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Properties and use of rosemary (*Rosmarinus officinalis* L.)

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ABSTRACT
Rosemary (*Rosmarinus officinalis* L.) is a spice herb found in most cuisines and in many spice blends on the Polish market. It deserves special attention, not only because of its unique taste and smell, but also due to a composition that provides health benefits. Its antimicrobial activity has been proven in relation to bacteria, fungi (including yeast) and viruses. Positive effects on the metabolism of carbohydrates and lipids, and the function of the nervous system, as well as hepatoprotective properties have been demonstrated. The plant itself and the extracts and essential oils obtained from it are used in home cooking, and the cosmetic and food industries. It also finds applications in agriculture as an animal feed additive.
The aim of the work was to review current scientific publications and present the properties and areas of use of rosemary .
Keywords: rosemary; *Rosmarinus officinalis* L.; chemical composition; applications.

ROSEMARY – A PLANT FROM THE *LAMIACEAE* FAMILY

Rosemary (*Rosmarinus officinalis* L.) is an evergreen brush belonging to the *Lamiaceae* family. In natural conditions, it can reach from approx. 1 m to even 2.5 m in height. The stems are quadrangular, erect, and tend to lignify in the 2nd year. They are densely covered with small needle-like leaves without stalks (sessiles); the leaves are linear with entire slightly revolute margins that are dark-green above, lighter and tomentose beneath. Rosemary blooms from early June to August. The flowers are very small, white or purplish-blue, gathered in terminal racemose inflorescences [1, 2]. Rosemary is cultivated in the Mediterranean region, as well as in the former Yugoslavia, along the Black Sea coast, in the USA and in Mexico [3]. It is best planted in a sunny position and must be protected from cold winds (mainly in temperate climate zones). The plant reproduces predominantly sexually. The soil needs to be loose and loamy with excellent drainage. When grown in such conditions, the plant will have a more intense aroma, though at the expense of size. Leaves produced at the beginning of bloom contain the highest amounts of oil, and is when they should be collected. Apart from the leaves, non-woody sprigs are also used. After harvesting, the material is air dried, in the shade preferably, at 30–35°C [1, 4].

CHEMICAL COMPOSITION OF ROSEMARY

Rosemary extract

The extract is produced mainly from the leaves. Solvents used for extraction include: ethanol, acetone and hexane, and extraction by means of supercritical CO_2 is also popular [5]. Extracts contain considerable amounts of biologically active substances [6], e.g. phenolic acids, flavonoids, terpenes [5]. Among the phenolic acids in rosemary extract, researchers have managed to isolate caffeic acid, 4-hydroxybenzoic acid, p-coumaric acid, and rosmarinic acid (0.14 mg/g) [7]. They also found some flavonoids: luteolin (0.26 mg/g), apigenin (0.45 mg/g), diosmetin (0.21 mg/g), hispidulin and hesperidin (0.36 mg/g). Besides di- and triterpenes they found: carnosic acid (128.15 mg/g), oleanic acid, ursolic acid, carnosol (30.08 mg/g), rosmanol (1.25 mg/g), rosmaridiphenol, betulin, picrosalvin, α-amyrin and β-amyrin. The biological effects of rosemary depend to a large extent on the constituents of its essential oil, which is therefore described separately in an analysis of the composition of the volatile oil fraction [7, 8].

Rosemary essential oil

Essential oils are found in glandular trichomes, at the bottom of the leaves and within flowering tops. The oil content in leaves ranges between 1.0–2.5%, depending on whether the leaves are young, or fully mature and dry. The composition of the essential oil may differ depending on the country of origin, weather and cultivation conditions, as well as the time of harvest, manner of drying and storing. Genetic variability is also a factor [9, 10]. In a quantitative analysis of the chemical composition of oils from different regions (Iran, Morocco, Spain, France, Algeria, Cuba, Argentina, Italy), the following constituents were identified as shared in common: α-pinene, β-pinene, 1,8-cineole, camphene, borneol, camphor, linalool and β-caryophyllene. Substances found in the majority of oils were: β-myrcene, bornyl acetate, verbenone, limonene and sabinene [11, 12], which are terpene compounds [13]. The 4 main chemotypes of rosemary that are characteristic of the different geographical regions are named according to the predominant constituent: α-pinene chemotype (Iran, Spain, France, Italy, Romania), 1,8-cineole chemotype (Algeria, Austria, Morocco), camphor chemotype (Cuba, India), and myrcene chemotype (Argentina, Portugal). While these are the most common chemotypes, there are many other combinations of relative quantitative values of the respective constituents. A study made in the Sudan demonstrated that the predominant constituent of the local rosemary oil was bornyl acetate, which is usually only found in small quantities in the material from other countries [9, 10].

