue River'. In all cultivars the same compounds were identified, however in various concentrations. The number of identified compounds was from 18 to 21. The main components of oils were: linalool (23.9–15.8%), linalyl anthranilate (12.3–1.6%), 1-terpinen-4-ol (9.7–5.5%), terpineol (*p*-Menth-1-en-8-ol) (7.9–4.0%) and linalool oxide (4.7–1.1%). According to Cong et al. (2008), there are 17 compounds derived from *Lavandula angustifolia*. The highest concentration was found for linalool (44.54%), geraniol (11.02%), lavandulyl acetate (10.78%), 3,7-dimethyl-2,6--octadien-1-ol (10.35%) and isoterpineol (6.75%).

Table 1. Main compounds of the essential oils from some of the most important *Lavandula* spp.
Tabela 1. Główne składniki olejków eterycznych najważniejszych gatunków *Lavandula spp.*

Species Gatunek	Country of origin Kraj pochodzenia	Type of cultivation Warunki uprawy	Part of plant Część rośliny	Major components Główne składniki	Reference Źródło literaturowe
L. dentata	Algeria	N	U	1,8-cineole (38.4%), cis-verbenol (4.3%), p-cymen-8-ol (3.8%), fenchone (2.3%)	Dob et al. (2005)
	Morocco	N	A	1, 8 cineol (41.3%), sabinene (13.7%), bicycle [3.1.0] hexan-3-Ol, 4-methylene-1-(1-methylethyl) (6.8%), myrtenal (5.1%), α-pinene (4.1%)	Imelouane et al. (2009)
	Yemen	N	A	camphor (12.4%), trans-pinocarveol (7.5%), β-eudesmol (7.1%), α-guiaol (6.1%), β-Selinene (4.5%)	Mothana et al. (2012)
L.x intermedia	Turkey	C	F	linalool (34.8–41.8%), linalyl acetate (29.5–42.5%), borneol (1.7–5.1%), cymene (1.5–3.3%), geraniol (1.2–2.2%)	Kara and Baydar (2013)
	Spain	C	F and A	Linalool (35–51%), eucalyptol (26–32%), camphor (10–18%), *α*-pinene (1–2%),*α*-terpineol (1–2%)	Carrasco et al. (2016)
L. latifolia	Spain	N	F and A	cineol (20.8-54.6%), camphor (11.4-43.5%), borneol (0.9–2.7%)	Munoz--Bertomeu et al. (2007)
L. multifida	Tunisia	C	A	linalool (50.1%), camphene (10.1%), linalyl acetate (7.3%), α-thujene (3.8%), bornyl acetate (3.0%)	Msaada et al. (2012)
L. pedunculata	Portugal	N	A	camphor (32.4%), 1,8-cineole (24%), α-pinene (6.9%), linalool (5.2%), α-cadinol (4.0%)	Zuzarte et al. 2010
L. pinnata	Madeira	C	A	β-phellandrene (12–32%), α-phellandrene (6–16%)	Figueiredo et al. (1995)
L. stoechans	Turkey	C	F	fenchon (32.0%), camphor (14.7%), myrtenyl acetate (11.7%), 1,8-cineole (7.7%), α-pinen (2.9%)	Giray et al. (2008)
	India	C	F	camphor (52.1%), fenchone (12.0%), 1,8-cineole (9.7%), bornyl acetate (6.2%), camphene (3.3%)	Raina and Negi (2012)
	Romania	C	F	camphor (32.7%), 1,8-cineole (26.9%), borneol (7.1%), caryophyllene (4.9%), α-bisabolol (4.2%)	Jianu et al. (2013)
L. viridis L'Hér	Portugal	C	A	1.8-cineole (21.9%), camphor (15.7%), α-pinene (10.3%), linalool (5.3%), borneol (4.1%)	Nogueira and Romano (2002)
	Portugal	C	A	1,8-cineole (34.5%–42.2%), camphor (13.4%), α-pinene (9.0%), linalool (7.9–6.7%)	Zuzarte et al. (2011)

N – natural condition – warunki naturalne, C – field-grown – warunki uprawne, F – flowers – kwiaty, A – aerial parts – części nadziemne, U – unknown – nieznane.

