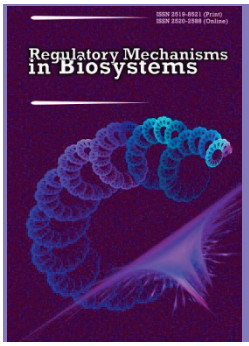

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Antibacterial and fungicidal activities of ethanol extracts from *Cotinus coggygria*, *Rhus typhina*, *R. trilobata*, *Toxicodendron orientale*, *Hedera helix*, *Aralia elata*, *Leptopus chinensis* and *Mahonia aquifolium*

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The search for promising plants with bactericidal and fungicidal activity is of great interest for practical and veterinary medicine, This article reveals the high antibacterial effect of the use of ethanol extracts from 8 species of plants of the families Anacardiaceae (*Cotinus coggygria* Scop., *Rhus typhina* L., *Rhus trilobata* Nutt. and *Toxicodendron orientale* Greene), Araliaceae (*Hedera helix* Linnaeus and *Aralia elata* (Miq.) Seem.), Phyllanthaceae (*Leptopus chinensis* (Bunge) Pojark.), Berberidaceae (*Mahonia aquifolium* (Pursh) Nutt.) against 23 strains of bacteria and one strain of fungi. The *in vitro* experiment revealed the zone of inhibition of growth of colonies exceeding 8 mm during the application of ethanol extracts of *C. coggygria* against twelve species of microorganisms (*Enterococcus faecalis*, *Escherichia coli*, *Staphylococcus aureus*, *S. epidermidis*, *Bacillus cereus*, *Listeria ivanovi*, *Corynebacterium xerosis*, *Rhodococcus equi*, *Proteus vulgaris*, *P. mirabilis*, *Serratia marcescens* and *Candida albicans*), *Rhus typhina* – against twelve species (*E. faecalis*, *E. coli*, *S. aureus*, *S. epidermidis*, *L. ivanovi*, *C. xerosis*, *Rh. equi*, *P. vulgaris*, *Salmonella typhimurium*, *S. adobraco*, *S. marcescens* and *C. albicans*), *Rhus trilobata* – against fourteen (*E. faecalis*, *E. coli*, *S. aureus*, *S. epidermidis*, *B. subtilis*, *B. cereus*, *L. ivanovi*, *C. xerosis*, *Rh. equi*, *P. vulgaris*, *P. mirabilis*, *Pseudomonas aeruginosa*, *Yersinia enterocolitica* and *C. albicans*), *Toxicodendron orientale* – against eleven (*E. faecalis*, *S. aureus*, *L. innocua*, *C. xerosis*, *Campylobacter jejuni*, *Rh. equi*, *P. vulgaris*, *P. mirabilis*, *P. aeruginosa* and *C. albicans*), *Hedera helix* – against seven (*S. aureus*, *S. epidermidis*, *L. monocytogenes*, *C. jejuni*, *Rh. equi*, *P. vulgaris* and *C. albicans*), *Aralia elata* – against nine (*E. coli*, *S. aureus*, *B. cereus*, *C. xerosis*, *P. vulgaris*, *P. mirabilis*, *S. typhimurium*, *S. marcescens* and *C. albicans*), *Leptopus chinensis* – only against four (*E. coli*, *S. epidermidis*, *B. cereus* and *P. mirabilis*) and *Mahonia aquifolium* – against only three species (*S. epidermidis*, *C. jejuni* and *P. vulgaris*). As a result of the research, the most promising for studying in future regarding *in vivo* antibacterial activity were determined to be *C. coggygria*, *Rhus typhina*, *R. trilobata*, *Toxicodendron orientale* and *Aralia elata*.

Keywords: growth inhibition zone; bacterial colonies; poly-resistant strain; candidiasis.