ANTIMICROBIAL PROPERTIES OF ROSEMARY

The inhibiting effect on bacterial growth depends on the type of rosemary preparation the bacteria are exposed to. Fresh leaves, essential oils, aqueous or alcoholic extracts all produce a different degree of inhibitory or bactericidal effect. This phenomenon is attributed to the different concentrations of biologically active compounds. The largest amounts are found in essential oils, followed by extracts. Both Gram(+) and Gram(−) bacteria are sensitive, but rosemary was reported to be a more potent inhibitor against Gram(+) bacteria due to the difference in the structure of the bacterial cell wall. The minimum inhibitory concentration (MIC) and minimum bactericidal concentration, at which the number of live bacteria is reduced to under 0.1% may differ even for the same bacterial strains, mainly due to the origin of the plant and, consequently, the different chemical composition determining antimicrobial activity. Differences are also related to the type of solvent used in extraction. Importantly, bacteria may develop resistance against the active components of plant extracts, rendering them less effective [14, 15, 16]. Rosemary has demonstrated bacteriostatic and bactericidal effects against the bacteria responsible for food spoilage and food poisoning. Sensitivity was observed in *Salmonella* (*S. typhimurium*, *S. anatum*, *S. enteritidis*) and *Listeria* (*L. monocytogenes*, *L. ivanovii*, *L. grayi*, *L. innocua*), as well as *Yersinia enterocolitica*, *Shigella flexneri*, *Staphylococcus aureus*, *Bacillus cereus*, isolated from meat products and dishes containing meat: sausage, chicken salads, steak tartare and meat pasties [17, 18, 19, 20, 21]. Rosemary also displays inhibitory and cidal activity against fungi. It was particularly effective against plant pathogenic species. Researchers investigated the sensitivity of *Fusarium* moulds (*F. culmorum*, *F. nygamai*, *F. avenaceum*, *F. sporotrichiodes*, *F. subglutinans*, *F. trincinctum*, *F. oxysporum*, *F. ploriferatum*, *F. semitectum*, *F. scirpi*, *F. nivale*, *F. graminearum*, *F. monoliforme*, *F. solani*) isolated from dried maize grains. The highest efficacy was observed with respect to *F. scirpi*, *F. avenaceum*, *F. semitectum* and *F. trincinctum*. Growth inhibition was observed in *Aspergillus* species (*A. flavus*, *A. ochraceus*, *A. parasiticus*, *A. fumigatus*, *A. flavipes*, *A. ustus*, *A. nidulans*, *A. wentii*, *A. sparsus*, *A. versicolor*, *A. terreus*, *A. humicola*). In some cases, the efficacy of the essential oil was comparable to that of nystatin [22].

Scholars also looked into the effect of rosemary on *Candida* strains collected from gynaecological patients. Activity was determined for aqueous, ethanol and ethyl acetate extracts of rosemary. For 9 strains, MIC ranged between 25–150 mg/mL for the ethanol extract and 12–50 mg/mL for the ethyl acetate extract. These findings suggest that extracts of rosemary may offer an alternative therapy for vaginal yeast infections. A precise therapeutic doses needs to be established, though, and various species and strains of *Candida* should be investigated. It is also important to examine synergistic effects with other preparations having a similar action and to observe cytotoxic effects [23]. Matsuzaki et al. [24] analysed extracts obtained by steam distillation of rosemary leaves from Spain, Tunisia and Morocco, representing chemotypes determined according to the predominant compounds, respectively: camphor, verbenone and 1,8-cineole. Extracts were examined with and without a surfactant for antimicrobial activity against *Candida albicans*. The highest inhibitory and antifungal activity was observed when the surfactant was added to the extracts. The 1,8-cineole chemotype showed the lowest MIC. Still, it is difficult to identify the exact compounds responsible for the inhibitory and antifungal activity against *Candida*. Research findings are not consistent in this regard. Consequently, researchers' attention should be directed at components present in trace amounts or those whose properties have not been described yet.

Rosemary essential oil was also investigated for its effect on *Bortrytis cinerea*, the fungus responsible for causing grey mould disease of tomato. With respect to the volatile vapour of rosemary oil, fungal growth was inhibited by more than 50% at 0.8 μg/mL air concentrations, and in terms of contact phase effects, 60% efficacy was observed at 12.8 μg/mL. Apart from inhibiting the growth of *B. cinerea*, rosemary oil was also observed to reduce the germination and growth of such weeds as *Stachys arvensis* and *Lolium rigidum*. The phytotoxic properties of rosemary, together with its antifungal activity, may open up an opportunity for developing a bio-pesticide combining herbicide and fungicide effects [25, 26].

