

The effect of different medicinal plants against dental plaque pathogens

✉ ZORAN TAMBUR^{1,2}, ✉ DOLORES OPAČIĆ², ✉ ADAM MALEŠEVIĆ¹,
✉ NEMANJA BOROVCANIN^{1,2}, ✉ VANJA MIJANOVIĆ¹, ✉ VLADIMIR BIOČANIN¹

¹Faculty of Stomatology in Pančevo, 13000 Pančevo, Serbia

²Military Medical Academy, 11000 Belgrade, Serbia

Received 22.07.2026

Accepted 31.08.2026

Tambur Z., Opačić D., Malešević A., Borovčanin N., Mijanović V., Biočanin V.
The effect of different medicinal plants against dental plaque pathogens

Summary

Medicinal plants are natural sources of active phytochemicals with therapeutic potential. The aim of this study was to investigate their effect against microorganisms frequently associated with oral diseases (*Streptococcus mutans*, *Enterococcus faecalis*, *Staphylococcus aureus*, *Lactobacillus acidophilus* and *Candida albicans*). The antimicrobial activity was evaluated based on the minimum inhibitory concentration (MIC) determined by the tryptic soy agar dilution method. Among five ethanolic extracts of medicinal plants investigated in this study, only *Hypericum perforatum* extract showed no activity. Extracts of *Origanum vulgare*, *Salvia officinalis*/ *Achilea millefolium*, *Centaureum erythraea* and *Chelidonium majus* showed antibacterial and antifungal activity in the range of 50–400 µg/mL. These results justify the use of selected medicinal plants for treatment of various infectious oral diseases. Further investigations are required before they can be recommended as antimicrobial drugs.

Keywords: medicinal plant extracts, oral cavity, dental pathogens, antimicrobial activity, minimum inhibitory concentrations

Dental plaque (bacterial biofilm) is usually associated with streptococci and lactobacilli, which are believed to be a causative factor for dental caries (23). Interest in natural phytochemicals as an alternative approach in the treatment of dental diseases is due to microbial resistance to antimicrobial agents and to their undesirable side effects (e.g. toxicity, tooth staining, vomiting).

Chlorhexidine is regarded as the gold standard chemical plaque control agent (3), against which other antiplaque and antigingivitis agents are measured. Many studies have shown that chlorhexidine acts against a wide array of bacteria, viruses, yeasts and fungi (38).

Phytochemicals (plant-derived bioactive compounds) are secondary metabolites with a wide antimicrobial activity (37). Medicinal plants of therapeutic value (e.g. *Origanum vulgare*, *Salvia officinalis*, *Achilea millefolium*, *Centaureum erythraea*, *Chelidonium majus* and *Hypericum perforatum*) are frequently used in Serbian traditional medicine because of their proven efficacy and safety (5, 28). Antimicrobial activity of medicinal plants can be attributed mostly to polyphenols and terpenes. Phenolic

compounds are a diverse group of bioactive secondary metabolites (e.g. carvacrol, fisetin, quercetin, coumaroylmalic acid, hypericin, hyperforin). Their antimicrobial properties include modification of cell membrane permeability and inactivation of specific microbial enzymes, as well as inhibition of virulence factors and oxydative phosphorylation (14). Terpenes (e.g. *p*-cymene, γ -terpinene, β -myrcene, β -copaen-4 α -ol, manool, 1,8-cineole, β -eudesmol, thymol, β -thujone) are another diverse family of natural products. Although not fully understood, their antimicrobial mechanisms are believed to involve disruption of membrane and protein motive force, as well as coagulation of cell contents (9). For some medicinal plants, no proven antimicrobial mechanism has yet been reported (2). Therefore, this study aimed to evaluate the antibacterial and antifungal effects of selected Serbian medicinal plants against reference strains.

