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Juniperus communis L.: A review of volatile organic compounds of wild and cultivated common juniper in Lithuania

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Juniper (*Juniperus communis* L.) is a common wild or cultivated plant, mainly distributed in the Northern hemisphere. The plant, being one of three natural conifers in the countries of the Baltic Sea region, grows separately or forms stands in Lithuania. It is an evergreen, long-lived shrub or a small tree.

Juniper synthesizes various (quantitatively and qualitatively as well) volatile organic compounds depending on the plant origin, organ and developing stage. Essential oils are prepared from different parts of juniper. Juniper berries, the fruit of *J. communis*, perhaps the most valuable part of the plant, are rich in essential oils. Preparations of them are used traditionally in folk medicine and veterinary as antiseptic, diuretic, anti-helminthic, anti-fungicidal, anti-rheumatic, antibacterial, tonic and anti-inflammatory remedy.

This paper reviews the published information concerning data on the chemical composition of essential oils obtained from various plant organs (sprouts, shouts, ripe and unripe berries, leaves, wood and bark) of junipers wild growing (or cultivated) in different localities in Lithuania. Alfa α-pinene is the most common constituent determined in Lithuanian juniper essential oils. This monoperpe hydrocarbon was evaluated as a predominant compound in most of investigated oils, obtained from juniper shoots, sprouts, needles and cones (both unripe and ripe ones).

Keywords: *Juniperus communis* L., essential oils, α-pinene and its enantiomers, sabinene, myrcene, β-phellandrene, longifolene, longiborneol, β-caryophyllene and its oxide, 1-epi-cubenol, δ-cadinene, nootkatone

INTRODUCTION

Juniperus genus (around 70 species) is attributed to the cypress family *Cupressaceae*, which contains both junipers and redwoods (up to 140 species in total).

Three sections are attributed to the genus; and one of the sections is *Juniperus* (syn: sect. *Oxycedrus* Spach), containing 12 species [1]. *Juniperus communis* (*Cupressaceae* Rich. Ex Bartl.), a highly variable taxon common around the Northern hemisphere, has the widest distribution of any juniper species. It is the only species found on both Eastern and Western hemispheres. The clustering data of RAPD molecular markers showed that the *communis* complex formed three groups: (1) *J. communis* var. *communis* and *J. communis* var. *saxatilis*,

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(2) *J. communis* var. *sibirica* (syn. *J. sibirica*) and (3) *J. communis* var. *oblonga* (syn. *J. oblonga*) [1].

Juniperus communis L. (known as a common juniper) is a volatile secondary metabolite-bearing and wide-spreading coniferous plant in the world, including the Baltic sea region, where it is one of three natural conifers. Juniper grows both separately (as individuals) and forming colonies. A wide ecological range is typical of *J. communis.* Several recent studies have focused on the research of biotic and abiotic environmental conditions and genetic diversity of Lithuanian populations of common juniper [2–5]. The plants grow mostly in dry pinewoods, mixed forests, on river slopes, in maritime conditions, being light demanding, but also shade tolerant [6]. Light (sandy), medium (loamy) and heavy (clay) soils are preferred growing localities for the plants; they can grow in very acidic and very alkaline soils. However, it was observed growing in dry or moist soil as well. A detailed research of morphological characteristics of juniper leaves (needles) and unripe cones (berries), and their correlation with soil parameters (such as: soil acidity, quantity of organic nitrogen, mobile phosphorus, mobile potassium and humus) and illumination intensity has been performed [5]. Even more, a correlation between morphological characteristics, ecological conditions and essential oil composition (mainly of pinene isomers (α- and β-) and yield) has been shown in the study above.

A few pure juniper stands with areas exceeding 1.0 ha have left in Lithuania. We should mention the Juniper Valley, a botanical reserve in the Arlaviškės Village (Lagoon Regional Park of Kaunas) on a steep slope of the Nemunas River. The Juniper Valley is included in the Natura 2000 Network.

Common juniper, an important forest tree species, is an evergreen, long-lived (up to 600 years) shrub or small tree with characteristic berries. It is a wind-pollinated and very slowly growing plant (about 20 cm in height during 5 years). The blooming period of junipers is in April–May. Their seed cones (berries) are matured in late autumn of the second year; therefore, both second-year unripe (of green colour) cones and third-year ripe (of blue or black colour) cones grow simultaneously on the same plant [7]. However, it has been evaluated that unripe cones are heavier than ripe ones [8]. In the study above [8], most probably that for the first time, dynamics of accumulation of phytoncides and essential oil in *Juniperus communis* of Lithuanian origin were studied.