Yucharoen and Tragoolpua [27] evaluated the influence of ethanol extracts of rosemary on the Herpes simplex virus (HSV), and more specifically: HSV-2G and HSV-1F. An inhibitory effect was observed both during and after viral adsorption. The extract under analysis interfered in the process of fusion of the viral envelope to cell membrane. Having identified a therapeutic potential, the authors suggested that further studies were needed to develop anti-HSV medication which would combine the extracts of both plants. Vijayan et al. [28] confirmed the antiviral activity of essential oil against HSV-1. High antiviral activity was demonstrated in a study of essential oil blends, which apart from rosemary leaf at 3% included the leaf of Tasmanian bluegum (3.52%), cinnamon bark (3.52%), wild carrot seed (1.04%) and camelina seed oil (88.9%). Findings included inhibition of HSV-1 viruses and the H1N1 influenza viral strain [29].

EFFECT OF ROSEMARY ON THE HUMAN BODY

Effect of rosemary on carbohydrate metabolism

Recent years have witnessed a growing interest in medicinal products of natural origin, driven among others by the side effects caused by pharmaceutical preparations. A variety of chemical compounds found in plants have insulin mimetic effects, which can be used in the treatment of diabetes. Phenolics, flavonoids and terpenoids, which bring down blood glucose levels, and therefore help control hyperglycaemia, are found in rosemary in large amounts. Therefore, the plant became the object of studies, which confirmed time and time again its health benefits [30].

Naimi et al. [31] demonstrated that rosemary extract and rosemary extract polyphenols (carnosic acid and rosmarinic acid) found in rosemary in large quantities, can produce insulin-like effects in target cells for insulin, as well as exhibit protective properties against hyperglycaemia. The effect was observed in different animal models used in experiments. Observed effects on hepatocytes in the liver included the suppression of gluconeogenesis and an increased glycolytic rate, as well as a decreased glycogen content. Treatment with rosemary extract or concentrated amounts of carnosic acid resulted in an increased glucose uptake in muscle tissue, skeletal muscles to be exact. Runtuwene et al. [32] confirmed the beneficial effects of rosemary. Rosmarinic acid on its own exhibits highly comprehensive action. Its effects on skeletal muscle upregulate the expression of glucose transporter type 4 (GLUT4), and consequently enhance glucose transport and utilisation, as well as reverse the development of insulin resistance. Moreover, researchers observed reduced expression of phosphoenolpyruvate carboxykinase (PEPCK), an enzyme participating in gluconeogenesis, whose elevated levels are present in chronic hyperglycaemic conditions. A lot of attention was also attracted by the discovery of the effect of rosmarinic acid on AMP-activated protein kinase – responsible for a variety of regulatory processes in lipid and carbohydrate metabolism. AMP-activated protein kinase phosphorylation increased, leading to an enhanced glucose uptake in muscle cells comparable to that with insulin and metformin stimulation [33, 34]. Wen and Yin [35] demonstrated a variety of protective effects caused by the administration of rosmarinic acid. In particular, the inflammatory response in the livers of diabetic mice was reduced, which was confirmed by lower levels of inflammatory parameters: interleukin 6, tumor necrosis factor, prostaglandin E2 and cyclooxygenase 2.

Research corroborates the efficacy of rosemary extracts in bringing down blood glucose levels. In studies on animal models, rosemary was found to produce positive hypoglycaemic effects in normoglycaemia, hyperglycaemia caused by excessive glucose supply, and in alloxan-induced diabetes. Administration of the extract at 200 mg/kg b.w. produced effects similar to that of glibenclamide (a drug reducing blood glucose levels). These effects were accompanied by increased insulin secretion [36]. The efficacy of rosemary leaf powder in humans was also demonstrated. Study participants (48 people) were divided into 3 groups and administered 2, 5 and 10 g of rosemary leaf powder a day, respectively. The best effect was obtained with the 10 g dosage, with blood glucose level dropping by 18.25%, compared to the baseline. For the 2 g and 5 g cohorts, the levels went down by 11.2% and 15.74% respectively [37]. Another study, also with human participants, and also with leaf powder, confirmed the reduction in glucose and additionally a reduction in glycated haemoglobin (HbA1c), the parameter used to monitor glycaemic control in people with diabetes. The participants took 3 g of rosemary leaf powder 3 times a day (total 9 g a day). Fasting glucose levels in healthy participants decreased by 14%, and by 18–23% in those with type 2 diabetes and on medication. The versatile activity of rosemary preparations in maintaining carbohydrate homoeostasis is highly promising for the future and merits deeper insights into the properties of the plant. Further research is needed to explore all the aspects of its activity and long-term effect on the body [38].