Material and methods

The plant parts were thoroughly washed under running tap water. The raw materials were disinfected by immersion in a chlorine solution (100 mg/L) for 10 minutes, followed by a final rinse with distilled water (4). To obtain fine and

homogenous powder, the mass of flower heads, leaves and the other aerial parts (previously dried in an oven at 50°C) was macerated separately with liquid nitrogen using a porcelain pestle and mortar. The extracts obtained by maceration were dissolved in methanol (HPLC grade, Merck) (1 : 20) at room temperature, and the plant material was then left in a bath sonicator for 10 minutes. The methanolic extract was then centrifuged for 15 minutes at 5000 rpm in a refrigerated centrifuge (Sigma 4K 15C, Sigma Laborzentrifugen GmbH Osterode am Harz, Germany). The centrifuged aliquot (supernatant) was collected. The residue was centrifuged again in a methanol solution to obtain a larger amount of the extract. The residue was then discarded, and the entire methanolic solution was collected and filtered. The solutions were concentrated to dryness under reduced pressure in a rotary evaporator (Buchi Rotavapor, Flawil, Switzerland). Vials containing the extracts were wrapped in aluminium foil and stored in a freezer at -30°C until analysis of potential antimicrobial activity.

The strains tested were gram-positive facultative anaerobes (*Streptococcus mutans* ATCC 25175, *Enterococcus faecalis* ATCC 14506, *Staphylococcus aureus* ATCC 25293, *Candida albicans* ATCC 10231) and non-facultative anaerobes (*Lactobacillus acidophilus* ATCC 4356), which were cultured in the presence of oxygen. All strains were grown overnight at 37°C in Miler-Hinton broth (HiMedia, Mumbai, Maharashtra, India) with a standard pH of 7.4.

Determination of minimum inhibitory concentrations. The antimicrobial activity was evaluated based on the minimum inhibitory concentration (MIC) determined by the tryptic soy agar dilution method (11). During the cooling of the substrate before it hardened, plant extracts are added in the appropriate concentration. Serial dilutions of the plant extracts were prepared in plates with concentrations of 12.5, 25, 50, 100, 200 and 400 µg/mL. The MIC was defined as the lowest concentration of the extract that completely prevented visible bacterial growth.

The comparison was made with a standard solution of 0.12% chlorhexidine (Galenika, Zemun, Belgrade, Serbia). Serial dilutions of chlorhexidine were prepared in plates with concentrations of 6.25, 12.5, 25, 50, 100, 200 and 400 µg/mL (34).

Statistical analysis. In this study, two independent groups of samples (chlorhexidine and five herbal extracts) were compared for antimicrobial and antifungal activity (growth or no growth of bacterial colonies). Since the dependent variable is not

normally distributed, the Wilcoxon Two-Sample test was used to determine the statistical significance of differences. The threshold for accepting or rejecting the null hypothesis was a *p* value of 0.05.

Results and discussion

The effect of different concentrations of chlorhexidine was investigated on four types of microorganisms (*S. mutans*, *E. faecalis*, *S. aureus* and *C. albicans*) in our previous study (34). Chlorhexidine, even at the lowest concentration, had an inhibitory effect on all strains tested in that study. It has antiplaque and antigingivitis properties. As a membrane-active agent it damages the inner cell membrane, causing leakage of intracellular components, which results in a bactericidal effect (7). A study by Ghilan et al. (13) showed that chlorhexidine was most successful in inhibiting and killing *S. mutans* ATCC at 0.039 and 0.0079 µg/mL, respectively. A significant bactericidal effect of chlorhexidine was also observed against *E. faecalis* (31) and *S. aureus* (24), while its

Tab. 1. Antimicrobial activity of *Hypericum perforatum* extract

	<i>Streptococcus mutans</i>	<i>Enterococcus faecalis</i>	<i>Staphylococcus aureus</i>	<i>Lactobacillus acidophilus</i>	<i>Candida albicans</i>
400 µg/mL	X	X	X	X	X
200 µg/mL	+	X	X	X	X
100 µg/mL	+	+	+	+	X
50 µg/mL	+	+	+	+	X
25 µg/mL	+	+	+	+	X
12.5 µg/mL	+	+	+	+	X

Explanations: + = growth; - = no growth (MIC); X = not analyzed

Tab. 2. Antimicrobial activity of *Origanum vulgare* extract

	<i>Streptococcus mutans</i>	<i>Enterococcus faecalis</i>	<i>Staphylococcus aureus</i>	<i>Lactobacillus acidophilus</i>	<i>Candida albicans</i>
400 µg/mL	X	-	-	X	-
200 µg/mL	-	-	-	-	-
100 µg/mL	-	+	+	-	X
50 µg/mL	+	+	+	+	X
25 µg/mL	+	+	+	+	X
12.5 µg/mL	+	+	+	+	X