Juniper has been used since ancient times, mainly for medical aims. Due to the strong and disinfectant odour, the plant has been applied for protective purposes (fields and crops against pests, animals and humans during epidemic diseases, etc.); and for many spiritual ceremonies (as well known 'verbos' (palms) prepared of juniper twigs are used during the Palm Sunday celebration). Preparations of the plant have been applied both in folk medicine and veterinary. Extracts of juniper possess diuretic, antiseptic, carminative, anthelminthic, antibacterial, antifungal, antiviral, antioxidant, anti-inflammatory, anti-rheumatic and other properties [9, 10]. The cones (berries) of *J. communis* (known as *Juniperi pseudofructus*) are used for healing cystitis, digestive problems, in therapy of chronicle arthritis and other disorders. The cones are edible, could be applied for food preservation; they are also as ingredients in many alcoholic beverages (beers, wines, liquors, etc.), in coffee and tea as well. The berries contain essential oil with a characteristic conifer-like aroma and bitter taste. Juniper-berry oil is included in some National Pharmacopoeias (of Poland, Austria, Italy, Switzerland, Germany, etc., and in Martindale: Complete Drug Reference). The European Pharmacopoeia 6th edition (issued in 2007) listed 28 essential oils; among them juniper oil (*Juniperi aetheroleum*) is counted. *J. communis* berry oil is a very good mosquito repellent; it is applied also in aromatherapy and in pharmaceutical preparations. It should be mentioned that essential oils could be obtained from all juniper parts (shoots, cones (ripe and unripe berries), leaves (needles), bark, wood). In Lithuania, the main producer and distributor of juniper essential oils is JSC 'Mėta', using raw material of ecological origin. The essential oils are made of crushed juniper berries, twigs and crushed wood, using a steam distillation procedure. Juniper oils of this company available on market are enriched additionally by some natural components, such as citronellol, geraniol and limonene.

The paper reviews already (during last fifteen years) published data from more than ten scientific articles on essential oils of juniper (*J. communis*) growing wild or cultivated in Lithuania.

CHEMICAL VARIABILITY OF THE ESSENTIAL OILS OF LITHUANIAN ORIGIN JUNIPERS (*JUNIPERUS COMMUNIS* L.)

The detailed compositional variation on the volatile chemistry of junipers of different populations and plant organs was presented in Tables 1 and 2 [5, 11–22]. Amounts of essential oils varied drastically according to the plant organ: from 0.075% in the bark up to 4.2% (v/w, on a dry weight basis) in the unripe berries (Table 1). Unripe cones being heavier than ripe ones accumulate on average 2.5 times more essential oils (0.3–4.2%) than ripe cones (~0.9%) and up to six times than leaves (0.1–0.9%). An evident variability in the essential oil yield in the cones and leaves of *J. communis* could be explained by a different structure of the secretory elements in these organs. The needles, which contain ducts and transfusion tissue, act as conduction structures, and the berries containing elongate tubercles which have a function of volatile oils reservoirs [23]. The intraspecific variability of the essential oil quantity was higher in unripe cones than in leaves. The content of the oil in sprouts and branches (0.2 and 0.16%, respectively) was almost equal.

It is evident that alfa α-pinene is a characteristic and the most common major constituent determined in Lithuanian juniper essential oils. This monoterpene hydrocarbon was evaluated as a predominant compound in the most investigated oils (in 370 oil samples), obtained from juniper shoots, sprouts, needles and cones (both unripe and ripe ones) (Tables 1 and 2; Fig. 1). It should be mentioned that alfa α-pinene is also a characteristic compound for essential oils of *J. communis* growing in other world countries. In general, the leaf and berry oils (both unripe and ripe ones) of common juniper are mostly of α-pinene chemotype [1, 24–36].

Table 1. **The main chemical composition (%) of essential oils from different plant organs of *J. communis* growing in Lithuania**

