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REWIEV ARTICLES

Composition, biological properties and therapeutic effects of lavender (*Lavandula angustifolia* L.). A review

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S u m m a r y

Lavender (*Lavandula angustifolia*) is a shrub of the family *Lamiaceae*, native to the Mediterranean region. The material used for herbal purposes includes lavender flowers (*Lavandula flores*) containing essential oil (3%), anthocyanins, phytosterols, sugars, minerals, and tannins. The qualitative and quantitative composition of the essential oil of lavender is variable and depends on genotype, growing location, climatic conditions, propagation, and morphological features. The essential oil contains over 300 chemical compounds. The dominant components are linalool, linalyl acetate, terpinen-4-ol, acetate lavandulol, ocimene, and cineole. Lavender essential oil has good antioxidant and antimicrobial activities and a significant positive effect on the digestive and nervous systems. Lavender extract prevents dementia and may inhibit the growth of cancer cells, while lavender hydrolate is recommended for the treatment of skin problems and burns.

Key words: *lavender, Lavandula angustifolia, herbs, essential oils, phytotherapy, secondary plant metabolites*

INTRODUCTION

The active compounds present in herbs exhibit multidirectional phytotherapeutic activity and are used in the treatment of gastrointestinal, cardiovascular, respiratory, and urinary infections, as well as in chronic diseases of children and

elderly people. Furthermore, they exhibit antibacterial, antifungal, antispasmodic, and antioxidant activity, and also regulate digestive activity. Due to the biologically active substances present in them, herbs have antimicrobial, antioxidant, and therapeutic properties, and may be extensively used, as they are effective as synthetic drugs.

Lavender (*Lavandula angustifolia*) is a plant with a number of beneficial properties for the human body. Besides its application in herbal treatment, lavender is widely used in the cosmetic, perfume, food, and aromatherapeutic industries [1,2].

ORIGIN AND CULTIVATION

Lavender, also known as medicinal lavender, true lavender, or common lavender (*Lavandula angustifolia*, *L. officinalis*, *L. vera*), is an evergreen perennial plant. Lavender is native to the Mediterranean region (France, Spain, Andorra, and Italy), but is grown in many other countries of the world, including Poland [3,4]. The name *lavender* comes from the Latin verb *lavo, lavare* and means to wash or to clean. Lavender has been known from ancient times, as evidenced by work of Dioscorides entitled "De Materia Medica," which praises its medicinal properties. The Romans used lavender as a bath additive, and in the Middle Ages it was one of the most valuable essential oil plants used in perfume and soap making. It was also used both as a food additive and a laxative.

Lavender grows to a height of 40–60 cm and forms compact, regular clumps. The lower part of stem is woody, while the upper part is green. Lavender has linear or lanceolate leaves with curled edges and a highly branched fibrous root system. Silver-green lavender leaves are covered with tomentum, which protects them from strong sunshine, wind, and excessive water loss. Lavender flowers grow in spikes, arranged in circles (3–5 flowers per circle) in the top part of the stem. They are of pale violet color, although, varieties with white flowers (Alba and Nana Alba) and pink flowers (Rosea) have also been bred [5].

Lavender (*L. angustifolia*) grows on well-drained, fertile and lime soils. It grows best in full sun with wind protection. In subsequent years of cultivation, lavender may be fertilized with manure or chemical fertilizers, but care should be taken not to acidify the soil or introduce too much nitrogen, as this causes excessive gain in the green parts with a simultaneous reduction in inflorescence. In Poland, lavender is not entirely hard to frost, so it needs a good cover for the winter [6].

Plants may be propagated generatively from seeds or vegetatively from soft and hard wood cuttings, or through tissue culture. Lavender shrubs are regularly pruned in order to stimulate plant growth and to promote flowering. The flowering period lasts from July to August. Harvesting should be carried out on dry, sunny days. Flowers should be collected before opening, dried in bundles in shaded and well-ventilated places. The plant portions used for herbal purposes

are flowers (*Flos Lavandulae*) or flowering aerial parts (*Herba Lavandulae*), and the material used for essential oil production consists of fresh or dried tops of flowering plants [5].

CHEMICAL COMPOSITION OF LAVENDER

Lavender (*L. angustifolia*) contains essential oil, anthocyanins, phytosterols, sugars, minerals, coumaric acid, glycolic acid, valeric acid, ursolic acid, herniarin, coumarin and tannins [5].