Explanations: + = growth; - = no growth (MIC); X = not analyzed

Tab. 3. Antimicrobial activity of *Salvia officinalis*/*Achillea millefolium* extract

	<i>Streptococcus mutans</i>	<i>Enterococcus faecalis</i>	<i>Staphylococcus aureus</i>	<i>Lactobacillus acidophilus</i>	<i>Candida albicans</i>
400 µg/mL	X	-	-	X	-
200 µg/mL	X	-	-	X	-
100 µg/mL	-	+	+	-	+
50 µg/mL	+	+	+	+	X
25 µg/mL	+	+	+	+	X
12.5 µg/mL	+	+	+	+	X

Explanations: + = growth; - = no growth (MIC); X = not analyzed

antifungal effectiveness was proportional to its concentration (19).

In this study, the antimicrobial activity of five ethanolic extracts was analyzed by the tryptic soy agar dilution method. *H. perforatum* extract showed no antimicrobial activity (Tab. 1). Four of the five extracts (*O. vulgare*, *S. officinalis*/*A. millefolium*, *C. erythraea* and *Ch. majus*) demonstrated activity against *L. acidophilus* in the range of 50-200 µg/mL and expressed excellent antimicrobial activity (100 µg/mL) against *S. mutans* (Tab. 2-5). Some extracts, such as *O. vulgare*

and *S. officinalis*/*A. millefolium* (Tab. 2 and Tab. 3), showed moderate activity against *E. faecalis* and *S. aureus* (200 µg/mL), while weak activity (400 µg/mL) against these strains was observed for *C. erythraea* and *Ch. majus* (Tab. 4 and Tab. 5).

Antifungal activity was observed at 200 µg/mL for *O. vulgare* and *S. officinalis*/*A. millefolium* extracts (Tab. 2 and Tab. 3) and at 400 µg/mL for *Ch. majus* (Tab. 5).

Statistically, these herbal extracts did not differ significantly from chlorhexidine in their activity against

Streptococcus mutans (Tab. 6). All five plant extracts demonstrated significantly lower activity against *E. faecalis* and *S. aureus* compared with chlorhexidine (Tab. 6). There were no significant differences between chlorhexidine and three herbal extracts, *O. vulgare*, *S. officinalis*/*A. millefolium* and *Ch. majus*, in their activity against *L. acidophilus* (Tab. 6). Plant extracts of *O. vulgare* and *S. officinalis*/*A. millefolium* did not differ significantly from chlorhexidine in their activity against *C. albicans*, whereas *Ch. majus* demonstrated significantly lower activity compared with chlorhexidine (Tab. 6).

The literature increasingly reports on the use of phytochemicals as preventative or treatment therapies for oral diseases (27). Many factors can affect the antimicrobial activity of medicinal plants. Different authors report different levels of antimicrobial activity depending on the solvents used for extraction and the quantitative composition of the extracts. For example, hydroalcoholic extracts expressed better antimicrobial activities against oral bacterial pathogens than aqueous extracts (17), which could be explained by the higher phenolic content of the former, especially ethanol extracts (1).

Yuan et al. (39) found that oregano essential oil, in addition its main ingredient carvacrol, also contained *p*-cymene, γ -terpinene and β -myrcene. On the other hand, thymol was, among others, the main constituent of oregano essential oil in a study by Stringaro et al. (33). Some authors speculate that the antistaphylococcal and

Tab. 4. Antimicrobial activity of *Centaureum erythraea* extract

	<i>Streptococcus mutans</i>	<i>Enterococcus faecalis</i>	<i>Staphylococcus aureus</i>	<i>Lactobacillus acidophilus</i>	<i>Candida albicans</i>
400 µg/mL	X	–	–	–	X
200 µg/mL	X	+	+	–	X
100 µg/mL	–	+	+	+	X
50 µg/mL	+	+	+	+	X
25 µg/mL	+	+	+	+	X
12.5 µg/mL	+	+	+	+	X