Introduction

Recently, reports have appeared with increasing frequency about the potential possibilities of the search for effective antibacterial substances in plant extracts in the context of the spread of antibiotic poly-resistant strains which are hard to treat (Zazharskyi et al., 2019a; Palchykov et al., 2020). Natural products produced by Embryophyta as secondary metabolites were found to be a rich source of biologically active compounds which may be the basis for the development of novel chemical substances for pharmaceutical preparations (Boyko & Brygadyrenko, 2016; Zazharskyi et al., 2019b; Palchykov et al., 2019). Plants contain a diverse group of very valuable and available resources of secondary metabolites, such as tannins, terpenoids, alkaloids and flavonoids with important pharmacological properties (Georgiev et al., 2014; Jeruto et al., 2017; Hussein & El-Anssary, 2019; Zazharskyi et al., 2019c). In general, herbal essential oils and extracts of many species of plants are considered as non-phytotoxic compounds and until now were surveyed only for presence of different types of biological activity, and their antimicrobial, anti-inflammatory, antioxidant, antimutagenic and anticancer effect have been partly described (Giriraju & Yunus, 2013; Matić et al., 2013; Kchaou et al., 2014).

Cotinus coggygria Scop., also known as smoke tree, is one of two species which compose a small genus of the Anacardiaceae family. It has a wide range extending from Southern Europe, the Mediterranean, Moldova and the Caucasus to Central China and the Himalayas (Novakovic et al., 2007). This plant is usually considered a large bush or small tree. The leaves are glaucous, simple, ovoid, 3–8 cm long. The flowers are pentagonal, pale yellow or yellow-green, hermaphrodite, or some of them are abortive, with long pedicels, in indeterminate inflorescences.

Plants of the Anacardiaceae family are well-known for their cultivated edible fruits and seeds, dermatitis-causing taxa (for example, *Comocladia*, *Metopium*, *Semecarpus*, *Toxicodendron*), medical compounds, valuable timber and varnish-bearing plants (*Toxicodendron* and *Gluta*). Many species of Anacardiaceae are also valuable for their attractiveness in gardens. Specimens of *Rhus*, *Schinus*, *Searsia*, *Pistacia chinensis* Bunge, *P. mexicana* Kunth, *Smodingium* and *Toxicodendron* are attractive because of their beautiful inflorescences, evergreen or bright-coluored autumn leaves. Some products of the species of the Anacardiaceae family, including mango (*Mangifera indica* L. and other species), pistachio (*Pistacia vera* L.), cashew (*Anacardium occidentale* L.) and rose pepper (*Schinus terebinthifolius* L.) are used in food all around the globe.

Rhus typhina L. is a fast-growing species which reproduces by rhizomes and seeds. Due to its biological advantages, this deciduous species of the Anacardiaceae family has been brought to urbanized landscapes of Ukraine from native areas in the East of North America. Dzhygan et al.

(2018) analyzed the changes in morphometric and physiological parameters of 12-year old plants of this species in artificial phytocenoses near the roads in Pavlohrad (Ukraine). Compared with plants in relatively clean zone, the greatest decrease in the length of annual shoots of the trees was observed in those at the distance of 25–40 m from the highway. Leaves of *R. typhina* contain several galloyltransferases which catalyze β-glucogallin-dependent transformation of 1,2,3,4,6-pentagalloylglucose to gallotannins, have excellent thermostability and high tolerance to cold (Niemetz & Gross, 2001). Allelopathy plays a role in the formation of resistance of *R. typhina* to invasion (Wei et al., 2017). Wang & Zhu (2017) suggest using *R. typhina* as an antioxidant in food, nutraceutical and cosmetic industries.

Methanol extract of leaves of *C. coggygria* was tested against seven strains of bacteria (*B. subtilis*, *S. aureus*, *E. coli*, *E. aerogenes*, *K. pneumoniae*, *P. vulgaris* and *P. aeruginosa*) using the method of disk diffusion. Extract from *C. coggygria* in the concentration of 10, 20 μg/mL and 1 mg/mL displayed moderate effect on all the named strains of bacteria (Singh et al., 2012).

Method of diffusion in agar was used to assess the activity of hexane, ethanolic and aqueous extracts from *C. coggygria* in the concentrations of 12.5, 25 and 50 mg/mL towards *Streptococcus mutans*, *S. sobrinus*, *Lactobacillus casei* and *Actinomyces viscosus*. Water and ethanolic extracts of *C. coggygria* demonstrated significant activity against all four indicated bacteria in all of the tested concentrations (Ferrazzano et al., 2013).