The content of macronutrients differs depending on lavender variety [7]. Potassium levels range from 17.7 $g \times kg^{-1}$ dry matter (d.m.) for the Munstead variety to 23.9 $g \times kg^{-1}$ d.m. for Lavender Lady. Climatic conditions have a significant impact on the amount of calcium – in lavender grown in Romania, the average value is 2.13 g Ca per 1 kg d.m. [8], while in Pakistan it is 10.50 g Ca per kg d.m. [9]. In turn, the Blue River variety has a calcium content of 8.10 $g \times kg^{-1}$ d.m., and the Munstead variety – 13.8 $g \times kg^{-1}$ d.m. Lavender is characterized by low levels of magnesium (from 1.40 $g \times kg^{-1}$ d.m. for Lavender Lady to 3.60 $g \times kg^{-1}$ d.m. for Munstead) and sodium (from 0.11 $g \times kg^{-1}$ d.m. for Munstead to 0.15 $g \times kg^{-1}$ d.m. for Lavender Lady). The studies by Colceru-Mihul et al. [8] and Adnan et al. [9] also confirmed the low content of these elements, from 2.19 g to 4.25 g Mg per kg d.m., and 0.37 g Na per kg d.m.

It has been found that the amount of trace elements depends on the variety. Zinc levels ranges from 23.0 to 106.27 $mg \times kg^{-1}$ d.m. [8,9]. The study of Adaszyńska et al. [7] also confirmed the high content of this micronutrient: from 25.7 $mg \times kg^{-1}$ d.m. for Lavender Lady to 39.2 $mg \times kg^{-1}$ d.m. for Ellagance Purple. The presence of copper amounts to 7.2–11.1 $mg \times kg^{-1}$ d.m. and that of manganese to 9.6–18.0 $mg \times kg^{-1}$ d.m. for the Munstead and Lavender Lady varieties, respectively. The highest content of iron has been found in Ellagance Purple (489 $mg \times kg^{-1}$ d.m.) while the smallest in Munstead (137 $mg \times kg^{-1}$ d.m).

ESSENTIAL OIL

The most valuable substance isolated from lavender (*L. angustifolia*) is essential oil (tab. 1), found in oil glands located on the surface of the calyx, in the furrows between fine hairs. Essential oil is present in amounts from 2% to 3%. It is obtained by hydrodistillation or steam distillation; it is yellow and has an intense floral-herbal lavender scent with a delicate hint of fruit and wood [4, 5, 10, 11].

The qualitative and quantitative composition of the essential oil of lavender (*L. angustifolia*) depends on genotype, growing location, climatic conditions, propagation, and morphological characteristics [12]. The essential oil consists of over 300 chemical compounds, the main ones are linalool (from 9.3% to 68.8%) and

linalyl acetate (from 1.2% to 59.4%). The near infrared spectrometry (NIR) profiles of the essential oil from fresh and dried lavender flowers grown in Poland are closest to those of the essential oil from French lavender (the matching rates are 90.39% for fresh lavender and 97.65% for dried lavender) [13].

The quality of essential oil of lavender depends both on the high content of linalool and linalyl acetate and their mutual proportions (higher than 1). The predominant compounds include borneol, α-terpineol, terpinene-4-ol, lavandulol acetate, as well as caryophyllene and linalool oxides. The main class of compounds consists of oxygenated monoterpenes (73.8%), with the greatest fraction of monoterpene alcohols (36%) [13]. The high concentration of lavandulol and lavandulol acetate gives a distinctive herbal-rosy scent, while the fragrance is adversely affected by ocimene, cineol, camphor, and terpinen-4-ol [12].

According to Lawrence [12], the fragrance of this essential oil is determined mainly by the presence of alcohols and their esters with acetic acid. The fresh, green herbal-floral tone rises due to the presence of (Z)-hex-3-enol and its ester; the herbal scent and the earthy aroma are produced by oct-1-en-3-ol and its ester; the fruity-fatty scent due to the presence of butyl and hexyl esters: linalool, lavandulol, and their esters (linalool acetate and lavandulol acetate) are responsible for fresh, floral smell; monoterpene aldehydes and ketones generate the herbal flavor; the sweet aromatic note is attributable to santalene derivatives and sesquiterpenes. The presence of pyridine affects fragrance modifications. The price of lavender essential oil is high and due to this fact it is often falsified by adding cheaper *Lavandula latifolia* essential oil or a hybrid of *L. angustifolia* and *L. latifolia*, or by the addition of synthetic chemicals.

