Medical and Biological Sciences, 2013, 27/1, 5-11

REVIEW / PRACA POGLĄDOWA

Michalina Adaszyńska, Maria Swarcewicz

ANTIMICROBIAL PROPERTIES OF SELECTED SECONDARY PLANT METABOLITES AND THEIR APPLICATION IN MEDICINE

WŁASNOŚCI ANTYMIKROBIOLOGICZNE WYBRANYCH WTÓRNYCH METABOLITÓW ROŚLINNYCH I ICH ZASTOSOWANIE W MEDYCYNIE

Institute of Organic Chemical Technology, Department of Organic Synthesis and Drug Technology,
West Pomeranian University of Technology
Head of Department: dr hab. inż. Maria Swarcewicz, prof. ZUT

Summary

One of the oldest achievements of human thought is the use of plants and plant extracts in therapeutics. Drugs of plant origin are characterized by multi-effects. In recent years, much interest in medicinal plants containing a mixture of biologically active substances with antimicrobial properties has increased. In medicine, Extracted from plants and their secondary metabolites and plant extracts have been used for many years used, but now by the development of organic chemistry, pharmacology and medicine, we can determine which biologically active substances produced by these plants are useful. Antimicrobial activity described selected groups of plant secondary metabolites, which potentially would allow their use as antimicrobial substances in medicine. These substances can be complementary to the basic medical treatment because their main advantage is the lower incidence of side effects. This paper presents an overview of research on the antimicrobial properties of alkaloids, coumarins, flavonoids, essential oils, phytosterols, and phenolic acids. Natural substances that inhibit the growth of microorganisms are becoming an alternative to synthetic compounds, as confirmed by this literature review.

Streszczenie

Jednym z najstarszych osiągnięć myśli ludzkiej jest zastosowanie roślin oraz ekstraktów roślinnych w lecznictwie. Leki pochodzenia roślinnego charakteryzują się działaniem wielokierunkowym. W ostatnich latach dużym zainteresowaniem cieszą się rośliny lecznicze zawierające mieszaniny substancji biologicznie aktywnych o właściwościach przeciwdrobnoustrojowych. W lecznictwie od wielu lat stosowane są rośliny oraz wyodrębnione z nich wtórne metabolity i ekstrakty roślinne, jednak dopiero teraz dzięki rozwojowi chemii organicznej, farmakologii i medycyny możemy określić, które substancje biologicznie aktywne produkowane przez te rośliny są użyteczne. Opisana została aktywność antymikrobiologiczna wybranych grup wtórnych metabolitów roślinnych, które potencjalnie umożliwiłyby ich wykorzystanie jako substancji antybiotycznych w lekach. Substancje te mogą być uzupełnieniem podstawowego leczenia farmakologicznego, gdyż zasadniczą ich zaletą jest rzadsze występowanie działań niepożądanych. W pracy przedstawiono przegląd badań nad właściwościami przeciwdrobnoustrojowymi alkaloidów, kumaryn, flawonoidów, olejków eterycznych, fitosteroli oraz fenolokwasów. Naturalne substancje hamujące wzrost mikroorganizmów stają się alternatywą dla związków syntetycznych, co ten przegląd literaturowy to potwierdza.

Key words: antimicrobial properties, secondary metabolites of plants, herbal medicines

Słowa kluczowe: własności antymikrobiologiczne, wtórne metabolity roślinne, leki ziołowe