Explanations: + = growth; – = no growth (MIC); X = not analyzed

Tab. 5. Antimicrobial activity of *Chelidonium majus* extract

	<i>Streptococcus mutans</i>	<i>Enterococcus faecalis</i>	<i>Staphylococcus aureus</i>	<i>Lactobacillus acidophilus</i>	<i>Candida albicans</i>
400 µg/mL	X	–	–	X	–
200 µg/mL	X	+	+	X	X
100 µg/mL	–	+	+	–	X
50 µg/mL	+	+	+	–	X
25 µg/mL	+	+	+	+	X
12.5 µg/mL	+	+	+	+	X

Explanations: + = growth; – = no growth (MIC); X = not analyzed

Tab. 6. Comparisons of antimicrobial and antifungal activity of chlorhexidine and five plant extracts (P-values from Wilcoxon Two-Sample Test)

<i>Streptococcus mutans</i>					
Chlorhexidine	<i>O. vulgare</i>	<i>S. officinalis</i>	<i>C. erythraea</i>	<i>Ch. majus</i>	<i>H. perforatum</i>
	NS	NS	NS	NS	0.0121
<i>Enterococcus faecalis</i>					
Chlorhexidine	<i>O. vulgare</i>	<i>S. officinalis</i>	<i>C. erythraea</i>	<i>Ch. majus</i>	<i>H. perforatum</i>
	0.0461	0.0461	0.0203	0.0203	0.0461
<i>Staphylococcus aureus</i>					
Chlorhexidine	<i>O. vulgare</i>	<i>S. officinalis</i>	<i>C. erythraea</i>	<i>Ch. majus</i>	<i>H. perforatum</i>
	0.0461	0.0461	0.0203	0.0203	0.0461
<i>Lactobacillus acidophilus</i>					
Chlorhexidine	<i>O. vulgare</i>	<i>S. officinalis</i>	<i>C. erythraea</i>	<i>Ch. majus</i>	<i>H. perforatum</i>
	NS	NS	0.0246	NS	0.004
<i>Candida albicans</i>					
Chlorhexidine	<i>O. vulgare</i>	<i>S. officinalis</i>	<i>C. erythraea</i>	<i>Ch. majus</i>	<i>H. perforatum</i>
	NS	NS	–	–	0.0121

Explanation: NS = not statistically significant

antistreptococcal action of oregano essential oil might be due to its disruptive effect on amino acid metabolism (15) and inhibition of virulence (39), respectively. Idir et al. (18) reported the strongest antimicrobial activity against oral pathogens (*Streptococcus*, *Enterococcus* and *Lactocaseibacillus*) for *O. vulgare* ethanolic extract. On the other hand, a combination of *O. vulgare* and *Pimpinella anisum* hydroalcoholic extracts showed highest activity against streptococcal dental caries bacteria in the range 2.5-10 µg/mL (23). Previous studies demonstrated maximal antimicrobial activity of *O. vulgare* extract against *E. faecalis* (MIC 25 µg/mL) and *S. aureus* (MIC 62.5-125 µg/mL) (6, 15, 20). In the present study, *O. vulgare* extract was more active against *S. mutans* and *L. acidophilus* (MIC 100 µg/mL) than against *E. faecalis*, *S. aureus* and *C. albicans* (MIC 200 µg/mL). Similar results against Gram-positive bacteria (MIC 120-250 µg/mL) were observed in earlier studies (21, 22). It is interesting to note that the antifungal potential of carvacrol alone was higher (MIC 97.5-195 µg/mL) than those of thymol and oregano essential oil (33).

Toplan et al. (36) identified 1,8-cineole and β-eudesmol in *A. millefolium* essential oil, whose chloroform and methanolic extracts displayed a moderate inhibitory activity against *S. aureus* (MIC 250 µg/mL). Apart from the commonly used solvents, the literature also mentions the aqueous extract of *A. millefolium*, whose antimicrobial effect on oral pathogens was achieved at a concentration of 50 mg/ml (12). With regard to the antifungal potential of *A. millefolium*, Cvetković et al. (10) reported a moderate activity of dichlormethane extracts against *C. albicans*.

In an earlier study, α-thujone, camphor, 1,8-cineole and carvacrol were the most important molecules identified in *S. officinalis* glycolic extract. At a concentration of 50 mg/ml, this extract eliminated all clinical isolates and reference strains capable of causing opportunistic infections (26). In the present study, a mixture of *S. officinalis* and *A. millefolium* extracts seemed to show antibacterial and antifungal activity similar to that of the abovementioned *O. vulgare* extract. In a study by Santos et al. (29), who also used *S. officinalis* in combination with another plant, hydroalcoholic extracts demonstrated effects against *E. faecalis* and *E. faecium* strains. However, other studies on *S. officinalis* essential oil (rich in β-thujone) failed to demonstrate its antibacterial and antifungal activity (8).