The process of steam distillation of essential oils lead to the formation of by-products called hydrolates [14,15]. Hydrolates, also known as hydrosols or herbal water, consist of water from the plant material and process water. Depending on their final volume (variant), hydrolates have an intense herbal aroma, a sweet floral-herbal lavender scent, or a barely perceptible lavender aroma. The total content of volatile organic compounds in hydrolates ranges from 24.83 to 97.23 mg/100 ml hydrolate [16]. The main chemical compounds are linalool (39%), α-terpineol (15%), and coumarin (7%). The hydrolates lack in linalyl acetate, a chemical compound present in a large amounts (1.2%–59.4%) in the essential oil of lavender.

The study by Śmigielski et al. [13] has shown that while drying, lavender (*L. angustifolia*) losses of more than 40% of its essential oils. However, if fresh lavender is dried in a fluidized bed, in a closed circuit system containing a drying agent and a heat exchanger, the dried product produces more volatile and biologically active substances at a predetermined humidity and condensed water from the plant, called Fluidolat® [17, 18]. This biologically active and innovative product is completely lost in processing using conventional technologies. The fragrance of lavender fluidolates is similar to the hydrolate aroma, but more intense and floral. The content of volatile organic compounds in fluidolates depends on the degree of material drying and ranges from 120.62 to 180.26 mg/100 ml fluidolate. The

dominant compounds are linalool (65.2%–79.2%), terpinen-4-ol (6.3%–16.4%) and lavandulol (0.8%–4.4%). The main group of compounds consists of oxygen derivatives of monoterpene hydrocarbons (80%–91%), including monoterpene alcohols (47%–61%). Fluidolates also lack in linalyl acetate.

Table 1.

Main compounds in essential oils of lavender (*L. angustifolia*) [10, 12, 13]

No.	Compound	Bulgaria [%]	Italy [%]	France [%]	Poland [%]
1	Ocimene	6.8–7.7	–	0.2–18.1	1.9–2.9
2	Cineol	2.1–3.0	0.02–0.2	0–3.4	0.2–0.5
3	Camphor	< 0.5	0.3–0.6	0–0.5	0.2–0.3
4	Linalool	30.1–33.7	33.3–42.2	9.3–68.8	27.3–34.7
5	Linalyl acetate	35.2–37.6	37.8–41.2	1.2–59.4	19.7–22.4
6	Terpinen-4-ol	4.5–5.8	2.8–3.6	0.1–13.5	1.1–2.0
7	Lavandulol	–	–	0–4.3	0.6–0.8
8	Lavandulol acetate	–	–	0.3–21.6	4.5–5.7

PROPERTIES AND APPLIANCE

Lavender (*L. angustifolia*) flowers, buds and leaves are edible and used to flavor broths and jellies (not consumed as a raw material). Lavender scent effectively deters moths and flies, so the plant is placed in closets and drawers. This insecticidal activity has been confirmed by the studies of Perrucci et al. [19] and O'Brien [20].

Infusions and tinctures of lavender flowers have sedative and analgesic properties. Lavender tincture is thought to alleviate depression, headaches, and anxiety, which has been confirmed by the study of Akhondzadeh et al. [21]. Lavender extract administered to rats prevented dementia caused by Alzheimer's disease [22], and a cytotoxic study of the effects of the extract on lung cancer showed the inhibition of carcinogenic cell growth [23].

Lavender essential oil is used in perfume, cosmetics and household chemicals. It is present in toilet water, eau de cologne, lotions, and after-shaves, giving them a strong top note, while imparts a scent of freshness and purity to household cleaning preparations. Many well-known cosmetic companies, such as Avon, Procter and Gamble, and Aloe Vera sell product with a lavender aroma.