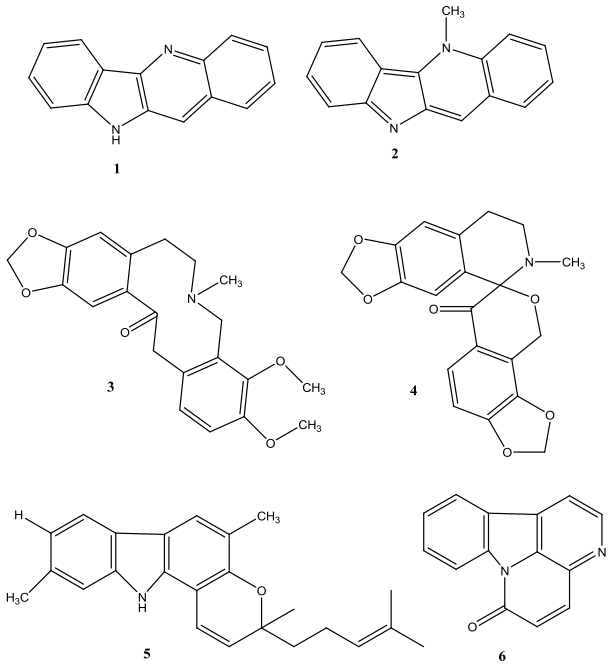
INTRODUCTION

Extracted from plants and their secondary metabolites and plant extracts have been used in medicine for a long time. With the development of organic chemistry, pharmacology and medicine, only now we can determine which biologically active substances produced by plants are useful in therapy. Each plant contains many biologically active components of complex chemical composition. Many plants have in their composition the mixture of substances with antimicrobial properties, and therapeutic antioxidant, which until recently was not used [1, 2]. It should be noted that mixtures of natural compounds that are gentler on plants operate more effectively and comprehensively, comparing them with some synthetic ingredients. Therefore, the pharmacists and dermatologists are interested in medicinal preparations of natural origin.

When the resistance of microorganisms to synthetic antibiotics is already, a serious problem to be tested natural substances in plants which can improve population health appears. In the twentieth century, despite the enormous achievements in the field of chemical synthesis, many researchers and practitioners turned to phytotherapy, or plant disease treatment means in the form of decoctions, syrups, capsules, tablets, aqueous extracts, alcohol and oil and essential oils. Plant secondary metabolites are substances with an extremely wide range of activities related to their different chemical structure. Secondary metabolites are not essential for basic life processes of plants; however, they serve multiple functions. Their presence is usually limited to specific groups of plants. In plant secondary metabolites there are a lot of compounds used in production of drugs (taxol, glycosides, saponins, terpenoids, salicylates). Medicinal plants that contain a mixture of biologically active substances with antimicrobial properties are very popular. Among the more important groups of biologically active substances with antimicrobial properties are alkaloids, polyacetylenes, essential oils and terpenoids, coumarins, flavonoids and isoflavones, iridoids, lignans, xanthones [2, 3].

Alkaloids

Natural substances with antimicrobial properties can be, among others, alkaloids, the variety of organic compounds of plant origin with a basic medium, containing mostly nitrogen. Plant alkaloids have a protective function. The alkaloids are present in the plant world, in microorganisms, fungi, and in some animals and there are more than 12 thousand of the known ones. In medicine alkaloids are used as antibacterial agents, analgesics, central nervous system stimulants (CNS), sleeping pills, as well as psychotropic drugs, narcotics, local anesthetics or vasoconstrictors. Many alkaloids show antibacterial activity [3–5]. Examples of alkaloids active against strains of S. *aureus*, E. *coli* and *E. faecalis* are quindoline (**1**) and cryptolepine (**2**) which are components of the extract of *Sida acuta* (MIC = 16-400 $\mu g\ ml^{-1}$) [5]. Okunade also described the plant alkaloids acting on mycobacterium, and they were: 3-formylcarbazole, 3-methoxycarbonyl-carbazole, 2-hydroxy-3-formyl-7-methoxycarbazole, clauszoline, echinuline, cleistopholine, sampangine (MIC = 0.78-100.0 $\mu g\ ml^{-1}$) [6].