Table 2. Main compounds of the *Lavandula angustifolia* essential oils includes country of origin
Tabela 2. Główne związki olejków eterycznych *Lavandula angustifolia* z uwzględnieniem kraju pochodzenia

Country of origin Kraj pochodzenia	Type of growth conditions Warunki wzrostu	Part of plant Część rośliny	Major components Główne składniki	Reference Źródło literaturowe
Brazil	U	F	1,8-cineole (28.3%), camphor (28.0%), isoborneol (9.9%), α-phellandrene (5.7%), myrcene (3.6%)	Maia et al. (2004)
Bulgaria	C	F	linalool (18.7–34.4%), linalool acetate (20.7–32.7%), lavandulyl acetate (2.5–7.00%), caryophyllene (1.00–3.8%), geranyl acetate (1.1–1.9%),	Zagorcheva et al. (2013)
China	C	U	linalool (37.6%), linalyl acetate (35.8%), terpinen-4-ol (4.5%), lavandulyl acetate (4.1%)	Zhang et al. (2006)
Greece	C	F	linalool (50.6%), linalyl acetate (15.7%), terpinen-4-ol (7.8%), (Z)-β-ocimene (4.3%), (E)-β-ocimene (2.7%)	Chatzopoulou et al. (2003)
Greece	U	U	linalool (44.5%), linalyl acetate (32.7%), terpinen-4-ol (6.9%), 1,8-cineole (4.8%), borneol (3.9%)	Daferera et al. (2000)
France	U	U	linalyl acetate (36.0%), linalool (34.0%), β-caryophyllene (4.5%), terpinen-4-ol (1.7%)	Dohi et al. (2009)
India	C	F	linalyl acetate (47.6 %), linalool (28.1 %), lavandulyl acetate (4.3 %), α-terpineol (3.7%)	Verma et al. (2010)
India	U	U	linalyl acetate (45.2%), linalool (27.1%), β-caryophyllene (4.6%), p-cymene (2.8%), α-terpineol (2.2%), limonene (1.2%)	Inouye et al. (2010)
India	C	F	linalyl acetate (35.8%), linalool (23.6%), α-terpineol (6.3%), lavandulyl acetate (4.8%), geraniol (3.3%)	Raina and Negi (2012)
Iran	N	A	1,8-cineole (37.9%), borneol (21.6%), camphor (21.3%), cryptone (2.6%), cumin aldehyde (2.3%)	Azar et al. (2011)
Iraq	N	F	linalool (24.6%), camphor (13.6%), linalyl acetate (8.9%), (Z)-β-ocimene (7.6%), 1,8-cineole (7.1%)	Hamad et al. (2013)
Italy	N	F	linalool (36–36.5%), linalyl acetate (21.7–14.4%), camphor (5.6–11.8%), 1,8-cineole (4.0–10.9%), terpinen-4-ol (2.1–6.6%)	Da Porto et al. (2009)
Italy	U	U	linalool (23.1%), linalyl acetate (23.1%), 1,8- -cineole (8.4%), camphor (6.6%), borneol (5.0%)	Romeo et al. (2008)
Poland	C	F	linalool (30.6%), linalyl acetate (14.2%), geraniol (5.3%), β-caryophyllene (4.7%), lavandulyl acetate (4.4%)	Śmigielski et al. (2009)
Poland	C	F	linalool (24.6%), linalyl acetate (14.4%), borneol (6.2%), caryophyllene oxide (5.2%), lavandulyl acetate (3.5%), α-terpineol (3.5%)	Śmigielski et al. (2013)
Poland	C	F	linalool (28.8–30.7%), linalyl acetate (12.3–17.7%), α-terpineol (7.6–11.5%), cis-linalool oxide (5.3–5.8%), lavandulyl acetate (2.4–3.2%)	Wesołowska et al. (2010)
Romania	C	F	caryophyllene (24.1%), β-phellandrene (16%), 1,8-cineole (15.6%), terpinen-4-ol (9.57%), α-terpineol (6.0%),	Jianu et al. (2013)
Serbia	C	F	linalyl acetate (27.5%), linalool (27.2%), limonene (8.5%), lavandulyl acetate (6.5%)	Sokovic et al. (2007)
Spain	C	F	linalool (29.9–35.4%), camphor (4.9–6.9%), borneol (3.7–4.7%), 1-8-cineole (1.9–4.2%), α-terpineol (1.3–1.9%)	Chavez (2007)
Tunisia	C	U	linalool (38.0%), 1,8-cineole (11.1%), terpinen-4-ol (8.2%), borneol (8.0%), (Z)-β-ocimene (3.6%)	Jilani et al. (2014)

N – natural condition – warunki naturalne, C – field-grown – warunki uprawne, F – flowers – kwiaty, A – aerial parts – części nadziemne, U – unknown – nieznane.

The analysis of oil isolated from plant tissues of the same species, conducted by Xie et al. (2002), showed 21 compounds, and the highest concentration was found for linalool, linalyl acetate, and 3-cyclohexon-1-ol, 4-methyl-1-(1methylbythyl).

The composition of essential oils is determined mainly by the plant genotype (Nurzyńska--Wierdak et al. 2012), yet developmental and environmental factors can also play a role (Boeckelmann 2008). GC-MS method was used to analyse the composition of essential oils derived from *Lavandula* species from different parts of the world: Algeria (Dob et al. 2005), Bulgaria (Ognyanov 1984), China (Cong et al. 2008), India (Verma et al. 2010), Iraq (Hamad et al. 2013), Yemen (Mothana et al. 2012), Morocco (Imelouane et al. 2009), Poland (Śmigielski et al. 2009), and Turkey (Kara and Baydar 2013) (Table 1). The research show that the composition of essential oils varies depending on the region of origin. Even essential oils derived from *Lavandula angustifolia* growing in various regions show difference in composition (Table 2).