The essential oil of lavender (*L. angustifolia*) has antibacterial activity at doses of 4.0–9.0 mg/ml [24]. The study of Mayaud et al. [25] confirmed its antimicrobial effects at concentrations of 0.94%–10% against 65 bacterial strains (the effectiveness against Gram-positive bacteria was higher than against Gram-negative). Lavender essential oil has an inhibitory effect on the growth of *S. enteritidis*, *K. pneumoniae*,

E. coli, S. aureus, P. aeruginosa, *C. albicans*, and *A. niger* [26]. Essential oils from plants of the genus *Lavandula* exhibit a broad spectrum of biological activities. The essential oil of *Lavandula dentata* has an inhibitory effect on the growth of bacteria, including *Salmonella*, *Enterobacter*, *Klebsiella*, *E. coli*, *S. aureus*, and *L. monocytogenes*. In turn, the essential oil of *L. bipinnata* exhibits antibacterial properties (against *E. coli*, *P. aeruginosa*, *S. aureus*, and *B. subtilis*) and antifungal properties (against *A. niger*, *P. notatum*, *C. albicans*) at concentrations of 0.5–2.0 $\mu g \times ml^{-1}$ for bacteria and 2.0–4.0 $\mu g \times ml^{-1}$ for fungi [27]. Lavender essential oil shows high activity against Gram-positive bacteria (*B. subtilis*, *S. aureus*) and Gram-negative bacteria (*E. coli*, *P. aeruginosa*), and inhibits their growth at concentrations of 0.6 or 1.0 $\mu l \times ml^{-1}$, depending on the strain (Prusinowska, unpublished).

In Poland, the essential oil of lavender (*L. angustifolia*) has been investigated in terms of antimicrobial activity. It has been found that the essential oil is active against yeasts and molds such as *Candida sp.*, *A. niger*, and *P. expansum*, with the MIC 2.5–3 times lower than that for bacteria. Lavender hydrolates also exhibit antimicrobial activity against *E. coli*, *P. aeruginosa*, *S. aureus*, *B. subtilis*, *Candida sp.*, and *A. niger* (Prusinowska, unpublished).

Essential oils have antioxidant properties protecting cells against the harmful impact of free radicals. The antioxidant activity of the essential oil of lavender was shown by Dapkevicius et al. [28]. Economou et al. [29] demonstrated the inhibitory effect of this oil on fat oxidation reactions and lipid peroxidation in a linoleic acid model system [30]. Chia-Wen Lin et al. [31] used DPPH to study the antioxidant properties of the essential oil of lavender (*L. angustifolia*), and, in particular, its ability to inactivate free radicals. The value of 15.18 ± 0.009% at a concentration of 5 $g \times l^{-1}$ indicates properties comparable with the essential oils of lime and marjoram. In contrast, Viuda-Martos et al. reported a significantly lower ability of the essential oil to inactivate free radicals at a similar concentration (4.11%) [32]. Studies testing the ability of this essential oil to reduce 50% DPPH radicals led to divergent results with values ranging from 289 $\mu g \times ml^{-1}$ [33] to 48.7 $mg \times ml^{-1}$ [32]. A study on the essential oil obtained from lavender grown in Poland determined this value to be IC50 = 338.0 $\mu l \times ml^{-1}$ (Prusinowska, unpublished).

According to Buchbauer et al. [34], some components of essential oils, such as linalool and terpineol, have an effect on the central nervous system, weakening the physical activity of humans and animals, reducing anxiety, and facilitating sleep. In mice and rats, a systemic administration of lavender essential oil also promotes sleepiness [35]. In a study of brain waves, 40 healthy adults showed increased activity of β waves and did better in math tests following inhalation of the essential oil of lavender. In turn, patients have been reported to feel relaxed and exhibit a positive attitude to life, which was accompanied by drowsiness [36].

Experiments conducted in humans in order to examine the soporific properties of lavender have shown that lavender oil aromatherapy leads to longer sleeping times, and, in the case of patients requiring hypnosis, results in a reduced use of drugs [37]. A clinical study on a group of 245 individuals showed that 72% of patients inhaling lavender oil experienced sound sleep, as compared

to only 11% in the control group. Four out of five patients subjected to the treatment reported a general feeling of well-being, in contrast to only 25% in the control group [38].

Lavender (*L. angustifolia*) also exhibits anxiolytic activity, as confirmed by a study conducted on pigs. A marked reduction in the incidence and severity of motion sickness (as measured by the concentration of cortisol in saliva) was observed in animals when the floor of the vehicle was covered by lavender [39]. In a randomized clinical trial conducted in 122 patients in critical condition, it was found that essential oil aromatherapy decreased anxiety, as compared to patients receiving a massage without aromatherapy and those who rested. There was no difference in blood pressure and state of respiratory tract between the two groups of patients [40]. A study involving the waiting room of a dental surgery has shown that aromatherapy with lavender essential oil reduces their anxiety related to the expected unpleasant sensations [41]. Yamada et al. [42] demonstrated that lavender essential oil administered by inhalation or intraperitoneally blocks convulsions caused by pentylenetetrazol or nicotine.