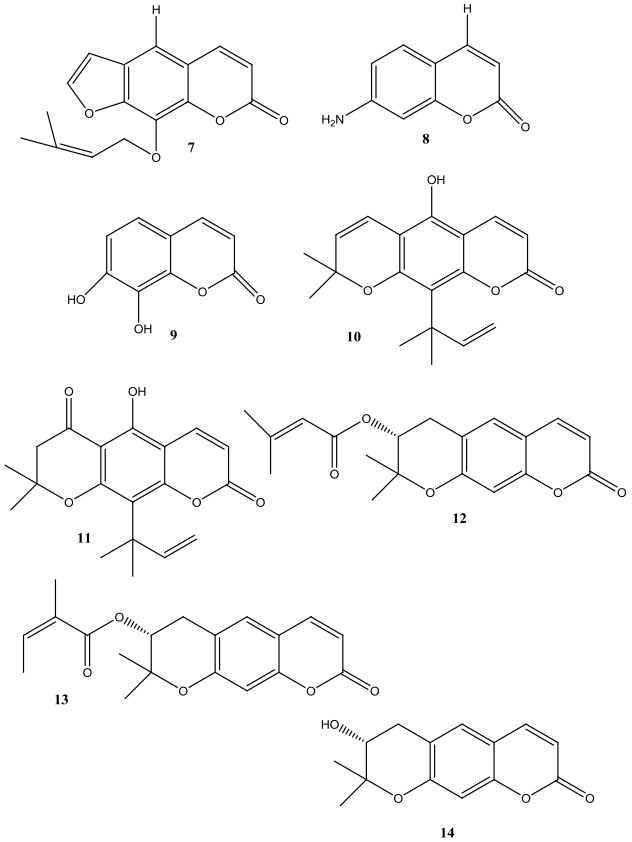
1 $C_{15}H_{10}N_2$
2 $C_{16}H_{12}N_2$
3 $C_{23}H_{23}NO_6$
4 $C_{20}H_{17}NO_6$
5 $C_{23}H_{25}NO$
6 $C_{14}H_8N_2O$

Fig. 1. *Alkaloids*
Rys. 1. *Alkaloidy*

Coumarins

The coumarin derivatives have the chroman ring system. Coumarin compounds are typically found in plants as glycosides, and constituents of essential oils and plant extracts. There were more than 300 coumarins compounds found. They usually occur in seeds, fruits and roots. The action of coumarins in the raw materials used in the form of herbal mixtures

depends on the degree of solubility in an aqueous medium. Recent studies have provided interesting new data on the pharmacological properties of coumarins. The pharmacological properties of coumarins are: calming effect, antispasmodic and vasodilator and anti-cancer [2]. In vivo studies conducted by Imaida 1% eskulina inhibited tumor growth promotion of rat induced by subcutaneous administration of 1,2-dimethyl-hydrazine (40 mg kg^{-1}, for a week) and then l-methyl-l-nitrosourea (20 mg kg^{-1}, twice a week for two weeks) [7]. Coumarins also exhibit significant antimicrobial activity [8-11]. Okunade and Arbab described activity of coumarins against mycobacterium. Highest activity of dentatin (**10**) andnordentatin (**11**) found by isolated from *Clausen excavata* (MIC 50.0-200.0 μg ml^{-1}) [6, 9]. Grandivittin antibacterial activity (**12**) agasyllin (**13**), aegelinol (**14**) isolated from *Ferulago campestris* were described Basile. These compounds against strains of *S. aureus*, *P. vulgaris*, *P. aeruginosa*, *P. mirabilit*, E. *cloacae* (MIC 16-250 μg ml^{-1}) [9].

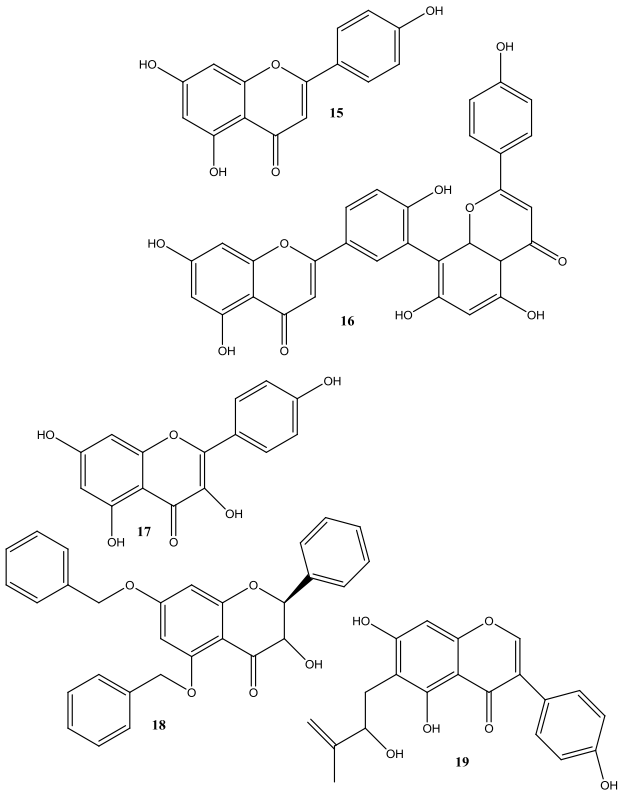


7 $C_{16}H_{14}O_4$
8 $C_9H_9NO_2$
9 $C_9H_6O_4$
10 $C_{19}H_{20}O_4$
11 $C_{20}H_{24}O_5$
12 $C_{18}H_{17}O_5$
13 $C_{18}H_{17}O_5$
14 $C_{14}H_{14}O_4$