Essential oils from leaves with young shoots of *C. coggygria* in Serbia were tested for antibacterial and antifungal activities (Novaković et al., 2007). Essential oil produced inhibition zones measuring 6–23 mm. The largest inhibition zones were observed against species of *Staphylococcus* and *Micrococcus* genera, while the smallest were observed against *Proteus mirabilis*. Essential oil exerted higher antibacterial activity than streptomycin, which was used as positive control, except in the case of *P. mirabilis*. Bacteriostatic activity of the oil ranged within the concentrations of 2.5–5.0 μL/mL, while its bactericidal concentration – 2.5–10.0 μL/mL.

There are two major ways of action of antiviral agents: the first one is inhibiting infection, and the other is inhibition of replication of virus. The activity of the extract from *C. coggygria* against infection and replication was determined using the methods of local effect and disk method (Jing et al., 2012). Ethanol extract from leaves of *C. coggygria* exhibited especially strong inhibiting activity towards the infection with Tobacco mosaic virus (TMV – 93.5%), and significantly inhibited the replication of this virus (38.2%).

Ilczuk & Jacygrad (2016) assessed the efficiency of aqueous extract from *C. coggygria* in an *in vitro* experiment against the tissue factor in the samples of saliva obtained from clinically healthy people. Extract from *C. coggygria* caused increase in the buffer ability of the saliva, decrease in the number of bacteria and prevented the aggregation of bacteria.

Rendeková et al. (2015) determined the anti-biofilm activity of extract from *C. coggygria* against two strains from the collection and ten clinical strains of *S. aureus*. The tested extract exerted bactericidal activity against all strains of *S. aureus*, particularly strains sensitive to meticyllin (in the concentrations of 0.313–0.625 mg/mL) The concentrations of extract from *C. coggygria* which inhibited the formation of biofilm were 10–100 times higher (up to 32 mg/mL). Phytochemical analysis of *C. coggygria* detected quercetin, rhamnoside, methyl gallate and methyl trigallate as the main constituents of the extract. The results of the research revealed that *C. coggygria* is rich in tannins and flavonoids and is a promising local antibacterial preparation with anti-biofilm activity (Rendeková et al., 2015). *C. coggygria* is a commercial decorative plant with broad range of medical use. It is one of the most important species of trees used in ecological and landscape plantations in China, the main component of the landscape formed of red leaves in Beijing region in autumn (Wang et al., 2012; Fraternale & Ricci, 2018).

Species of the *Hedera* genus are widely used in greening. Researchers from Dresden University of Applied Sciences (Germany) are undertaking surveys on hydroponic facing of facades using Hedera (Koleva, 2015), as well as possibility of future optimization of these new ecosystems.

Hu & Wang (2008) demonstrated that arasolide A obtained from the seeds of *Aralia elata* (Miq.) Seem.) has anti-inflammatory activity which inhibits the production of NO and anti-cancer activity against SNU, cancer cells of AGS and cancer cells of melanoma, despite its low antioxidant activity. Hu & Wang (2008) presume that triterpene saponins from *A. elata* can play important role in displaying antibacterial and neuroprotective properties of tinctures of the plant.

Fadıloğlu & Çoban (2019) state that alcohol extract of *Rhus trilobata* Nutt. may be used as a natural antioxidant, antibacterial agent and glaze material for slowing of the oxidation of lipids and inhibition of loss of quality of frozen fish.

Zhang & Shi (2020) presume that correct addition of *Leptopus chinensis* (Bunge) Pojark. could be one of the strategies of feeding which improve the digestion and digestion of dietary fibre and potentially reduce deficiency in quality feed for ruminant animals, modeling the microbial community of scar.

Therefore, the species of plants we analyze in this paper remain unstudied regarding their antimicrobial activity and could have a significant potential for human and veterinary medicine. The objective of this article was determining the antibacterial effect of ethanol extracts from *Cotinus coggygria*, *Rhus typhina*, *R. trilobata*, *Toxicodendron orientale*, *Hedera helix*, *Aralia elata*, *Leptopus chinensis* and *Mahonia aquifolium* on separate species of microorganisms in *in vitro* experiments.

Materials and methods

The leaves and shoots of eight species of plants (Table 1) were collected in the territory of the Botanical Garden of Oles Honchar Dnipro National University (Khromykh et al., 2018; Boyko & Brygadyrenko, 2019), dried at room temperature, fragmented, weighed and maintained for 10 days in 70% ethyl alcohol, and filtered.