Effect of rosemary on lipid metabolism

Literature also reports on the effects of rosemary on total cholesterol, high-density lipoprotein (HDL) and low-density lipoprotein (LDL) fractions, as well as the concentrations of triglycerides (TG) in serum. Afonso et al. [39] evaluated the effect of an aqueous extract and its phenolic fractions on changes in blood serum composition and the condition of tissues in rats with diet-induced hypercholesterolemia. The extract, administered at concentrations of 70 and 140 mg/kg b.w., led to a significant increase in HDL cholesterol and a decline in serum TG. The level of total cholesterol, on the other hand, was reduced with both the aqueous extract and the phenolic fractions. The best therapeutic effect was obtained with the extract at 70 mg/kg b.w., which apart from improving the lipid profile, brought down the levels of thiobarbituric acid reactive substance, a marker of oxidative stress, thus helping in the battle against complications.

Selmi et al. [40] investigated the protective effect of essential oils in alloxan-induced metabolic disorders. The study confirmed the beneficial effects of rosemary on normalising cholesterol and triglyceride parameters. The biochemical parameters of the lipid profile were also reduced in a study of patients who received powdered rosemary for 8 weeks at 2.5 and 10 g; the best results were achieved with a 10 g dosage [37]. Stefanon et al. [41] reported that rosemary may affect adipocyte lifecycle at different stages. Importantly, this effect also applies to the cells of the visceral fat tissue, which plays the most important role in the development of the metabolic syndrome. In another study, the focus was placed on carnosic acid and carnosol. They were found to be involved in inhibiting the differentiation of preadipocytes into mature fat cells – adipocytes [42]. Bustanji et al. [43] attempted to explain the mechanism behind the hypoglycaemic and hypolipidemic properties of rosemary. They posited that one of the reasons is the effect of rosemary on hormone sensitive lipase (HSL), also referred to as cholesterol esterase, which is involved in regulating fatty tissue metabolism. Under normal physiological conditions, the activity of this enzyme is inhibited by insulin, but insulin resistance compromises this ability. Rosemary extract was demonstrated to have an inhibitory effect on HSL. It means that the improvement of the glycaemic and lipid profiles is linked to the activity of rosemary, which despite insulin resistance regulates the parameters of the interrelated processes of lipid and carbohydrate metabolism [44, 45].

Effect of rosemary on the nervous system

Reports about rosemary also point to its anxiolytic and antinociceptive effects. Abdelhalim et al. [46] demonstrated such activity for 3 compounds isolated from rosemary: rosmanol, salvigenin and cirsimaritin. The study was based on standardised tests checking the response in mouse models to factors inducing anxiety and pain. Positive results were observed in all areas tested, and the antinociceptive effect was comparable to that of tramadol – an opioid analgesic. Another study demonstrated that anxiety in mice subjected to a forced swimming test and a tail suspension test was lower after the administration of a hydroalcoholic extract. The effect was compared to that of an anti-depressant (fluoxetine). Rosemary interacted with dopaminergic, noradrenergic and serotonergic receptors [47]. The hydroalcoholic extract was also analysed for effects on biochemical and behavioural parameters of mice following olfactory bulbectomy. The procedure induces similar behavioural and neurological alterations as those observed in people with depression. Researchers reported reduced activity of acetylcholinesterase, whose elevated expression causes anhedonic behaviour. The effects were again compared to those of fluoxetine. These findings raise hopes for assisting in the treatment of major depression episodes in the course of bipolar affective disorder [48].

Nematolahi et al. [49] investigated rosemary as a potential remedy for the widespread prevalence of sleep disorders, anxiety and depression among university students and their increasing use of stimulants to improve memory performance and to reduce stress levels. About 100 students (aged: 20–25 years) were included in the study and divided into 2 groups. One group received starch capsules as a placebo, the other received powdered rosemary capsules (one 500 g capsule twice a day). At the beginning and then at the end of the experiment, the students filled out questionnaires testing their stress and depression parameters, sleep quality, prospective and retrospective memory. Rosemary was demonstrated to have positive effects on enhancing memory performance, reducing anxiety and depression. Moreover, the group which received rosemary reported improved sleep onset latency and better sleep quality. It may therefore be concluded that rosemary preparations could provide a herbal alternative to stimulant substances that many people resort to at times of intense mental effort. There have been promising reports about the effects of the extract and components isolated from rosemary on inhibiting neurodegenerative processes. One of the lines of research is looking into the phenomenon of induced cerebral ischaemic tolerance. Seyedemadi et al. [50] investigated the effect of hydroalcoholic extract in rats. They found a reduced number of complications following acute ischaemic stroke which, notably, was also observed in the ischaemic penumbra (the area immediately surrounding an ischaemic event).