Fig. 2. *Cumarins*
Rys. 2. *Kumaryny*

Flavonoids

Flavonoids are widespread plant secondary metabolites. These are compounds of a dye. In plants, as active biochemical components they give the color of flowers and fruits, are copigments of anthocyanidins, as a filter that protects the plant from UV radiation, significant antioxidant properties, protecting the plant from free radicals generated during photosynthesis. Flavonoid compounds are characterized by multidirectional biological activity, which is used for medical, therapeutic and cosmetic. Some flavonoids seal the blood vessels, inflammatory, antioxidant and estrogen. Many flavonoids characterized activity of antibacterial, antifungal and antiviral [2]. The mechanism and the strength of their action depend on the chemical structure and the presence or absence of different functional groups [13]. An example of a comprehensive action is kaempferol. (**17**). This compound inhibited Gram-positive and Gram-negative pathogens (MIC 2.4-10.1μg ml^{-1}), and the fungi of the genus *Candida glabrata* (MIC 4.8-9.7 μg ml^{-1}) [2, 12]. Amentoflavone and apigenin reveal a strong effect against the fungal pathogens *C. albicans*, *S. cerevisiae* and *T. beigelii* (MIC = 5 μg/ml), which was described by Saleem et al. [2].



15 $C_{15}H_{10}O_5$
16 $C_{30}H_{20}O_{10}$
17 $C_{15}H_{10}O_6$
18 $C_{29}H_{14}O_5$
19 $C_{25}H_{26}O_6$

Fig. 3. *Flavonoids*
Rys. 3. *Flawonoidy*

Flavonoids are active against antibiotic-resistant strains. Saleem et al. also described the strong effect of apigenin isolated from *Scutellaria barbata* (*Lamiaceae*) against 20 strains of MRSA (MIC 3.9 - 15.6 μg ml^{-1}) [2]. Studies have shown that polyhydroxy derivatives of flavonoids reveal activity against methicillin-resistant strains of *S. aureus* (MRSA). The important action is the presence of at least one hydroxyl group in ring A and B at positions C-3, 5, 7. Inhibited the growth of MRSA strains: flavone, kaempferol, datiscetin, quercetin, luteolin, myricetin (in descending order). Pinocembrin, chrysin, galangin and tamariksetin were inactive. Aglycones of sugar abolish activity, for example glycosides of quercetin and myricetin were inactive [13]. Some flavonoids inhibit the activity of *Helicobacter pylori*, which is responsible for 80% of cases of gastric ulcer and 90% of patients with duodenal ulcer. Infection with this bacterium may also influence the development of cancer of the stomach. Defining characteristic of these bacteria is resistant to gastric acid. They produce large quantities of urease, the enzyme catalyzes the breakdown of urea into carbon dioxide and ammonia. Ammonia causes the neutralization of hydrochloric acid (present in gastric juice) in the immediate vicinity of H. pylori, which is essential for their survival [12]. Some of the flavonoid aglycones have the ability to inhibit urease (glycosides act decisively less). Revealing the activity of flavonoids, which have a methoxy group at C-4', while the presence of a hydroxyl group or an additional OH in ring B reduces this effect. Such action shows, for example ponceritin (MIC 10 μg ml^{-1}), hesperetin (MIC 20 μg ml^{-1}), naringenin (MIC 40 μg ml^{-1}), diosmetin (MIC 80 μg ml^{-1}) ampicillin (MIC l μg ml^{-1}) [13].