Collecting site [b]	Plant organ	Essential oil yield, %[c]	Main composition	Reference
Vilnius d. four localities: Družilai v., Pagiriai v., Rūdininkai forest and Bezdonys v.	Fresh ripe (black) and unripe (green) berries, small and big shrubs	* In unripe berries ~1.2, in ripe berries ~0.9	α-Pinene (39.7–64.9), myrcene (4.8–19.6), α-cadinol (2.7–7.1), terpinen-4-ol (≤6.1)	[11]
Vilnius d. six locations: Bezdonys v., Lazdėnai v., Družilai v., Pagiriai v., Rūdininkai v. and Nemenčinė v.	Fresh needles (leaves)	** ~0.37	α-Pinene (38.5–59.9), β-phellandrene (≤11.4), α-cadinol (≤8.7), γ-cadinene (≤6.2), 14-hydroxy-α-humulene (6.2)	[12]
North-Eastern Lithuania, five habitats: Vilnius City, Baldis Lake, Utena d. Svėdasai v., Vilnius d. Bezdonėlė River, Švenčionys d. Švenčionėliai v. and Vilnius d. Dūkštos v.	Fresh ripe berries (black)	** ~0.9	α-Pinene (21.0–46.3), myrcene (7.6–17.4), terpinen-4-ol (9.6), α-terpineol (≤6.0)	[13]
North-Eastern Lithuania, five habitats: Vilnius d. Bezdonys v., Varėna d. Pirčiupiai v., Švenčionys d. Švenčionėliai v., Trakai d. Paluknys v. and Ropėjai v.	Leaves (needles)	** ~0.37	α-Pinene (40.3–66.5), δ-3-carene (≤5.2)	[14]
Vilnius d. five habitats: Družilai v., Pagiriai v., Rūdininkai forest, Bezdonys v. and Nemenčinė v.	Fresh twigs with unripe (green) and ripe (black) berries, fresh leaves	** In unripe berries ~1.2, in ripe berries ~0.9, in needles ~0.37	α-Pinene (27.7–64.9), myrcene (≤19.6), β-phellandrene (≤9.1), terpinen-4-ol (6.1), α-cadinol (≤8.7)	[15]

Table 1. **(continued)**

Collecting site [b]	Plant organ	Essential oil yield, %[c]	Main composition	Reference
Druskininkai d. (precise collecting sites not indicated)	Wood, needles, unripe and ripe berries	** In unripe berries ~1.2, in ripe berries ~0.9, in wood ~0.22, in needles ~0.37	Wood: α-pinene (15.9–31.0), nootkatone (18.4); leaf, unripe and ripe berries: α-pinene (42.4–67.4); ripe berries: myrcene (≤13.8), unripe berries: spathulenol (5.6)	[16]
Thirty-four habitats: Druskininkai d. Leipalingis v., Kaunas d. Arlaviškės v., Vilnius d. (around the lakes Baldis and Tapeliai), Dūkštos v., Šilėnai v., Nemenčinė v. and Bezdonys v., Šalčininkai d. Gelūnai v., Molėtai d. Suginčiai v. and Plavėjai v., Trakai d. Rudiškės v. and Paluknys v., Anykščiai d. Svėdasai v., Ignalina d. Dūkštas Lake and Varėna d. Zervynos v.	Fresh needles, berries (unripe and ripe)	** In needles ~0.37%, in unripe ~1.2 and ripe berries ~0.9	Needles: α-pinene (11.7–66.5), sabinene (34.1–40.8), terpinen-4-ol (6.9–9.3); berries: α-pinene (21.0–67.4); unripe berries: sabinene (6.3–19.6), myrcene (4.3–12.8), terpinen-4-ol (13.1); ripe berries: myrcene (7.8–18.7), terpinen-4-ol (3.2–9.6)	[17]
Plants cultivated in the field collection of the Institute of Botany (Vilnius)	Unripe and ripe berries of two morphotypes (with light-green and bluish-green berries)	*** (due to a low amount of plant material, it was not possible to collect pure oil)	α-Pinene (26.8–42.7), myrcene (9.2–25.4), β-caryophyllene ≤11.4, caryophyllene oxide ≤17.9	[18]
Eleven habitats across Lithuania (110 samples = trees) (precise collecting sites not indicated)	Leaves and unripe cones (berries)	*** (yield not indicated)	(1R)-(+)-α-Pinene in leaves 74 ± 1(SD); in unripe cones 69 ± 2(SD); (1S)-(–)-α-pinene: in leaves 26 ± 1(SD); in unripe cones 31 ± 2(SD)	[19]
Eleven natural habitats (samples 110): Kaunas d. Arlaviškės v., Kaišiadorys d. Sekionys v., Trakai d. Savaitiškės v., Skuodas d. Šaukliai v., Zarasai d. Bradesiai v., Ignalina d. Šuminai v., Šalčininkai d. Tetervinai v., Varėna d. Degsnės v., Šalčininkai d. Rudnia v., Kelmė d. Peleniai v. and Ignalina d. Ginučiai v.	Leaves and unripe cones	*** In unripe cones 1.3 ± 0.63 (SD), in leaves 0.4 ± 0.14 (SD)	Average means of α-pinene 54.1 ± 13.9(SD) in leaves and 58.0 ± 4.6(SD) in unripe cones	[20]
Eleven natural habitats (samples 110) (collecting sites are the same as in [20])	Leafy twigs with unripe cones	*** In unripe cones 0.3–4.2, in leaves 0.1–0.9	(1*R*)-(+)-α-Pinene: 74 ± 13(SD) in leaves; 69 ± 17(SD) in unripe cones; 26 ± 13(SD) in leaves; 31 ± 17(SD) in unripe cones	[21]
Eleven natural habitats (the same as in [19, 20])	First-year (unripe) cones; current-year shoots	*** In leaves 0.1–0.9 (0.4 ± 0.14 (SD)); in unripe cones 0.3–4.2 (1.3 ± 0.64% (SD))	α-Pinene: in leaves 58.9 ± 14.2(SD); in unripe cones 53.9 ± 14.2(SD)	[5]