Antibacterial activity of the plant tinctures were determined using disk diffusion in agar. From daily culture of ethanol strains of microorganisms, we prepared weighed amounts according to the standard of opacity of bacterial suspension equaling 0.5 units of density according to McFarland (McF) 1.5×10^8 CFU (colony-forming units), which was determined using a densitometer (Densimeter II).

The obtained weighed amount was inoculated to Muller-Hinton agar (Himedia) with subsequent cultivation in TCO-80/1 thermostat for 24 h at the temperature of 37 °C. On top of the inoculations, we put disks saturated with the tinctures of the extracted ethanol tinctures of four species of plants (Table 1).

Table 1
Used part of four species of plants and the most important information on their antibacterial activity

Family	Species	Used part of the plant	Literature sources about the action of plants on bacteria
Anacardiaceae	*Cotinus coggygria* Scop.	shoots	Novakovic et al. (2007)
	Rhus trilobata Nutt.	shoots	Pfeiffer & Drinnenberg (2010)
	R. typhina L.	leaves	Kossah et al. (2011), Zhu et al. (2020)
	Toxicodendron orientale Greene	leaves	Zhao & Zhu (2014), Krüger (2017)
Araliaceae	*Hedera helix* Linnaeus	leaves	Pane et al. (2007), Pollet et al. (2009), Strelau et al. (2018)
	Aralia elata (Miq.) Seem.	leaves	Zhang et al. (2018)
Phyllanthaceae	*Leptopus chinensis* (Bunge) Pojark.	leaves	Zhang & Shi (2020)
Berberidaceae	*Mahonia aquifolium* (Pursh) Nutt.	shoots	Sochorova, R. (1998)

As positive control, we used disks with 15.0 μg of azithromycin – 9-deoxo-9a-aza-9a-methyl-9a-homoerythromycin A – macrolide antibiotic of broad spectrum of action. Discs with 15.0 μg amphotericinin were also used as a second control against *C. albicans* (Valle et al., 2015). After 24 h, the growth of the culture was assessed using antibiotic zone scale for measuring the growth inhibition zones of microorganisms (Antibiotic

Zone Scale-C, model PW297, India) and software TpsDig2 (F. James Rohlf, 2016). The data in tables are presented as x ± SD (standard deviation).

Results

Prevention of growth of separate strains of microorganisms was seen under the influence of ethanol extracts from the studied plants (Table 2, 3).

C. coggygria exhibited the highest inhibiting activity, slowing the growth of *E. faecalis* (10.2 mm, hereafter the average radius of growth inhibition zone is indicated in mm), two strains of *E. coli* (F50 and 055 – 16.4 and 12.4 mm respectively), *Proteus vulgaris* (10.7), *P. mirabilis* (12.4), *S. marcescens* (13.7) during moderate slowing of growth for *Y. enterocolitica* (5.7). The extract from *Rhus typhina* competed with *C. coggygria* for influence on *E. faecalis* (11.3), *E. coli* F50 (12.5), *S. aureus* and *S. epidermidis* (8.3 and 10.7), *L. ivanovi* (9.7), *C. xerosis* (11.7), *Rh. equi* (10.3), *P. vulgaris* (9.6), *S. typhimurium* and *S. adobraco* (10.2 and 10.6), *S. marcescens* (12.3) and *C. albicans* (9.3), and at the same time moderately slowed the growth of *B. subtilis* (3.5), *P. mirabilis* (7.8), *P. aeruginosa* ATCC 2799 (6.3) and *Y. enterocolitica* (4.5). Antibacterial effectiveness was determined for alcohol extract of *R. trilobata* against *E. faecalis* (10.4), *E. coli* 055 (11.4), *P. vulgaris* and *P. mirabilis* (11.7 and 20.7), *Y. enterocolitica* (11.3), it also moderately slowed the growth of *P. aeruginosa* (4.2). Extract of *T. orientale* had notable inhibiting activity towards *E. faecalis* (12.7), *P. vulgaris* (10.5), moderate activity towards *E. coli* 055 (6.8) and *P. mirabilis* (8.7).