Essential oils and terpenoids

Researches on antibacterial and antifungal properties of essential oils were carried out for a long time. The main components of essential oils are terpenoid compounds that have a broad spectrum of biological properties. Microbiological activity of terpenes and terpenoids is of interest of many researchers. Antibacterial and antifungal activity has been demonstrated (1, 2, 14-16). In their study Cantrell et al. found 118 of natural and synthetic terpenoids compounds, with proven microbiological activity against haemophilus tuberculosis [19]. The best effects of the terpenoids in the destruction of tuberculosis bacilli collected and described by a team led by Okunade. Terpenoids were potent phorbol esters (**20**-**25**), dustanin (**26**), 15-acetoxydustain (**27**), cycloartenol (**28**) (MIC 3.12-32.0 μg ml^{-1}) [2]. Plant preparations that have antibacterial properties are used as monotherapy, for example in the treatment of inflammatory airways. This group includes plant preparations and in their lineup essential oils with terpenoid compounds content are inluded. Among the essential oils, pharmacological properties of different types, depending on the nature of the main components, are observed. Many essential oils have antimicrobial activity, including garlic, chamomile, peppermint, lavender oil [14]. An example of the use of essential oils with antimicrobial properties is the Salviasept (Herbapol, Lublin, Poland). This preparation is used to prevent and treat infections in the oral cavity. It includes oils such as sage, thyme, marjoram, peppermint, clove and extracts with baskets chamomile, sage leaves, yarrow herb, peppermint, thyme, fennel fruit, cineol, menthol and ethanol. Many studies showed that essential oils or plant extracts that are included in the Salviasept are active against many aerobic bacteria, anaerobic bacteria and fungi yeast derivatives and mold, e.g. *Staphylococcus aureus*, *Enterococcus faecalis*, *Micrococcus luteus*, *Lactobacillus* spp, *Escherichia coli*, *Salmonella typhimurium*, *Mycobacterium avium*, *Enterococcus faecalis*, *Klebsiella pneumoniae*, *Bacillus cereus*, *Proteus vulgaris*, *Aspergillus flavus*, *Bacteroides fragilis*, *Fusobacterium nucleatum*, *Propionibacterium agnes* [16-18].

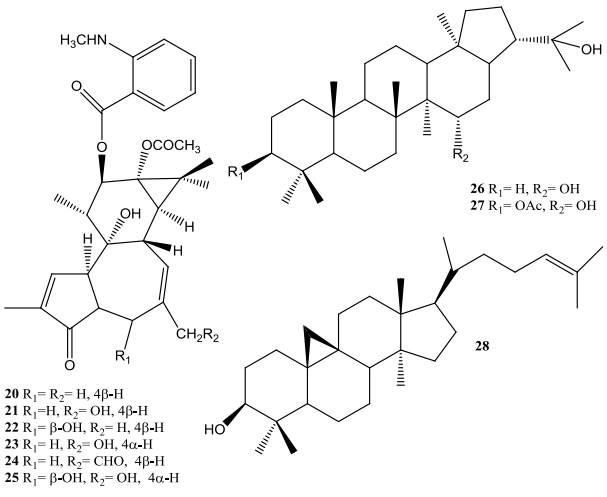


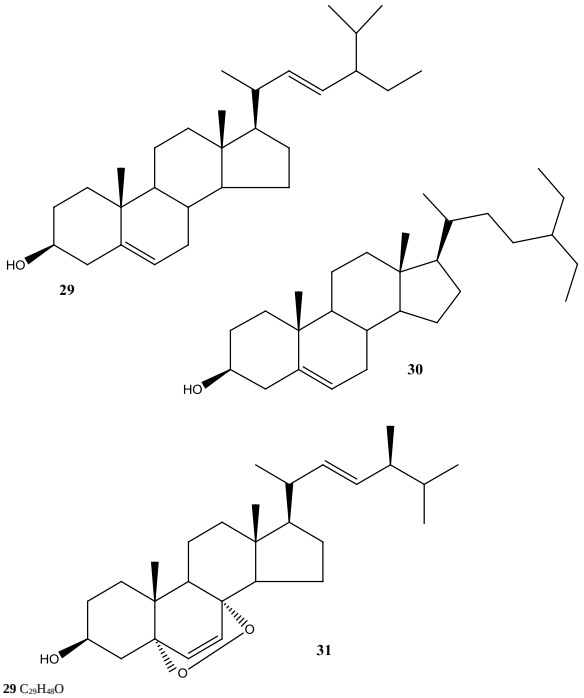
Fig. 4. *Terepenoids*
Rys. 4. *Terpenoidy*

Antibiotic resistance in bacteria is encoded in the plasmid DNA and is passed on to future generations of

bacteria. Studies show that some bacteria are not yet adequate defense mechanism on selected essential oils. The published data shows that to the fight against drug-resistant bacteria can be via essential oils and treated as an effective alternative to antibiotics [14]. Current research on rapid development of antimicrobial substances raises hope that well-known essential oils, as well as those of new varieties of herbs, may be an important group of substances of therapeutic and antimicrobial importance and address the problems facing today's pharmaceutical industry.