The essential oil of lavender also has an antispasmodic effect by increasing the levels of messenger cAMP, but the exact mechanism of this is unclear [43]. The *in vitro* studies have proven this essential oil to have analgesic activity [44], and experiments on rabbits have revealed its anesthetic properties [45]. Massage with lavender essential oil reduced the need for pain relievers among young patients with HIV, and in some cases removed pain completely [46].

Inhalation of lavender essential oil by rabbits has contributed to reduced content of cholesterol and atherosclerosis in aorta, but had no effect cholesterol levels in serum [47]. Studies have shown that inhalation of the essential oil of lavender causes a reduction in systolic and diastolic blood pressure and lowers the heart rate [48]. Lavender essential oil helps in the treatment of digestive disorders, regulates bowel movements and the biliary tract, also prevents against flatulence. Studies on rats have shown that inhalation of lavender essential oil can increase bile secretion [49] and restore normal activity of the oxidative enzymes involved in catabolism [50]. In the guinea pig, the essential oil of lavender was found to be a smooth muscle relaxant inhibiting the contractile response of acetylcholine and histamine [51, 52].

Lavender is considered to be both an aphrodisiac and a good remedy for hair growth. Gruss and Hirsch [53] conducted clinical trials on a group of 31 men who inhaled 30 different scents and found that the lavender aroma and pumpkin dough caused the largest increase in blood flow to the penis – by 40% as compared to the control. This indicates the potential use of odoriferous substances for the treatment of sexual disorders. Essential oil of lavender is also good for hair growth – a group of 86 patients with alopecia areata was subjected to massage with essential oils, including lavender, for seven weeks, which was found to improve hair growth in almost half of the patients [54].

Lavender hydrolates have not only refreshing and calming properties but also

help to treat insomnia and headaches. They are recommended for skin conditions and burns [24, 26, 55]. Both hydrolates and fluidolates of lavender can be successfully used in natural and organic cosmetic products. It is expected that fluidolates may have similar properties, judging by their chemical composition, but research in this area is still ongoing.

Presented literature review indicates that both lavender (*L. angustifolia*) and its secondary metabolites have multidirectional biological activity. Our research has shown that lavender grown in Poland is a valuable plant resource with chemical and biological properties similar to French lavender, and thus should attract greater interest among local herb producers.

It seems that modern medicine should pay attention to the synergistic action of plant secondary metabolites and synthetic drugs, as they may help solve many problems, including microbial resistance to synthetic antibiotics.

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LAWENDA WĄSKOLISTNA (*LAVANDULA ANGUSTIFOLIA*) – LECZNICZA SIŁA NATURY. PRZEGLĄD

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Streszczenie

Lawenda wąskolistna (*Lavandula angustifolia*) to krzewiasta roślina z rodziny jasnotowatych (*Lamiaceae*), pochodząca z terenów basenu Morza Śródziemnego. Surowcem zielarskim są kwiaty lawendy (*Lavandula flores*), zawierające olejek eteryczny (do 3%), antocyjany, fitosterole, cukry, związki mineralne i garbniki. Skład jakościowy i ilościowy olejku eterycznego z lawendy jest zmienny i zależy od genotypu, miejsca uprawy, warunków klimatycznych, sposobu rozmnażania i cech morfologicznych. W olejku eterycznym wstępuje ponad 300 związków chemicznych, składnikami dominującymi są linalol, octan linalilu, terpinen-4-ol, octan lawandulolu, ocymen oraz cyneol. Olejek eteryczny charakteryzuje dobra aktywność przeciwdrobnoustrojowa i antyoksydacyjna oraz wyraźny pozytywny wpływ na układ trawienny i nerwowy. Ekstrakt z lawendy przeciwdziałała otępieniu oraz może wpływać hamująco na rozwój komórek rakowych, zaś hydrolat lawendowy zalecany jest w leczeniu problemów skórnych i poparzeń.

Słowa kluczowe: *lawenda wąskolistna, Lavandula angustifolia, ziołolecznictwo, olejek eteryczny, fitoterapia, wtórne metabolity roślinne*