Table 1. **(continued)**

Collecting site [b]	Plant organ	Essential oil yield, %[c]	Main composition	Reference
Eastern Lithuania: Anykščiai d. Svėdasai v. and Elektrėnai d. Vievis v.	One-year old sprouts, leaves (needles), branches (without needles), bark from stem, peeled wood (of ~5 cm diameter, without peel)	*** In sprouts ~0.2, in leaves 0.34–0.46, in branches ~0.16, in bark ~0.075, in wood ~0.06	α-Pinene: in sprout (43.5–57.1%), in needle (31.0–44.7%) and in shoot (25.4–46.3%) oils. Longifolene (25.3–28.8%) and longiborneol (10.8–11.6%) in bark oil. 1-epi-Cubenol (≤10.5%) and δ-cadinene (≤13.4%) in wood oil	[22]

[a] Data presented in a chronological order; [b] abbreviations: d. is district, v. is village; [c] essential oil yield was expressed in v/w percentage on a dried weight basis;
* time of hydro-distillation procedure not indicated;
** time of hydro-distillation 3 h;
*** duration of hydro-distillation 2 h.

Table 2. **Available detailed composition (three main constituents) of Lithuanian juniper essential oils obtained from different plant parts [11–18, 22]**

Plant organ	The first, %	The second, %	The third, %	Literature
Shoots	α-Pinene 25.4–46.3 (*n* = 2)	Limonene 5.5 (*n* = 1), δ-3-carene 9.1 (*n* = 1)	δ-3-Carene 3.5 (*n* = 1), β-caryophyllene 5.7 (*n* = 1)	[22]
Sprouts	a-Pinene 43.5–57.1 (*n* = 2)	Limonene 5.5 (*n* = 1), α-cadinol 6.0 (*n* = 1)	Myrcene 4.1 (*n* = 1), α-cadinol 4.0 (*n* = 1)	[22]
Unripe cones (berries)	α-Pinene 22.2–67.4 (*n* = 24)	Myrcene 3.9–25.4 (*n* = 17), sabinene 10.2 (*n* = 1), terpinen-4-ol 13.1 (*n* = 1), α-cadinol 8.2 (*n* = 1), spathulenol 5.6 (*n* = 1), caryophyllene oxide 12.9–17.9 (*n* = 3)	Myrcene 4.3–14.7 (*n* = 5), sabinene 6.3–12.3 (*n* = 3), β-pinene 2.2 (*n* = 1), trans-verbenol 5.1 (n = 1), α-cadinol 2.8–4.5 (*n* = 5), caryophyllene 10.2–11.4 (*n* = 6), caryophyllene oxide 11.0–13.1 (*n* = 3)	[11, 15–18]
Ripe cones (berries)	α-Pinene 20.3–59.2 (*n* = 21)	Myrcene 6.2–24.4 (*n* = 19), α-terpineol 4.6 (*n* = 1), α-cadinol 8.6 (*n* = 1)	Myrcene 6.3 (*n* = 1), terpinen-4-ol 3.2–9.6 (*n* = 6), α-terpineol (2.9–6.0 (*n* = 3), α-cadinol 3.4–7.1 (*n* = 6), p-mentha-1,5-dien-8-ol 4.5 (*n* = 1), caryophyllene 9.8–11.3 (*n* = 2), caryophyllene oxide 5.6–10.0 (*n* = 2)	[11, 13, 15–18]
Leaves (needles)	α-Pinene 38.5–66.5 (*n* = 17), sabinene 34.1–40.8 (*n* = 4)	α-Pinene 11.0–27.8 (*n* = 4), β-phellandrene 2.2–12.5 (*n* = 10), myrcene 4.4–4.7 (*n* = 2), δ-3-carene 3.5 (*n* = 1), limonene 6.9–9.8 (*n* = 2), trans-pinocarveol 3.6 (*n* = 1), α-cadinol 8.7 (*n* = 1)	β-Pinene 3.9 (*n* = 1), myrcene 2.1–3.4 (*n* = 2), sabinene 4.3–4.6 (*n* = 2), δ-3-carene 3.6–5.2 (*n* = 3), β-phellandrene 3.0 (*n* = 1), p-mentha-1,5-dien-8-ol 2.6 (*n* = 1), terpinen-4-ol 6.9–9.3 (*n* = 3), δ-cadinene 6.2 (*n* = 1), α-cadinol 3.3–8.7 (*n* = 7)	[12, 14–17]
Wood	α-Pinene 31.0 (*n* = 1), nootkatone 18.4 (*n* = 1)	δ-Pinene 15.9 (*n* = 1), p-mentha-1,5-dien-8-ol 4.5 (*n* = 1)	δ-3-Carene 4.0 (*n* = 1), α-cadinol 3.8 (*n* = 1)	[16]
Debarked wood	δ-Cadinene 13.4 (*n* = 1), 1-epi-cubenol 10.5 (*n* = 1)	δ-Cadinene 7.2 (*n* = 1), 1-epi-cubenol 10.0 (*n* = 1)	Cubenol 7.0 (*n* = 1), unknown compound 7.0 (M^+ 284) (*n* = 1)	[22]
Bark	Longifolene 25.3–28.8 (*n* = 2)	Limonene 15.1 (*n* = 1), longiborneol 10.8 (*n* = 1)	δ-3-Carene 4.8 (*n* = 1), longiborneol 11.6 (*n* = 1)	[22]