Phytosterols

Numerous studies have shown that phytosterols have anticoagulant properties, which reduce the risk of heart attack and stroke. Furthermore, it was observed that the high content of phytosterols in the diet prevents the development of many cancers, particularly colon, prostate and breast. In medicine, plant sterols help to treat prostate enlargement, and help when difficulties with urination appear. The indication for consumption of phytosterols is also surgical procedures on the prostate gland. Consuming large quantities of phytosterols does not cause side effects.



29 $C_{29}H_{48}O$
30 $C_{28}H_{48}O$
31 $C_{27}H_{41}O_3$

Fig. 5. *Phytosterols*
Rys. 5. *Fitosterole*

High doses of phytosterols have estrogenic activity, which reduces the symptoms of menopause in women, such as hot flashes and excessive sweating. In addition, plant sterols inhibit the production of free radicals, which accelerate the aging of the excess of the body and cause of many diseases. In addition, many of phytosterols has antibacterial activity [1, 2, 20]. Examples include: β-sitosterol, stigmasterol, pidoxysterol isolated from *Morinda citrifolia* (*Rubiaceae*), which showed strong activity against *Mycobacterium intracellulare* (MIC 2.5-128 μg ml^{-1}) [2].

Phenolic (other than flavonoids and lignanas)

Phenolic natural function is to protect these plants from synthesizing bacterial infections and diseases caused by fungi [21]. Antibacterial activity was confirmed for the acids: caffeic, vanillic, *p*-coumaric, *p*-hydroxybenzoic acid [23], found in *scrophularia, sambucifolia jrutescens* and phenolic acids such as ferulic, isovanillic, *p*-hydroxycinnamic acid, syringic, caffeic, gentisic and protocatechuic which have antimicrobial properties, especially against Gram-positive (*Bacillus sp*). Raw materials are used in traditional medicine as an anti-inflammatory and fighting various dermatoses, and antiparasitic (scabies) [22].

Confirmed the antiviral activity of rosemary and caffeic acid [22]. Caffeic acids also act as an antiseptic. Some depsides lichens inhibit the growth of *Mycobacterium tuberculosis* [23].

SUMMARY

A literature review shows how a great interest in this subject. It is not surprising that the natural substances that inhibit the growth of microorganisms are becoming an alternative to synthetic compounds. Until now explore the properties of many plant extracts. Although many compounds are known, there are probably still many unidentified. These, some of which have been tested, require further analysis to confirm their interesting properties *in vivo* and in clinical trials. Special hopes are connected with antibacterial properties. It is also important to know biosynthetic pathways and their modification in order to more efficiently produce biologically active substances in various systems, such as vegetable bioreactor cultures. It is important to investigate the synergistic action of plant secondary metabolites of synthetic drugs.

Table 1. *Antimicrobial activity compounds by class*
Tabela 1. *Aktywność mikrobiologiczna klas związków*