β-copaen-4α-ol, manool and carvacrol have been shown to be the main constituents of *Centaureum erythraea* essential oil (32). With MIC values >100 µg/mL, *C. erythraea* proved to be the least effective against almost all oral pathogens, except for *Streptococcus salivarius* (MIC 25 mg/ml) (18). However, ATCC strains of *C. albicans* and *S. aureus* were shown to be susceptible to *C. erythraea* essential oil (at 12.5 and 25 µl/mL, respectively), while *E. faecalis* was resistant (32). In the present study, *S. mutans* showed the

highest sensitivity to *C. erythraea* extract (MIC 100 µg/mL). *L. acidophilus*, *E. faecalis* and *S. aureus* were less sensitive, with MIC values of 200-400 µg/mL.

Some of the phenolic compounds (fisetin, quercetin and coumaroylmalic acid) identified in *Ch. majus* are known for their antimicrobial properties (16, 35). The results of the present study demonstrate an extraordinary antibacterial activity of its ethanolic extract against *L. acidophilus* (MIC 50 µg/mL) and significant activity against *S. mutans* (MIC 100 µg/mL). Investigating different *Streptococcus* strains, Hong et al. (16) revealed that *Ch. majus* ethyl-acetate fraction exhibited high antimicrobial activity, with MIC values ranging from 125 to 250 µg/mL. In the present study, it showed moderate activity against *E. faecalis*, *S. aureus* and *C. albicans* (MIC 400 µg/mL).

The antimicrobial properties of *H. perforatum* have been known for decades (30). Bagheri et al. (2) and Al-haliem et al. (1) investigated the antimicrobial effect of *H. perforatum* on common pathogens of periodontitis. Growth inhibition was observed at concentrations of 32 µg/mL for *E. faecalis*, 64 µg/mL for *S. aureus* and 128 µg/mL for *S. mutans*. These studies demonstrated that extracts rich in phenolic compounds (hypericin, hyperforin, kaempferol, chlorogenic acid, syringic acid, p-coumaric acid) could be used in treating periodontal infections. In a previous study, hypericin extract inhibited oral isolates of *Lactobacillus* spp. at MIC of 0.625 µg/mL (25). No growth-inhibitory effect was seen against Gram-positive bacteria investigated in the present study.

Medicinal plants have a significant potential to destroy microorganisms. Among the four extracts that demonstrated antimicrobial activity, *Chelidonium majus* was the most effective against *Lactobacillus acidophilus* (50 µg/mL). All four extracts (*Origanum vulgare*, *Salvia officinalis*/*Achillea millefolium*, *Centaureum erythraea* and *Chelidonium majus*) showed excellent activity (100 µg/mL) against *S. mutans*. Only *Hypericum perforatum* extract showed no antimicrobial activity. This investigation has demonstrated that some medicinal plants used in traditional medicine can be as effective as contemporary medicine in combating oral pathogens.

References

1. Al-Haliem S. M., Mohammed M. J., Hesarinejad M. A., Abdelmaksoud T. G.: Antimicrobial, anti-biofilm activity and antioxidants of phenolic compounds isolated from *Hypericum perforatum* on periodontal pathogenic oral bacteria. Food Sci. Nutr. 2025, 13, e70336, doi: 10.1002/fsn3.70336.
2. Bagheri R., Bohlouli S., Dizaj S. M., Shahi Sh., Memar M. Y., Salatin S.: The antimicrobial and anti-biofilm effects of *Hypericum perforatum* oil on common pathogens of periodontitis: an in vitro study. Clin. Pract. 2022, 12, 1009-1019, doi: 10.3390/clinpract12060104.
3. Balagopal Sh., Arjunker R.: Chlorhexidine: the gold standard antiplaque agent. J. Pharm. Sci. Res. 2013, 5, 270-274.
4. Barbosa A. F., Pereira C. S. S. de, Mendes M. F., Carvalho Junior R. N. de, Carvalho M. G. de, Maia J. G. S., Sabaa-Srur A. U. O.: Spilanthal content in the extract obtained by super-critical CO₂ at different storage times of *Acmella oleracea* L. J. Food Process. Eng. 2017, 40, e12441, doi: 10.1111/jfpe.12441.
5. Biocanin V., Opacic D., Besu Zizak I., Zizak Z., Malesevic A., Tambur Z.: The potential antiproliferative effect of some medicinal plants from Serbian