Table 2

The width of zone of growth inhibition (mm) for the ethanol extracts of Anacardiaceae families against 24 strains of microorganisms (n = 8)

Strains of microorganisms	*Cotinus coggygria*	*Rhus typhina*	*Rhus trilobata*	*Toxicodendron orientale*	Control*
Enterococcus faecalis ATCC 19433	10.2 ± 1.32	11.3 ± 1.13	10.4 ± 0.78	12.7 ± 1.34	23.9 ± 2.45
Enterobacter aegorenes ATCC 10006	2.7 ± 0.19	1.6 ± 0.14	4.2 ± 0.42	2.6 ± 0.41	15.9 ± 1.67
Escherichia coli F50	16.4 ± 1.56	12.5 ± 1.24	0 ± 0	1.5 ± 0.16	17.8 ± 1.87
E. coli 055	12.4 ± 1.34	0 ± 0	11.4 ± 1.43	6.8 ± 0.55	15.6 ± 1.62
Staphylococcus aureus ATCC 25923	13.3 ± 1.12	8.3 ± 0.46	15.8 ± 1.29	10.8 ± 0.87	21.6 ± 2.45
S. epidermidis ATCC 14990	11.9 ± 1.54	10.7 ± 1.22	14.4 ± 0.78	0 ± 0	10.3 ± 1.34
Bacillus subtilis ATCC 6633	0 ± 0	3.5 ± 0.86	12.8 ± 1.45	4.5 ± 0.77	30.3 ± 3.05
B. cereus ATCC 10702	12.6 ± 1.43	2.3 ± 0.89	9.5 ± 1.76	4.2 ± 0.92	16.8 ± 1.86
Listeria ivanovi	9.8 ± 0.7	9.7 ± 0.87	9.9 ± 0.77	4.3 ± 0.32	14.7 ± 1.21
L. innocua ATCC 33090	0 ± 0	0 ± 0	0 ± 0	10.7 ± 1.41	25.1 ± 1.98
L. monocytogenes ATCC 19112	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Corynebacterium xerosis 1911	15.8 ± 1.45	11.7 ± 1.23	11.5 ± 0.78	11.7 ± 0.79	9.3 ± 1.34
Campylobacter jejuni ATCC 11322	0 ± 0	0 ± 0	0 ± 0	12.7 ± 1.43	0 ± 0
Rhodococcus equi ATCC 6939	11.7 ± 0.83	10.3 ± 0.12	12.6 ± 1.36	10.2 ± 0.89	19.1 ± 1.98
Proteus vulgaris ATCC 13315	10.7 ± 1.22	9.6 ± 0.86	11.7 ± 1.28	10.5 ± 1.12	0 ± 0
P. mirabilis ATCC 14153	12.4 ± 1.21	7.8 ± 0.88	20.7 ± 2.24	8.7 ± 0.67	0 ± 0
Salmonella typhimurium ATCC 14028	0 ± 0	10.2 ± 0.96	0 ± 0	1.7 ± 0.33	20.3 ± 1.54
S. adobraco 1	0 ± 0	10.6 ± 0.89	0 ± 0	0 ± 0	26.3 ± 2.76
Pseudomonas aeruginosa ATCC 2353	0 ± 0	0 ± 0	10.1 ± 0.88	17.4 ± 1.54	0 ± 0
P. aeruginosa ATCC 2799	0 ± 0	6.3 ± 0.41	6.5 ± 0.65	6.3 ± 0.67	0 ± 0
Klebsiella pneumoniae ATCC 13883	0 ± 0	1.3 ± 0.14	0 ± 0	1.3 ± 0.13	0 ± 0
Yersinia enterocolitica ATCC 9610	5.7 ± 0.45	4.5 ± 0.25	11.3 ± 0.94	2.3 ± 0.35	12.8 ± 1.27
Serratia marcescens ATCC 8100	13.7 ± 1.45	12.3 ± 1.09	0 ± 0	2.8 ± 0.25	0 ± 0
Candida albicans ATCC 2091	11.2 ± 1.38	9.3 ± 0.89	16.8 ± 1.78	17.8 ± 1.78	0 ± 0* / 2.4 ± 0.21**

Note: * – discs with 15.0 μg of azithromycin were used for all bacteria as positive control; ** – discs with 15.0 μg amphotericinin were used as positive control for *C. albicans*.