Compound class and name Klasa i nazwa związków	Plant Roślina	Activity / MIC Aktywność /MIC [μg/ml]	References Literatura
Alkaloids / Alkaloidy			
Quindoline **(1)** Kuindolina Cryptolepine **(2)** Kryptolepina	*Sida acuta*	*Staphylococcus aureus* (80–400), *Enterococcus* faecalis (16), *Escherichia coli* (80)	[5]
Allocryptopine **(3)** Allokryptolepina Hipecorinine **(4)** Hipekorinina	*Hypecoum erectum*	*Staphylococcus aureus* (250), *Escherichia coli* (125), *Pseudomonas aeruginosa* (125)	[4]
Mahanibicine **(5)**	*Murraya koenigii*	*Staphylococcus aureus* (250), *Escherichia coli* (250), *Streptococcus* pneumoniae (125)	[15]
Canthin-6-one **(6)**	*Allium neapolitanum*, *Zanthoxylum chiloperone var. angustifolium*	*Aspergillus fumigatus*, *Aspergillus niger* *Candida albicans*, *Candida tropicalis*, *Candida glabrata*, *Cryptococcus neoformans*, *Geotrichum candidum*, *Saccharomyces cerevisiae*, *Trichosporon beigelii*, *Trichosporon cutaneum* (1.66–10.12)	[2]
Cumarins / Kumaryny			
Imperatorin **(7)** Imperatoryna	*Angelica lucida*	*Staphylococcus aureus* (40.0), *Staphylococcus epidermidis* (35.0), *Escherichia coli* (25.0)	[11]
7-amino-4-methylcoumarin **(8)** 7-amino-4-metylokumaryna	*Ginkgo biloba*	*Staphylococcus aureus* (10.0), *Escherichia coli* (10.0), *Candida albicans* (15.0),*Salmonella enteritidis* (8.5)	[2]
Daphnetin **(9)** (7,8-dihydroksykumaryna)	*Daphne gnidium*	*Pseudomonas aeruginosa* (50.0), *Staphylococcus aureus* (100.0), *Escherichia coli* (100.0)	[10]
Dentatin **(10),** Dentatyna *Nordentatin* **(11)**	*Clausena excavate*	Mykobakterie Mycobacteria (50.0–200.0)	[6, 9]
Grandivittin **(12)**, Agasyllin **(13)**, Aegelinol **(14)**	*Ferulago campestris*	*Staphylococcus aureus* (16–250), *Proteus vulgaris* (32–64), *Pseudomonas aeruginosa* (32–250), *Proteus mirabilit* (64–125), *Enterobacter cloacae* (16–125)	[8]
Flavonoids / Flawonoidy			
Apigenin **(15)** Apigenina	*Scutellaria barbata*	MRSA (3.9–15.6)	[13]
Amentoflavone **(16)** Amentoflawon	*Selaginella tamariscina*	*Candida albicans*, *Saccharomyces* cerevisiae, *T.richosporon beigelii* (5.0)	[13]
Kaempferol **(17)** Kemferol	*Vismia laurentii*	*Candida glabrata* (4.8-9.7)	[13]
Dibenzyloxyflavone **(18)**	*Helichrysum gymnocomum*	*Cryptococcus neoformans* (7.8)	[13]
Laburnetin **(19)**	*Ficus chlamydocarpa*	*Mycobacterium smegmatis*, *Mycobacterium tuberculosis* (0.61-4.98)	[13]
Terpenoids / Terpenoidy			
Phorbol esters (**20**-**25**) Estry forbolu	*Sesame indicum*	Mykobakterie Mycobacteria (3.12–50)	[6, 19]
Dustanin (**26**) Dustanina	*Aschersonia tubulata*	Mykobakterie Mycobacteria (12.5)	[6, 19]
15-acetoxydustain (**27**) 15-acetooksydustaina	*Asclepias* tubulata	Mykobakterie Mykobacteria (12.5)	[6, 19]
Cykloartenol (**28**)	*Morinda citrifolia*	Mykobakterie Mycobacteria (32.0)	[6, 19]
Phytosterols ***Fitosterole***			
Stigmasterol **(29)** Stigmasterol, β-sitosterol **(30)** β-sitosterol**,** Epidioxystero **(31)** Epidioksysterol	*Morinda citrifolia*	Mykobakterie Mycobacteria (2.5–128.0)	[6]