Cornejo et al. [51] evaluated epiisorosmanol, rosmanol, carnosol, carnosic and rosmarinic acid isolated from rosemary. They were observed to play a part in inhibiting structural neurodegenerative changes in the course of brain diseases caused by the aggregation of various undesirable compounds, in this case, tau proteins. Moreover, findings pointed to the protective effects of rosmarinic acid against neurotoxicity induced by β-amyloid. By combining these 2 actions against tau proteins and β-amyloid, rosemary offers a therapeutic potential for both slowing down and preventing the development of Alzheimer's disease [52].

Effect of rosemary on liver function

In search of hepatoprotective properties of rosemary, researchers elicited metabolic stress response with the use of compounds causing toxic damage to liver cells. Amin and Hamza [53] reported that pretreatment with an aqueous rosemary extract before the administration of hepatotoxic azathioprine prevented subsequent increases in the levels of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in serum. The absence of upregulation in these markers suggested that there was no liver damage, which was confirmed by histopathological examination. Moreover, researchers observed reduced levels of compounds accompanying adverse lipid peroxidation in oxidative stress conditions. These effects were attributed to the high levels of antioxidants. Abdel-Wahhab et al. [54], in a study on rats, evaluated the hepatoprotective action of aqueous extract in tetrachloromethane-induced toxicity. The protective effects were confirmed and attributed to anti-free radical properties. The parameters of liver function in rats that were given the extract before the tetrachloromethane suggest that the induced hepatoxicity was suppressed. Researchers tested AST, ALT, alkaline phosphatase, glutathione reductase, malondialdehyde and bilirubin. A similar study had been carried out earlier, leading to similar findings [55]. The protective action in hepatotoxicity is promising as it involves the inhibition of the primary mechanisms leading to the development of disorders. The risk of hepatic lipid accumulation is reduced, and in the long run also that of cirrhosis. Shan et al. [56] investigated the effect of carnosic acid on the progression of non-alcoholic fatty liver disease. They observed activation of one of the pathways attenuating hepatocyte apoptosis. The production of compounds responsible for stimulating the intensity of apoptosis was inhibited. Al Attar and Shawush [57] proposed that rosemary should be combined with other products with highly antioxidant properties, e.g. olive oil, to maximise the hepatoprotective effect. Rosemary was found to produce positive effects at various stages of liver disease, no matter how advanced.

APPLICATIONS OF ROSEMARY

Herbs in the kitchen, apart from enhancing the taste of foods, also produce some additional health benefits. Rosemary combines well with marjoram, savory, and is an ingredient of the traditional herbes de Provence. Rosemary leaves can be added to any type of meat, including fish, in any cooking method. They are a valuable addition to legumes, cauliflower, potatoes and herb butter. Rosemary also works very well with tomatoes, either fresh or in tomato-based sauces; and can be successfully used in baking (with bread, rolls or pizza). Furthermore, rosemary can be an ingredient of vinegar- and oil-based marinades and is also used to infuse liqueurs, flavoured bitter vodkas, herbal wine, mead and beer [3, 58]. Both the leaves and the flowers can be used: added to salads, candied as food garnish or mixed with sugar and cream and added to fruit mousse [1]. Extract of rosemary (E392) has been approved by the European Commission for use in the food industry as an antioxidant. It can be used in products with a fat content. Maximum usage levels for extracts of rosemary have been established. For products with a fat content not higher than 10%, it is 15 mg/kg, and for products with a higher fat content – up to 150 mg/kg, according to the fat content in the respective food category [59]. Table 1 presents the max. levels of the extract [60].

TABLE 1. Maximum levels of E392 (mg/L or mg/kg as appropriate) depending on food category

Food category	Max. level of E392 (mg/L or mg/kg as appropriate)
Dried milk for manufacturing of ice cream; vegetable oils where content of polyunsaturated fatty acids (PUFA) is higher than 15% w/w of the total fatty acid (excluding virgin oils and olive oils), for the use in non-heat-treated food products	30
Ready-to-eat foods based on: potatoes, cereals, flour and starch; soups, broths; tin greasing products; algae and fish oils; lard; beef, poultry, sheep and pork fat for heat-treated foods; frying oil and frying fat excluding olive and pomace oil	50
Mustards; dried sausages; sauces	100
Processed fish and fisheries products, molluscs and crustaceans; dehydrated meat	150
Processed nuts, nut butters; seasonings and condiments; processed eggs and egg products; fine bakery wares; chewing gum; dehydrated potato products; milk powder for vending machines	200
Food supplements supplied in a liquid, syrup-type or chewable form	400