GENETIC BASIS OF ESSENTIAL OILS PRODUCTION

The production of essential oils by lavender is to a large extent attributed to the fact that this genus belongs to *Lamiaceae* family. Even though the composition of essential oils is determined by environmental factors (such as temperature, the length of the day) as well as agricultural practices (for example irrigation, fertilisation), it is the genotype of the plant that affects the composition of the oils produced by a plant to the greatest extent (Kokkini et al. 1997; Boira and Blanquer 1998; Russo et al. 1998).

In order to determine some mechanisms controlling monoterpene compounds, their content in tissues of *Lavandula angustifolia* and *Lavandula x intermedia* were measured. The results confirmed that efficiency of oil and the content of camphor, borneol, linalool and limonene are species-specific. During the flowering of lavender, the content of monoterpene compounds varies and there are some differences in their biosynthesis pathway. The amount of produced linalool is correlated with linalool synthase gene transcription, however there is a difference in *L. angustifolia* and *L. x intermedia* synthase transcription, and, consequently in the mechanisms controlling the production of linalool in these species (Boeckelmann 2008).

Biosynthesis of monoterpene compounds starts with condensation of isopentenyldiphosphate (IPP) and dimethylallyldiphosphate (DMAPP) and gives the basic intermediate product – geranyldiphoshate (GPP, in. C10). Monoterpene synthase enzyme (mTPSs) transforms GPP to a respective monoterpene. In some cases, monoterpene production is directly correlated with the activity of transcription of respective monoterpene synthase enzymes (MTP). Linalool accrued in *L. angustifolia* correlates with the level of linalool synthase gene transcription (Lane et al. 2010).

For the purpose of constructing genomic library of *Lavandula*, Demissie et al. (2011) obtained more than 14.000 EST (expressed sequence tag) for leaves and flowers of *L. angustifolia* used in the production of essential oil. They determined the series of previously uncharacterized terpene synthase genes (TPS).

Construction of cDNA library of leaves and flowers of *L. angustifolia* was undertaken earlier by Lane et al. (2010). *Lavandula angustifolia* was previously used as a model plant for the purpose of investigating the processes behind essential oil production at a molecular level. The construction of two cDNA libraries, separately for leaves and flowers, gave information on 14.213 high quality specific expression markers (ESTs). Transcriptional activity for EST was evaluated with the use of microarray in the development of leaves and flowers. The results of the analysis indicate the presence of two previously uncharacterised TPS sequences, including LabPHLS and LaTPS-I which showed strong expression in young leaves and flowers characterised by the greatest production of essential oils.

The genotype combining *Lavandula angustifolia* and *Lavandula latifolia* was obtained by creation of transgenic lavandula (*Lavandula × intermedia*) (Lammerink et al. 1989). It contains cDNA limonene synthase gene (LIMS) from *Lavandula angustifolia* which is endoded by the constructive promoter 35S. Tsuro and Asada (2014) investigated gene expression and its effect on essential oil production and found that suppression of limonene synthase expression contributes to the variability in the overall composition of essential oil, such as significant decrease in limonene, linalool and linalyl acetate concentration. The results suggest that the constitutive promoter acts as a suppressor in tissues with strong expression of endogenous gene. Therefore, there occurs a change in fragrance in transgenic plants – the fragrance of these plants was more camphorous, resulting from the presence of compounds such as borneol, camphor and 1,8-cyneol. The results suggest that inhibition of terpene synthase gene expression is an effective way of changing the fragrance despite the decrease in the total production of essential oils.

CONCLUSION

Due to antifungal, antibacterial and antioxidant properties of lavender, it is widely used in cosmetics, pharmaceutical, agro-food and feed industry. Essential oils are used in perfume industry and for the purpose of aromatisation of cosmetics and household chemicals. The beautiful smell of all species of *Lavandula spp.* is attributed to rich composition of the essential oils which is a species- and cultivar-dependent characteristic. Linalool and linalyl acetate were found to be most abundant components of essential oils.

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Abstract. Lavender is mainly used in medicine, cosmetics industry, aromatherapy, perfume industry and as a culinary herb. It is most often grown for the purpose of obtaining essential oils characterized by a pleasant fragrance as well as antibacterial, antifungal and antioxidant properties. The present paper is an overview of information on essential oils obtained from plant tissue of the *Lavandula* genus, including the methods of extraction, chemical composition and potential use. The chemical composition of plant oil is determined by various parameters such as environmental conditions, growing season, harvest time, methods of drying and storing until the time of oil extraction, method of oil isolation as well as the specific conditions of the analysis (column, set temperature) used to identify the compounds.