Table 3

Width of growth inhibition zone (mm) produced by ethanol extracts of *Hedera helix*, *Aralia elata*, *Leptopus chinensis* and *Mahonia aquifolium* against 24 strains of microorganisms (n = 8)

Strains of microorganisms	*Hedera helix*	*Aralia elata*	*Leptopus chinensis*	*Mahonia aquifolium*	Control*
Enterococcus faecalis ATCC 19433	0 ± 0	0 ± 0	0 ± 0	3.2 ± 0.65	23.9 ± 2.45
Enterobacter aegorenes ATCC 10006	0 ± 0	1.3 ± 0.17	0 ± 0	1.3 ± 0.14	15.9 ± 1.67
Escherichia coli F50	3.8 ± 0.34	11.9 ± 1.16	11.5 ± 0.78	1,5±0,12	17.8 ± 1.87
E. coli 055	0 ± 0	10.6 ± 0.98	3,6 ± 0.32	2,7±0,43	15.6 ± 1.62
Staphylococcus aureus ATCC 25923	23.5 ± 2.78	9.7 ± 0.78	2.6 ± 0.21	2.8 ± 0.19	21.6 ± 2.45
S. epidermidis ATCC 14990	26.3 ± 2.15	0 ± 0	18.7 ± 1.78	21.6 ± 2.34	10.3 ± 1.34
Bacillus subtilis ATCC 6633	0 ± 0	0 ± 0	0 ± 0	2.2 ± 0.67	30.3 ± 3.05
B. cereus ATCC 10702	0 ± 0	15.8 ± 2.34	10.8 ± 0.98	4.7 ± 1.21	16.8 ± 1.86
Listeria ivanovi	0 ± 0	0 ± 0	1.6 ± 0.19	0 ± 0	14.7 ± 1.21
L. innocua ATCC 33090	0 ± 0	0 ± 0	0 ± 0	0 ± 0	25.1 ± 1.98
L. monocytogenes ATCC 19112	9.3 ± 1.22	0 ± 0	0 ± 0	2.1 ± 0.34	0 ± 0
Corynebacterium xerosis 1911	4.4 ± 0.19	8.4 ± 0.89	0 ± 0	3.6 ± 0.21	9.3 ± 1.34
Campylobacter jejuni ATCC 11322	12.4 ± 1.26	0 ± 0	2.4 ± 0.32	17.5 ± 1.43	0 ± 0
Rhodococcus equi ATCC 6939	11.8 ± 0.77	2.2 ± 0.18	1.3 ± 0.13	1.6 ± 0.21	19.1 ± 1.98
Proteus vulgaris ATCC 13315	10.8 ± 1.21	9.3 ± 1.11	4.2 ± 0.77	9.4 ± 0.97	0 ± 0
P. mirabilis ATCC 14153	1.5 ± 0.14	14.7 ± 1.34	10.6 ± 0.68	4.3 ± 0.43	0 ± 0
Salmonella typhimurium ATCC 14028	5.4 ± 0.77	9.7 ± 0.76	0 ± 0	1.4 ± 0.18	20.3 ± 1.54
S. adobraco 1	0 ± 0	4.4 ± 0.57	2.3 ± 0.22	7.2 ± 0.76	26.3 ± 2.76
Pseudomonas aeruginosa ATCC 2353	2.8 ± 0.54	0 ± 0	0 ± 0	0 ± 0	0 ± 0
P. aeruginosa ATCC 2799	2.3 ± 0.45	0 ± 0	0 ± 0	2.2 ± 0.34	0 ± 0
Klebsiella pneumoniae ATCC 13883	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
Yersinia enterocolitica ATCC 9610	4.6 ± 0.32	0 ± 0	0 ± 0	0 ± 0	12.8 ± 1.27
Serratia marcescens ATCC 8100	2.8 ± 0.35	8.2 ± 0.78	3.5 ± 0.34	1.1 ± 0.16	0 ± 0
Candida albicans ATCC 2091	10.7 ± 1.03	13.6 ± 1.45	2.6 ± 0.32	5.7 ± 0.45	0 ± 0* / 2.4 ± 0.21**

Note: see Table 2.