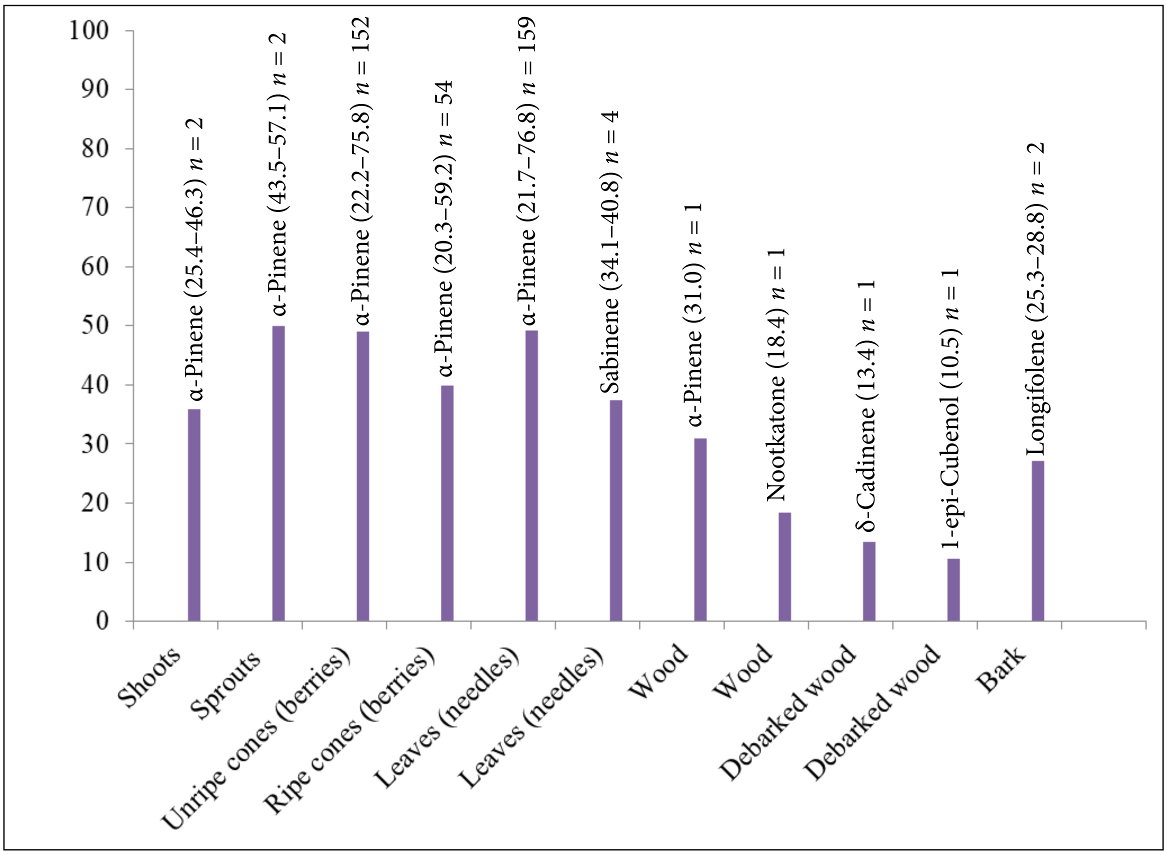

Fig. 1. Percentage of the first principal constituent in various organs of Lithuanian juniper (*Juniperus communis* L.) essential oils investigated by different authors [11–18, 20, 22]

Most of the terpenes present in nature are chiral compounds, and they may exist in one form (when one optical isomer significantly predominates over other, the so-called enantiomerically pure (anantiopure)) or as an enantiomeric mixture. Usually, physical and chemical properties of enantiomers are different, so subsequently their biological activities as well. Enantiomers often react in a different way with other enantiomer compounds. For example, often only one enantiomer is responsible for the desired physiological activity in pharmaceuticals, while the other enantiomer is less active or sometimes even exhibits undesirable effects.

It is well known that most of monoterpene hydrocarbons determined in juniper essential oil exhibit optical activity. *α*-Pinene, being one of the most predominant and characteristic components of juniper essential oils, exists in both enantiomeric forms, dextrorotatory (1R)-(+) and laevorotatory (1S)-(–). Even more, various isomers of the same compound may possess different odour characteristics; it depends on the exact ration of the optical isomers. The (1R)-(+) enantiomer of α-pinene contains some minty fragrance notes, whereas the (1S)-(–) enantiomer exerts a characteristic pine tree aroma [37]. Several papers were devoted to the enantiomeric analysis of α-pinene in Lithuanian juniper essential oils (Table 1, Fig. 2) [18–21, 38]. The first paper concerning this topic was published in 2010 [18], where raw material was gathered from cultivated plants in the field collection and berries of different morphotypes (distinguished by light-green and bluish-green colour) were selected for the study. The quantity of (1R)-(+)-α-pinene was 66.5–88.5% and the percentage of (1S)-(–)-α-pinene was 11.5–33.5% in unripe berries during April–September. In ripe berries during this time period, amounts of α-pinene laevorotatory form ((1S)-(–)-) and dextrorotatory ((1R)-(+)-) varied from 11.1–31.6% and 68.4–88.9%, respectively. In the study above, the ratio of (1R)-(+) and (1S)-(–) enantiomers was 6.4–8.0 in the oils of light-green berries and 2.0–2.2 in the oils from another morphotype, with bluish-green berries. The obtained results clearly demonstrated that the berries during ripening