REFERENCES

1. Okpuzor J, Adebesia O, Ogbunugafor H, Amadi I. The potential of medicinal plants in sickle cell disease control: A review. Internat Biomed Health Sci, 2008, 4 (2): 47–55.
2. Saleem M, Nazir M, Shaig M, Hussain H. Antimicrobial natural products : an update on future antibiotic drug candidates. Nat Prod Rep 2010, 27: 238–254.
3. Sher A. Antimicrobial activity of natural products from medicinal plants. Gomal J Med Sci, 2009, 7, (1): 72–78.
4. Su Y, Li S, Li N, Chen L, Zhang Z. Seven alkaloids and their antibacterial activity from *Hypecoum erectum* L. J Med Plants Res , 2011, 5 (22): 5428-5432.
5. Karou D, Savadogo D, Canini A, Yameogo S. Antibacterial activity of alkaloids from *Sida acuta.* Afri J Biotech, 2006, 5 (2): 195-200.
6. Okunade AL, Elvin-Lewis PF, Lewis WH. Natural antimycobacterial metabolites: current status, Phytochemistry, 2004, 65: 1017.
7. Imaida K, Hirose M, Yamaguchi S, Tanahashi S. Effects of naturally antioxidants on combined 1,2-dimethylhydrazine- and 1-methyl-1-nitrosourea-initiated carcinogenesis in F344 male rats. Cancer Lett 1990, 5: 53–59.
8. Basile A, Sorbo S, Spadaro V, Maurizio B. Antimicrobial and antioxidant activities of coumarins from the roots of *Ferulago campestris* (*Apiaceae*), Molecules, 2009, 14*:* 939–952.
9. Arbab IA, Abdul AB, Aspollah M, Abdullah R. *Clausena excavata* Burm. f. (Rutaceae): A review of its traditional uses, pharmacological and phytochemical properties. J Med Plants Research, 2011, 5 (33): 7177–7184.
10. Cottiglia F, Loy G., Garau D, Floris C. Antimicrobial evaluation of coumarins and flavonoids from the stems of *Daphne gnidium* L. Phytomedicine, 2001, 8 (4): 302–305.
11. Widelski J., Popova M., Graikou K., Glowniak K., Chinou K., Coumarins from *Angelica lucida* L. - antibacterial activities. Molecules 2009, 14*:* 2729–2734.
12. Cushnie TP, Lamb AJ. Antimicrobial activity of flavonoids. Internat J Antimic Agents, 2005, 26: 343–356.
13. Byłka W, Matławska I, Pilewski NA: Natural flavonoids as antimicrobial agents. JANA. 2004, 7 (2): 9–16.
14. Bakkali F, Averbeck S, Averbeck DI. Biological effects of essential oils – A review. Food Chem Toxicol, 2008, 46: 446–475.
15. Nagappan T, Ramasamy P, Effendy M, Wahid A. Biological activity of carbazole alkaloids and essential oil of *Murraya koenigii* against antibiotic resistant microbes and cancer cell lines. Molecules 2011, 16: 9651–9664.
16. Kędzia A, Kochańska B, Molęda-Ciszewska B, Wojtaszek-Słowińska A. Sensitivity of microaerophilic bacteria to Salviasept®. Dent Med Probl 2010, 47, 3: 328–333.
17. Malik T, Singh P. Antimicrobial effects of essential oils against uropathogenes with varying sensitivity to antibiotics. Asian J. Biol. Sci. 2010, 3: 92–98.
18. Saković MD, Vukojevic J, Marin PD, Brkic DD. Chemical composition of essential oils of *Thymus* and *Mentha* species and their antifungal activities. Molecules 2009, 14: 238–249.
19. Cantrell CL, Franzblau SG., Fischer NH. Antimycobacterial plant terpenoids, Planta Med, 2001, 67: 685–692.
20. Mehtiev AR, Misharim A. Biological activity of phytosterols and their derivatives. Biochemistry (Moscow) Supplemental Series: Biomedical chemistry, 2008, 2 (1) 1–17.
21. Cueva C, Moreno-Arribas MV, Martín-Álvarez PJ. Antimicrobial activity of phenolic acids against commensal, probiotic and pathogenic bacteria. Research Microbiol, 2010, 161 (5): 372–382.
22. Borkowski B, Biesiadecka A, Litwińska B: Porównanie aktywności wirusostatycznej kwasów: kawowego, chlorogenowego i rozmarynowego. Herba Polonica 1996, 4: 317–320.
23. Borkowski B: Fenolokwasy i ich estry cz. I, Herba Polonica, 1993, 3: 77–79.

Address for correspondence:
Institute of Organic Chemical Technology
Department of Organic Synthesis
and Drug Technology
West Pomeranian University of Technology,
Aleja Piastów 42
71-065 Szczecin, Poland
dr hab. inż. Maria Swarcewicz, prof. ZUT
e-mail: mswar@zut.edu.pl
phone: 91 449 47 41

Received: 25.07.2012
Accepted for publication: 18.09.2012