Antibacterial effect was determined for the extracts of *R. trilobata* and *T. orientale* on *P. aeruginosa* (10.1 and 17.4); *T. orientale* – against *C. jejuni* (12.7), both of which had antibiotic resistance to azithromycin (growth inhibition zone of 0 mm). Also, significant inhibiting effect of the tested alcohol extracts should be noted against *S. aureus* (15.8 and 10.8 mm, respectively). During the study on the influence of the extracts

on the microorganisms of the Bacillaceae family, notable impact was observed for *C. coggygria* on *B. cereus* (12.6) and *R. trilobata* on *B. subtilis* and *B. cereus* (12.8 and 9.5). Moderate and high inhibitory effects on the microorganisms of the Listeriaaceae family: *C. coggygria* slowed the growth of *L. ivanovi* (9.8), *T. orientale – L. innocua* (10.7). Azitromycin was not effective against *L. monocytogenes* (0 mm). There was seen high inhibiting effect of the extracts from *C. coggygria*, *R. trilobata* and *T. orientale* against *C. xerosis* (15.8, 11.5, 11.7), *Rh. equi* (11.7, 12.6, 10.2) and *C. albicans* (11.2, 16.8 and 17.8 mm, respectively). At the same time, the radius of the zone of inhibition of growth produced by amphotericinum equaled only 2.4 mm.

Against the background of effective inhibition of microorganisms *E. faecalis*, *E. coli* 055 (except *Rhus typhina*), *S. aureus*, *S. epidermidis* (except *T. orientale*), *L. ivanovi*, *C. xerosis*, *Rh. equi*, *P. vulgaris*, *P. mirabilis* and *C. albicans* by ethanol extracts of plants of the Anacardiaceae family, we should note antibiotic-resistance of *P. vulgaris*, *P. mirabilis*, *K. pneumoniae*, *S. marcescens* to azithromycin (0 mm).

Extracts from *H. helix*, *L. chinensis* and *M. aquifolium* have high inhibitory effect on *S. epidermidis* (26.3, 18.7 and 21.6 mm), at the same time the growth inhibition zone exceeded the control by 16.0, 8.4 and 11.3 mm; *H. helix* and *A. elata* showed impact against *S. aureus* (23.5 and 9.7 mm), *C. albicans* (10.7 and 13.6 mm), *H. helix*, *A. elata* and *M. aquifolium* against *P. vulgaris* (10.8, 9.3 and 9.4 mm), *A. elata* and *L. chinensis – E. coli* F50 (11.9 and 11.5 mm), *B. cereus* (15.8 and 10.8 mm), *P. mirabilis* (14.7 and 10.6 mm), *H. helix* and *M. aquifolium – C. jejuni* (12.4 and 17.5 mm).

Furthermore, high antibacterial effect of *H. helix* was displayed against *L. monocytogenes* (9.3), *A. elata – E. coli* 055 (10.6), *S. typhimurium* (9.7), while *M. aquifolium* moderately inhibited *S. adobraco* and *C. albicans* (7.2 and 5.7 mm). Antibiotic resistance was determined for *L. monocytogenes*, *C. jejuni*, *P. vulgaris*, *P. mirabilis*, *P. aeruginosa*, *K. pneumoniae*, *S. marcescens* to the control group (azithromycin 0) and *C. albicans* to amphotericinin (2.4).

Discussion

Antimicrobial activity of ethanol extract of *C. coggygria* was surveyed by Milošević et al. (2008). Extracts from leaves of *C. coggygria* inhibited *S. aureus* and *P. aeruginosa*, producing growth inhibition zones of 13 and 10 mm. Despite the fact that *C. albicans* and *E. coli* were included in this study, Milošević et al. (2008) did not report about inhibition of these microorganisms.

Antibacterial activity of extracts from leaves of *C. coggygria* growing mostly naturally in Turkey (Han et al., 2009), prepared using different solvents, was determined using disk diffusion method. The extract was found to be most efficient against *E. faecalis* (diameter of the inhibition zone of 20 mm) in distilled water, and methanol extract was most effective against *S. aureus*, *S. epidermidis* and *E. faecalis* (Han et al., 2009). Antimicrobial activity expressed as minimum inhibitory concentration (MIC) of acetone extract and fractions obtained from young shoots of *C. coggygria* ranged 3–200 mg/mL (Marčetić et al., 2012). Acetone extract inhibited the growth of Gram-positive bacteria *S. epidermidis* (MIC = 25 mg/mL) and *S. aureus* (MIC = 25 mg/mL), whereas the ethyl acetate fraction was active against *B. subtilis* (MIC = 25 mg/mL), *K. pneumoniae* (MIC = 50 mg/mL) and *E. coli* (MIC = 50 mg/mL). The greatest activity with chloroform fraction was seen towards *C. albicans* yeasts (MIC = 3.1 mg/mL), more efficiently than with the control antifungal preparation – nystatin (6.2 mg/mL).