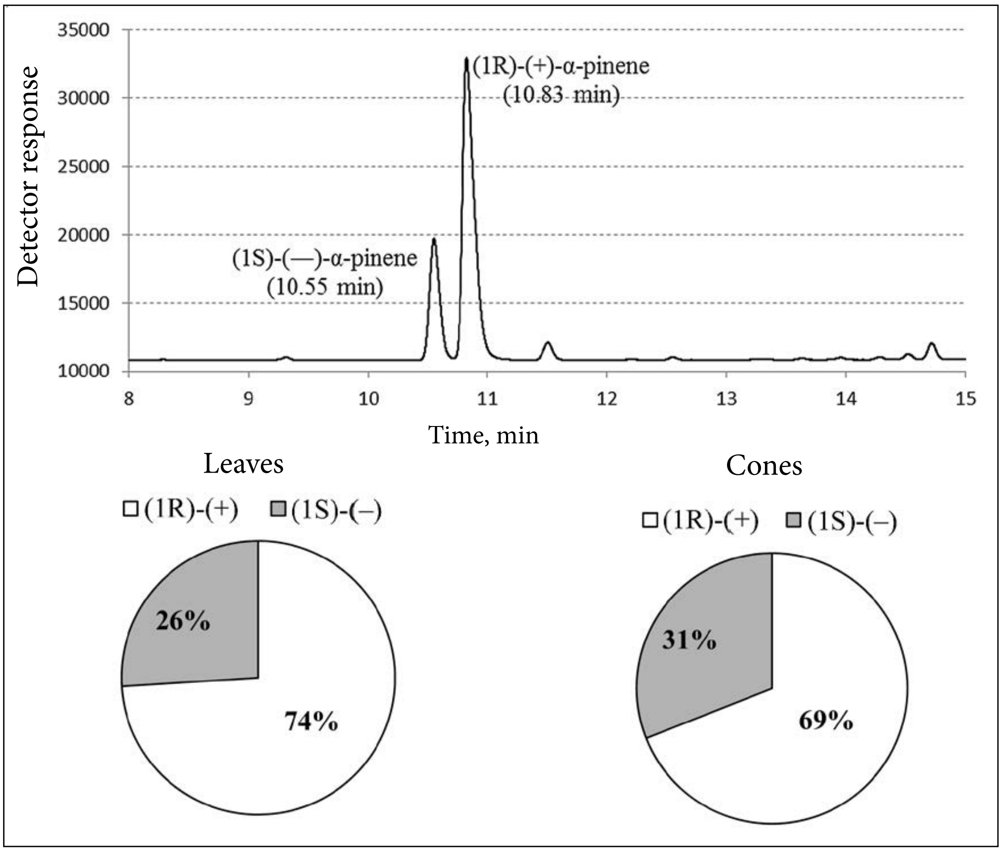

Fig. 2. (Taken from [38]). Ratio of (1R)-(+)-α-pinene and (1S)-(–)-α-pinene (determined by chiral chromatography) in essential oils of leaves and cones of *Juniperus communis* L. growing wild in Lithuania [38]

produced constant proportions of (1R)-(+) and (1S)-(–)-α-pinene enantiomers during all harvesting periods [18].

Another study on essential oils of 110 individual juniper tress (from eleven habitats over all the territory of Lithuania) has shown that most of leaf and unripe cone samples were rich in (1R)-(+)-α-pinene [19]. Leaves and unripe cones contained approximately equal amounts of this monoterpene (average means of α-pinene 54.1 ± 13.9 (SD) in leaves and 58.0 ± 4.6 (SD) in unripe cones, 54.1 SD 13.9% and 58.0 SD 14.62%, respectively) [20]. However, a total predomination of the (1R)-(+)-α-pinene was determined neither in leaves nor in unripe cones. (1R)-(+)-α-pinene prevailed over (1S)-(–)-α-pinene amounting to 74 ± 13% in leaves and 69 ± 17% in unripe cones; and 26 ± 13% in leaves and 31 ± 17% in unripe cones, respectively [21]. Laevorotatory form (1S)-(–)-α-pinene predominated only in 2.7% samples of leaves and in 10.9% of unripe cones. A prevalence of (1S)-(–)-α-pinene was observed in leaf oils only of two *J. communis* individuals [19]. Additionally, it was established that amounts of α-pinene and its enantiomeric composition did not correlate significantly with sun illumination and soil characteristics of habitats neither in leaves nor in unripe cones [20]. The variability of percentages of α-pinene enantiomers and amounts of the essential oils was higher in unripe cones than in leaves [21].