- traditional medicine. *Indian J. Pharm. Sci.* 2025, 87, 66-71, doi: 10.36468/pharmaceutical-sciences.1479.
6. Brđanin S., Bogdanović N., Kolundžić M., Milenković M., Golić N., Kojić M., Kundaković T.: Antimicrobial activity of oregano (*Origanum vulgare* L.) and basil (*Ocimum basilicum* L.) extracts. *Adv. Technol.* 2015, 4, 5-10, udc 582.929.4:66.061.34:579.86.
 7. Brookes Z. L. S., Bescos R., Belfield L. A., Kamran A., Roberts A.: Current uses of chlorhexidine for management of oral disease: a narrative review. *J. Dent.* 2020, 103, 103497, doi: 10.1016/j.jdent.2020.103497.
 8. Ciobotaru G. V., Goje I.-D., Dehelean C. A., Danciu C., Magyari-Pavel I. Z., Moacă E.-A., Muntean D., Imbrea I. M., Sărățeanu V., Pop G.: Analysis of the antioxidant and antimicrobial activity, cytotoxic, and anti-migratory properties of the essential oils obtained from cultivated medicinal Lamiaceae species. *Plants* 2025, 14, 846, doi: 10.3390/plants14060846.
 9. Chouhan S., Sharma K., Guleria S.: Antimicrobial activity of some essential oils – present status and future perspectives. *Medicines* 2017, 4, 58, doi: 10.3390/medicines/4030058.
 10. Cvetković S., Ignjatijević A., Kukić-Marković J., Vuletić S., Ušjak Lj., Milutinović V., Mitić-Čulafić D., Petrović S., Nikolić B.: Further insights into antimicrobial and cytotoxic potential of *Achillea millefolium* herb methanol and dichloromethane extracts. *Ind. Crop. Prod.* 2025, 225, 120553, doi: 10.1016/j.indcrop.2025.120553.
 11. European Committee for Antimicrobial Susceptibility Testing (EUCAST) of the European Society of Clinical Microbiology and Infectious Diseases (ESCMID). Determination of minimum inhibitory concentrations (MICs) of antibacterial agents by agar dilution. *Clin. Microbiol. Infect.* 2000, 6, 509-515, doi: 10.1046/j.1469-0691.2000.00142.x.
 12. Fallah N., Namazi S., Balmeh N., Mahmoudi S., Mirzaei Poor F.: In-vitro antibacterial effects of aqueous, ethanolic, methanolic, acetone and hydro ethanolic extracts of *Achillea millefolium* on standard *Klebsiella*, *S. pyogenes*, and oral bacteria strains. *Tabari Biomed. Stu. Res. J.* 2020, 2, 22-27, doi: 10.18502/tbsrj.v2i3.4529.
 13. Ghilan A.-K. M., Alharbi N. S., Khaled J. M., Kadaikunnan Sh., Alobaidi A. S.: Virulence factors analysis and determination of the suitable chemical agent to inhibit *Streptococcus mutans* growth and biofilm formation. *J. King Saud Univ. Sci.* 2023, 35, 102892, doi: 10.1016/j.jksus.2023.102892.
 14. Górniak I., Bartoszewski R., Królczyński J.: Comprehensive review of antimicrobial activities of plant flavonoids. *Phytochem. Rev.* 2019, 18, 241-272, doi: 10.1007/s11101-018-9591-z.
 15. Hao Y., Li J., Shi L.: A carvacrol-rich essential oil extracted from oregano (*Origanum vulgare* „Hot & Spicy“) exerts potent antibacterial effects against *Staphylococcus aureus*. *Front. Microbiol.* 2021, 12, 741861, doi: 10.3389/fmicb.2021.741861.
 16. Hong S., Park J., Park M., Park J. M., Lee H.: Exploring the antioxidant and antimicrobial potential of *Chelidonium majus* extracts against oral microorganisms. *Biocatal. Agric. Biotechnol.* 2024, 59, 103231, doi: 10.1016/j.beab.2024.103231.