Rosemary also finds applications in cosmetics. Its extraordinary properties and fragrance had been recognised by the 16th century, as illustrated by one of the oldest European cosmetics – Hungary water, also known as "spirits of rosemary", a perfume combining rosemary and lavender. The invention is attributed to Queen Elizabeth of Hungary, from the Polish royal House of Piast, sister of Casimir III the Great. Hungary water was used as a refreshing tonic, to wash the face and rub on the body. Several compounds are responsible for its scent. The top note contains fresh scents, originating from low-boiling aliphatic ingredients; sharp, penetrating scents of monoterpene origin, and a fruity scent of complex aliphatic ketones. The middle note includes: a refreshing scent of mint/eucalyptus (from 1,8-cyneole), balsamic pine (from borneol and bornyl acetate), camphor-like – thanks to the presence of camphor and a typical herbal aroma, released by verbenone. The base note contains sweet, grassy and woody/balsamic aromas, produced by benzenoids, carbonylic compounds and sesquiterpenes. Because of the antioxidant properties of rosemary, it is included in cosmetics intended to maintain youthful and healthy skin. The same antioxidant properties additionally help extend the shelf life of cosmetics. Oils and extracts are used as ingredients in colognes, adding a pleasant piney camphor-like scent. Rosemary is used in daily skincare products as well as haircare products designed to nourish the hair and add shine. It is recommended for dark hair because the compounds found in rosemary produce a gentle darkening effect. It is best suited for greasy hair and hair prone to dandruff. Because of its stimulating effect on hair follicles, increasing vascular pressure and circulation in the scalp, it is effective against hair loss and thinning – whether premature or old age-related [2, 6]. In contrast, rosemary-based cosmetics have been known to cause allergic reactions and irritation. Reszke and Reich [61] report cases of people who had an adverse reaction to rosemary preparations. A worker in a food factory presented with contact dermatitis, which was attributed to carnosol. Other symptoms included erythema, swelling and cheilitis. It is important to maintain caution when using rosemary preparations and patch test every skincare product for reaction before regular use. Cross-reactivity was observed in combination with thyme, sage and lavender. This is particularly true of the leaves, but no such information was reported about the flowers.

Rosemary is a valuable herb in aromatherapy. The practice, going back to 1928, offers natural safe treatments. Aromatherapy does not focus just on the symptoms, but promotes whole-body healing. There are several subcategories within the field of aromatherapy: clinical, aesthetic and holistic aromatherapy. The applications of rosemary are mainly aesthetic (beauty and relaxation treatments) and it is also used in clinical aromatherapy, e.g. in France where it is valued by physicians as aiding in treating infections and illnesses [62]. Rosemary oil is one of the most popular aromatherapeutic products. It is believed to have invigorating, refreshing, stimulating and warming properties, acting as a tonic and boosting the immune system. Its warming properties make it useful as a massage oil or bath oil additive. It has a beneficial effect on muscles, relaxing them, relieving stiffness and fatigue. It is also beneficial for people who spend a long time in the same position; baths, massage and compresses are the recommended applications. Rosemary is also used for chronic gastrointestinal problems (affecting the stomach, intestine, gallbladder) as it stimulates the production of stomach acid, relieves gas and regulates bile release. Minor ailments (like colic) can be alleviated by massaging some oil onto the abdomen. By activating the lymphatic system, it helps detoxify the body. Through the combination of warming and antiseptic properties, inhaling the vapours of rosemary oil is excellent for upper respiratory tract infections, colds, or when feeling weak or generally out-of-sorts. By dilating blood vessels, the blood supply to the brain is increased, promoting wellbeing and improving concentration [63, 64]. Moss et al. [65] explain the mechanisms behind the behavioural effects of essential oil. Volatile compounds enter the bloodstream via the mucous membrane inside the nose by the pharmacological mechanism or by immediately impacting on the olfactory nerve, and then on the limbic system of the brain. In turn, Sayorwan et al. [66] demonstrated that the inhalation of rosemary oil affects brain wave activity, producing a nervous system response, which in turn influences mood states. Its stimulating effects increased brain activity in areas responsible for alertness, cognitive processes and mental exertion. In consequence, this led to reduced sleepiness, higher productivity and feeling refreshed. Moreover, rosemary is recommended for rheumatic and arthritis pain, swelling and sexual dysfunctions. As such, it can be an aromatherapeutic remedy of great benefit for the elderly. Its comprehensive effects can alleviate problems related to old age and improve the quality of life (e.g. by relieving joint pain caused by degenerative diseases). Caution must be exercised when administering rosemary to pregnant women, children under the age of 6, and people suffering from epilepsy or arterial hypertension [67]. The oil should never be used undiluted, ingested or applied to fresh skin lesions, open or oozing wounds. Any application to the eye area requires special caution. In case of doubt, it is good to consult a qualified aromatherapist or a natural medicine specialist [62].