Hooshyar et al. (2014) recommend further research on the use of the main constituents of *H. helix*, especially hederasaponin (saponin K10), to study the antileishmanial activity towards *L. major*. Shckorbatov (2017) recommends using *H. helix* in the sphere of food chemistry, food technologies and nutraceutical studies (for diet-therapy and cosmetics).

García-Ramírez et al. (2016) studied *in vitro* anti-amoebic activity of extracts from fruits and stems of *Rhus trilobata* towards *Entamoeba histolytica*. Also, Varela-Rodríguez et al. (2019) report that flavonoids, phenolic and fatty acids, and also quercetin, methyl gallate, epigallocatechin 3-cinnamate, fisetin and margaric acid, included in the content of *R. trilobata*, can have anti-cancer properties.

Aschenbeck & Hylwa (2017) consider that *Toxicodendron orientale* has local antibacterial effect.

Ethanolic tincture of *Aralia elata* (Brygadyrenko et al., 2019) exerted low immunosuppressive action, in the conditions of high fat diet, leading to increase in the quantity of typical *Escherichia coli*, decrease in *Enterococcus* spp. and *Enterobacter* spp. High concentrations of it (0.1% ethanolic tincture of *A. elata*) killed bacteria of *Clostridium* and *Klebsiella* genera and various yeast fungi in the intestine. Male rats on a diet with excess of fat were observed to have no serious changes in the composition of the normal gut microbiota (*Bifidobacterium* spp., *Lactobacillus* spp., *Proteus* spp., *Staphylococcus* spp., *Candida* spp.), and no lactose-negative enterobacteria (*Citrobacter* genus) were detected.

R. typhina decreases the diversity of the soil bacterial community compared with other species of plants: soil was characterized by higher number of Actinobacteria and lower Proteobacteria and Acidobacteria (Zhu et al., 2020). A difference was found in the relative amount of *Nocardioides* and *Streptomyces*, which may be useful for the growth of *R. typhina*. Concentration of total carbon, potassium and nitrates are the main soil factors which affect the relative number of soil bacteria. Extract from *R. typhina* exhibited strong antimicrobial activity depending on the concentration and broad spectrum towards the tested bacteria of *Bacillus cereus* and *Helicobacter pylori* with MIC equaling 0.10%. Yeasts displayed lower susceptibility with MIC of 0.60–0.75%. Furthermore, Zhang et al. (2018) surveyed the antioxidant activity of the extract, including the absorbing activity of radicals 2,2-diphenyl-1 picrylhydrazyl (DPPH, MIC = 0.016 mg/mL) (Kossah et al., 2011). Extract of *Mahonia aquifolium* is recommended for the treatment of psoriasis in humans (Sochorova, 1998; Na, 2006).

Conclusion

Thus, all the 8 surveyed species of plants have no notable antibacterial effect against multi-resistant strains *Enterobacter aegorenes*, *Listeria innocua*, *P. aeruginosa* ATCC 2799, *K. pneumoniae*. High inhibitory effect was determined for ethanol extracts from *Cotinus coggygria* against 13 strains of microorganisms, *Rhus typhina* – against 12, *Rhus trilobata* – 14, *Toxicodendron orientale* – 10, *Hedera helix* –7, *Aralia elata* –10, *Leptopus chinensis* –4 and *Mahonia aquifolium* – 3 of 24 surveyed poly-resistant strains of bacteria and fungi. We think that it is possible to recommend the extracts from *C. coggygria*, *R. typhina*, *R. trilobata*, *T. orientale*, *H. helix*, *A. elata*, *L. chinensis* and *M. aquifolium* or individual compounds they contain for further study of methods against poly-resistant strains of the abovementioned microorganisms.

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