 17. Hosseini S., Kargar P., Khanahmadi M., Kazemi N., Yari Kh.: In vitro antibacterial activity of hydroalcoholic and aqueous extracts of *Echinophora platyloba* against some pathogenic bacteria of the oral cavity. *J. Med. Plants By-Prod.* 2025, 14, 291-296, doi: 10.22034/jmpb.2024.366579.1731.
 18. Idir F., Ginneken S. van, Coppola G. A., Grenier D., Steenackers H. P., Bendali F.: *Origanum vulgare* ethanolic extracts as a promising source of compounds with antimicrobial, anti-biofilm, and anti-virulence activity against dental plaque bacteria. *Front. Microbiol.* 2022, 13, 999839, doi: 10.3389/fmicb.2022.999839.
 19. Jain N., Varma R. B., Kumar J. S., Kumaran P., Xavier A. M.: Antimicrobial activity of chlorhexidine on *Candida albicans* and *Streptococcus mutans* isolated in children with early childhood caries – an in vitro study. *J. Appl. Pharm. Sci.* 2023, 13, 113-116, doi: 10.7324/JAPS.2023.130213.
 20. Janani K., Ajitha P., Sandhya R., Teja K. V.: Chemical constituent, minimal inhibitory concentration, and antimicrobial efficiency of essential oil from *oreganum vulgare* against *Enterococcus faecalis*: An in vitro study. *J. Conserv. Dent.* 2019, 22, 538-543, doi: 10.4103/JCD.JCD_80_19.
 21. Khan S. T., Khan M., Ahmad J., Wahab R., Abd-Elkader O. H., Musarrat J., Alkhathlan H. Z., Al-Kedhairi A. A.: Thymol and carvacrol induce autolysis, stress, growth inhibition and reduce the biofilm formation by *Streptococcus mutans*. *AMB Express* 2017, 7, 49, doi: 10.1186/s13568-017-0344-y.
 22. Kumari P., Joshi G. C., Tewari L. M., Singh B. K.: Quantitative assessment and antibacterial activity of *Origanum vulgare* L. *J. Phytol.* 2011, 3, 15-21, issn: 2075-6240.
 23. Lavaee F., Moghaddas A., Modarresi F., Nowrouzi M.: The effect of *Pimpinella anisum* and *Origanum vulgare* extracts against *Streptococcus sanguinis*, *Streptococcus mutans*, and *Streptococcus salivarius*. *J. Dent. Shiraz Univ. Med. Sci.* 2022, 23, 113-120, doi: 10.30476/DENTJODS.2021.85691.1145.
 24. Nagappan N., Palaneeswaran K., Kumarappan K., Natarajan R., Tajuddin R., Anusha Y.: Antimicrobial efficacy of herbal and chlorhexidine mouthrinse against *Staphylococcus aureus* – an in vitro microbiological study. *J. Pharm. Bioall. Sci.* 2022, 14, S318-322, doi: 10.4103/jpbs.jpbs_821_21.
 25. Nezhad S. K., Zenouz A. T., Aghazadeh M., Kafil H. S.: Strong antimicrobial activity of *Hypericum perforatum* L. against oral isolates of *Lactobacillus* spp. *Cell. Mol. Biol.* 2017, 63, 58-62, doi: 10.14715/cmb/2017.63.11.11.
 26. Oliveira J. R. de, Graças Figueiredo Vilela P. das, Aguiar Almeida R. B. de, Oliveira F. E. de, Carvalho C. A. T., Camargo S. E. A., Jorge A. O. C., Oliveira L. D. de: Antimicrobial activity of noncytotoxic concentrations of *Salvia officinalis* extract against bacterial and fungal species from the oral cavity. *Gen. Dent.* 2019, 67, 22-26, pmid: 30644826.
 27. Palombo E. A.: Traditional medicinal plant extracts and natural products with activity against oral bacteria: potential application in the prevention and treatment of oral diseases. *eCAM.* 2011, 2011, 680354, doi: 10.1093/ecam/nep067.
 28. Radovanović K., Gavarić N., Aćimović M.: Anti-inflammatory properties of plants from Serbian traditional medicine. *Life* 2023, 13, 874, doi: 10.3390/life13040874.