The literature sources report different conclusions about the enantiomeric composition of this monoterpene in different parts of plants. Sometimes the ratio of R and S enantiomers of alfa α-pinene depends on the tissues or organ of the plant, but sometimes the monoterpene composition remains constant in the whole plant. Studies of juniper essential oil samples collected from different locations in Europe showed that the ratio of alfa α-pinene enantiomers may vary drastically. It was documented that *J. communis* berries and leaves collected from different populations in Austria, France, Italy and central Poland accumulated more (1S)-(–)-α-pinene than (1R)-(+)-α-pinene; and in some cases the amount of (1S)-(–) enantiomer riched up to 80% in the berries and 100% in the leaf oils [39, 40]. In contast, an opposite ration (levo-enantiomer prevailing over the (1S)-(–)-α-pinene, as the same tendency is characteristic of Lithuanian samples) was determined in juniper raw material collected in Finland and in the northern part of Poland [40, 41].

Besides numerous juniper essential oils of α-pinene chemotype, only several oils (4 samples) of sabinene type were determined for the needles (Tables 1 and 2) [17]. Junipers synthesising sabinene chemotype needle oils are growing in Druskininkai (Leipalingis v.), Kaunas (Arlaviškės v.) and Vilnius (near Baldis Lake) districts. Even more, in the study above it was found for the first time that needles and berries of the same plants produced essential oils of different chemotypes. Some needle essential oils of *J. communis* from Scandinavian countries, Poland, Iran, Portugal, France (Corsica Island), India and Italy (Sardinia Island) contained also predominant amounts of sabinene [23, 28, 30, 31, 40–45].