Rosemary was also investigated as a feed additive, and was found to improve the quality of goat milk; milk and lard/tallow from pigs and lambs. Savoini et al. [68] researched the effects of rosemary extract on the quality of milk and the prevalence of mammary infections in organically-managed dairy goats. One group of goats was given the extract orally at 800 mg/d, the other at 1600 mg/d. The experiment began 10 days before kidding and continued for 7 weeks. In this time, milk and colostrum were tested for nutrient levels and the number of somatic cells. Blood white cell parameters were also compared between the study groups: the control, the group receiving low-dose extract at 800 mg/d (LD) and the group receiving high-dose extract at 1600 mg/d. In the LD group, fat content was reduced by 3.4% compared to the control. An increase in milk yield and reduced number of somatic cells was also observed, again in the LD group. Increased amounts of polyunsaturated fatty acids in milk were demonstrated, as was a shorter coagulation time [69]. In turn, the meat of lambs whose mothers were fed distilled rosemary leaves presented lower levels of lipid oxidation, lower bacterial counts and better colour stability during storage in a modified atmosphere. Improvement in colour stability was observed even within the gluteus medius, which is particularly prone to discolouration. The effect was attributed to carnosic acid [70, 71]. It was observed that polyphenols contained in rosemary leaves and supplied with the diet of pregnant ewes were present in the young lambs. Lamb meat analysis revealed a higher content of rosmarinic acid, carnosol and carnosic acid compared to the the control group [72]. The study in which the diet of pigs was supplemented with rosemary extract focused on the effects on lipid oxidation. Analyses of lard from pigs fed rosemary demonstrated increased amounts of Omega-6 fatty acids and some Omega-3 fatty acids, in particular linoleic acid and arachidonic acid. An improved polyunsaturated fatty acids:saturated fatty acids (PUFA:SFA) ratio was also demonstrated [73].