 29. Silva Alves Santos T. da, Meccatti V. M., Pereira T. C., Marcucci M. C., Hasna A. A., Valera M. C., Oliveira L. D. de, Carvalho C. A. T.: Antibacterial effect of combinations of *Salvia officinalis* and *Glycyrrhiza glabra* hydroalcoholic extracts against *Enterococcus* spp. *Coatings* 2023, 13, 1579, doi: 10.3390/coatings13091579.
 30. Schempp C. M., Pelz K., Wittmer A., Schöpf E., Simon J. C.: Antibacterial activity of hyperforin from St. John's wort, against multiresistant *Staphylococcus aureus* and gram-positive bacteria. *Lancet* 1999, 353, 2129.
 31. Shmueli A., Yaya A., Lam N., Haim Y., Zamsky L., Fux Noy A., Ram D., Moskovitz M., Polak D.: Elimination of *E. faecalis* with NaOCl versus chlorhexidine gluconate from primary molar root canal systems: an ex vivo model study. *Clin. Oral. Investig.* 2024, 28, 265, doi: 10.1007/s00784-024-05621-6.
 32. Soltani F. Z., Meddah B., Chelli N., Touil A. T., Sonnet P.: *Atriplex halimus* L. and *Centaureum erythraea* Rafn. essential oils: The phytochemical profile, antimicrobial and antioxidant properties. *Agric. Conspec. Sci.* 2023, 88, 215-223, hal-04563111.
 33. Stringaro A., Colone M., Cecchetti S., Zeppetella E., Spadaro F., Angiolella L.: In vivo and in vitro antimicrobial activity of *Origanum vulgare* essential oil and its two phenolic compounds on clinical isolates of *Candida* spp. *Arch. Microbiol.* 2023, 205, 15, doi: 10.1007/s00203-022-03355-1.
 34. Tambur Z., Avramov S., Aleksić E., Joksić A., Dimitrijević U., Biočanin V.: Antimicrobial effect of *Sphalantes acmella* on *Streptococcus mutans*, *Staphylococcus aureus*, *Enterococcus faecalis* and *Candida albicans* in oral cavity. *Serbian Den. J.* 2025, 72, 5-13, doi: 10.2298/SGS2501003T.
 35. Tian Ch., Liu X., Chang Y., Wang R., Lv T., Cui C., Liu M.: Investigation of the anti-inflammatory and antioxidant activities of luteolin, kaempferol, apigenin, and quercetin. *S. Afr. J. Bot.* 2021, 137, 257-264, doi: 10.1016/j.sajb.2020.10.022.
 36. Toplan G. G., Taşkın T., Işcan G., Göger F., Kürkçüoğlu M., Civaş A., Ecevit-Genç G., Mat A., Başer K. H. C.: Comparative studies on essential oil and phenolic content with in vitro antioxidant, anticholinesterase, antimicrobial activities of *Achillea biebersteinii* Afan. and *A. millefolium* subsp. *millefolium* Afan. L. growing in eastern Turkey. *Molecules* 2022, 27, 1956, doi: 10.3390/molecules27061956.
 37. Vaou N., Stavropoulou E., Voidarou Ch., Tsigalou Ch., Bezirtzoglou E.: Towards advances in medicinal plant antimicrobial activity: a review study on challenges and future perspectives. *Microorganisms* 2021, 9, 2041, doi: 10.3390/microorganisms9102041.
 38. Vianna M. E., Gomes B. P. F. A., Berber V. B., Zaia A. A., Ferraz C. C. R., Souza-Filho F. J. de: In vitro evaluation of the antimicrobial activity of chlorhexidine and sodium hypochlorite. *Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol. Endod.* 2004, 97, 79-84, doi: 10.1016/s1079-2104(03)00360-3.
 39. Yuan Y., Sun J., Song Y., Raka R. N., Xiang J., Wu H., Xiao J., Jin J., Hui X. L.: Antibacterial activity of oregano essential oils against *Streptococcus mutans* in vitro and analysis of active components. *BMC Compl. Med. Ther.* 2023, 23, 61, doi: 10.1186/s12906-023-03890-4.

Corresponding author: Prof. dr Zoran Tambur, Žarka Zrenjanina 179, 26 000 Pančevo, Serbia; e-mail: tambur.zoran@gmail.com