α-Pinene prevailed in Lithuanian juniper oils obtained from the first-year sprouts and shoots (Table 2) [22]. This monoterpene has been determined in amounts up to 62.0% in juniper branch oils of Estonian origin [45].

It is evident that to summarise the results on the juniper wood and bark volatile composition is quite complicated because of a very limited number of the investigated samples (Table 2) [16, 22]. Juniper wood oils were characterized by α-pinene (15.9–31.0), nootkatone (18.4) and δ-cadinene (≤13.4%), while debarked wood contained as predominant compounds δ-cadinene (13.4%) and 1-epi-cubenol (10.5%) in the studies above. Longifolene (25.3–28.8%) and longiborneol (10.8–11.6%) were the main compounds in the bark oil [22]. To the best of our knowledge, there are no available already reported data concerning juniper debarked wood and bark essential oils investigated in other countries. Sesquiterpenoids prevailed in *J. communis* wood oils from the South-Western part of France and Sweden [1, 29]. The monoterpenoid fraction with the main compounds, such as α-pinene, p-cymene limonene, β-phellandrene, α-terpineol and α-terpenyl acetate, has been determined as the major one in wood oils of junipers growing in different lacations in Poland, Corsica and Sardinia islands [40, 47, 48]. There is no data available on the chemical composition of Lithuanian juniper root essential oils, though this part of *J. communis* has been investigated in other countries [47].

Up to date, there is no available research on biological activities of Lithuanian juniper essential oils. However, α-pinene (being one of the most predominant constituents in the juniper oil) was tested on bacteria, yeasts and fungi [49]. This monoterpene with various enantiomeric compositions was extracted from *J. communis* growing in Lithuania. The results of the above-mentioned study showed that various enantiomeric composition of α-pinene had different impact on microorganisms: essential oil with the (1S)-(–) ≈ (1R)-(+) composition of α-pinene (the so-called racemate) influenced some microorganisms stronger than essential oil with the (1S)-(–) < (1R)-(+) ratio of α-pinene. Pure natural α-pinene with the enantiomeric composition S < R more strongly inhibited the growth of the investigated bacteria and *Candida* yeasts, α-pinene with the ratio of S ≈ R inhibited the growth of *Trichophyton* and *Aspergillus*. (1S)-(–) and (1R)-(+) enantiomeric forms of α-pinene can also have different synergistic effects with other constituents of the essential oil. The results of the study show that the same amount of α-pinene with different enantiomeric ratio can have diverse antimicrobial potential due to different specific interactions with other chemical components of essential oil [49].

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Asta Judžentienė

APŽVALGINIS STRAIPSNIS: LAKIEJI ORGANINIAI JUNGINIAI, NUSTATYTI LAUKINIUOSE AR LIETUVOJE AUGINAMUOSE KADAGIUOSE (*JUNIPERUS COMMUNIS* L.)

Santrauka

Kadagys (*Juniperus communis* L.) yra natūraliai augantis arba auginamas augalas, plačiai paplitęs Šiauriniame žemės pusrutulyje. Šis augalas – vienas iš trijų Baltijos jūros regiono šalių natūralioje gamtoje aptinkamų spygliuočių, Lietuvoje jis auga pavienis arba kolonijomis. Tai visžalis, ilgaamžis krūmas arba nedidelis medis. Kadagiai sintetina įvairius lakius organinius junginius, jų sudėtis (tiek kiekybiškai, tiek ir kokybiškai) priklauso nuo augalo dalies bei augimo stadijos. Kadagio eteriniai aliejai yra išgaunami iš įvairių jo dalių. *J. communis* uogos (arba vaisiai) yra bene vertingiausia augalo dalis, kurioje gausu eterinių aliejų. Uogos tradiciškai yra naudojamos tiek liaudies medicinoje, tiek ir veterinarijoje dėl antiseptinių, skysčius varančių, prieškirmėlinių, antifungicidinių, antireumatinių, antibakterinių, tonizuojančių ir priešuždegiminių savybių.

Straipsnyje apibendrinti kadagių, auginamų ir augančių įvairiose Lietuvos vietose, eterinių aliejų duomenys. Ištirtos skirtingos augalo dalys – ūgliai, šakelės, uogos (prinokusios ir neprinokusios), spygliai, mediena ir žievė. α-Pinenas yra charakteringas ir dažniausiai randamas komponentas kadagių aliejuose. Šis monoterpeninis angliavandenilis buvo nustatytas kaip dominuojantis junginys daugumoje tirtų aliejų, išgautų iš kadagio ūglių, šakelių, spyglių ir uogų (tiek prinokusių, tiek ir neprinokusių).