REFERENCES

1. Bremness L. Wielka księga ziół. Warszawa: Wiedza i życie; 1991.
2. Kozłowski JA, Wielgosz T, Cis J, Nowak G, Aszkiewicz E, Chojnacka R, et al. Zioła z apteki natury. Poznań: Publicat; 2012.
3. Taraszewska A, Jarosz M. Zioła a alergia pokarmowa. Warszawa: Borgis; 2006.
4. Kora M. Apteka w ogrodzie. Warszawa: Książka i Wiedza; 2003.
5. Aguilar F, Autrup H, Barlow S, Castle L, Crebelli R, Dekant W, et al. Use of rosemary extracts as a food additive. Scientific opinion of the panel on food additives, flavourings, processing aids and materials in contact with food. EFSA J 2008;721:1-29.
6. Nowak K, Jaworska M, Ogonowski J. Rozmaryn – roślina bogata w związki biologicznie czynne. Chemik 2013;67(2):11-13.
7. Mena P, Cirlini M, Tassotti M, Herrlinger KA, Dall'Asta C, Del Rio D. Phytochemical profiling of flavonoids, phenolic acids, terpenoids, and volatile fraction of a rosemary (*Rosmarinus officinalis* L.) extract. Molecules 2016;21(11):1576.
8. Kowalska K, Olejnik A. Rozmaryn – roślin a zielarska o potencjale terapeutycznym. Post Fitoter 2010;2:114-22.
9. Elhassan IA, Osman NM. New chemotype *Rosmarinus officinalis* L. (Rosemary) "*R. officinalis* ct. bornyl acetate". Am J Res Commun 2014;2(4):232-40.
10. Marotti M, Piccaglia R, Giovanelli E, Deans SG, Eaglesham E. Effects of variety and ontogenic stage on the essentials oil composition and biological activity of fennel (*Foeniculum vulgare* Mill.). J Essent Oil Res 1994;6(1):57-62.
11. Jamshidi R, Afzali Z, Afzali D. Chemical composition of hydrodistillation essential oil of rosemary in different origins in Iran and comparison with other countries. American-Eurasian J Agric Environ Sci 2009;5(1):78-81.
12. Zaouali Y, Bouzaine T, Boussaid M. Essential oils composition in two *Rosmarinus officinalis* L. varieties and incidence for antimicrobial and antioxidant activities. Food Chem Toxicol 2010;48(11):3144-52.
13. Begum A, Sandhya S, Shaffath Ali S, Vinod KR, Reddy S, Banji D. An in-depth review on the medicinal flora *Rosmarinus officinalis* (*Lamiaceae*). Acta Sci Pol Technol Aliment 2013;12(1):61-73.
14. Hać-Szymańczuk E, Roman J, Bednarczyk K. Badanie aktywności przeciwbakteryjnej rozmarynu lekarskiego (*Rosmarinus officinalis*). Nauka Przyr Technol 2009;3(4):1-9.
15. El Kichaoui A, Abdelmoneim A, Elbaba H, El Hindi M. The antimicrobial effects of Boswellia carterii, Glycyrrhiza glabra and *Rosmarinus officinalis* some pathogenic microorganisms. IUGNES 2017;25(2):208-13.
16. Hameed IH, Mohammed JG. Phytochemistry, antioxidant, antibacterial activity, and medicinal uses of aromatic (medicinal plant *Rosmarinus officinalis*). In: El-Shemy H, editor. Aromatic and Medicinal Plants – Back to Nature. Rijeka: InTech; 2017. doi: 10.5772/66605. https://mts.intechopen.com/books/aromatic-and-medicinal-plants-back-to-nature/phytochemistry-antioxidant-antibacterial-activity-and-medicinal-uses-of-aromatic-medicinal-plant-ros (27.03.2018).
17. Rota C, Carramiñana JJ, Burillo J, Herrera A. In vitro antimicrobial activity of essential oils from aromatic plants against selected foodborne pathogens. J Food Prot 2004;67(6):1252-6.
18. Burt S. Essential oils: their antibacterial properties and potential applications in foods – a review. Int J Food Microbiol 2004;94(3):223-53.
19. Shan B, Yi-Zhong C, Brooks JD, Corke H. The in vitro antibacterial activity of dietary spice and medicinal herb extracts. Int J Food Microbiol 2007;117(1):112-9.
20. Rožman T, Jeršek B. Antimicrobial activity of rosemary extracts (*Rosmarinus officinalis* L.) against different species of Listeria. Acta Agric Slov 2009;93(1):51-8.
21. Bajpai VK, Baek KH, Chul Kang S. Control of Salmonella in foods by using essential oils: A review. Food Res Int 2012;45(2):722-34.
22. Nyukuri NJ, Wagara IN, Matasyoh JC, Nakavuma LJ. Inhibitory action of some essential oils on growth of various moulds isolated from dried maize grains. Egerton J Sci Technol 2013;13:1-10.
23. Bogavac MA, Karaman MA, Sudi JJ, Radovanović BB, Janjušević LN, Ćetković NB, et al. Antimicrobial potential of *Rosmarinus officinalis* commercial essential oil in the treatment of vaginal infections in pregnant women. Nat Prod Commun 2017;12(1):127-30.
24. MatsuzakiY, Tsujisawa T, Nishihara T, Nakamura M, Kakinoki Y. Antifungal activity of chemotype essential oils from rosemary against Candida albicans. Open J Stomatol 2013;3:176-82.
25. Hanana M, Mansour MB, Algabr M, Amri I, Gargouri S, Romanei A, et al. Potential use of essential oils from four Tunisian species of *Lamiaceae*: Biological alternative for fungal and weed control. Rec Nat Prod 2017;11(3):258-69.
26. Rasooli I, Fakoor MH, Yadegarinia D, Gachkar L, Allameh A, Rezaei MB. Antimycotoxigenic characteristics of *Rosmarinus officinalis* and *Trachyspermum copticum* L. essential oils. Int J Food Microbiol 2008;122(1-2):135-9.

27. Yucharoen R, Tragoolpua Y. Inhibitory effect of *Rosmarinus officinalis* L., *Senna alata* (L.) Roxb., *Acalypha indica* L., and *Elephantopus scaber* L. against herpes simplex viruses. IJPS 2015;10(4):207-14.
28. Vijayan P, Raghu C, Ashok G, Dhanaraj SA, Suresh B. Antiviral activity of medicinal plants of Nilgiris. Indian J Med Res 2004;120(1):24-9.
29. Brochot A, Guilbot A, Haddioui L, Roques C. Antibacterial, antifungal, and antiviral effects of three essential oil blends. Microbiologyopen 2017;6(4):e00459.
30. Rao MN, Sreenivasulu M, Chengaiah B, Jaganmohan Reddy K, Madhusudhana Chetty C. Herbal medicines for diabetes mellitus: a review. Int J Pharmtech Res 2010;2(3):1883-92.
31. Naimi M, Vlavcheski F, Shamshoum H, Tsiani E. Rosemary extract as a potent anti-hyperglycemic agent: current evidence and future perspectives. Nutrients 2017;9(9):968.
32. Runtuwene J, Cheng KC, Asakawa A, Amitani H, Amitani M, Morinaga A, et al. Rosmarinic acid ameliorates hyperglycemia and insulin sensitivity in diabetic rats, potentially by modulating the expression of PEPCK and GLUT4. Drug Des Devel Ther 2016;10:2193-202.
33. Dziewulska A, Dobrzyń P, Dobrzyń A. Rola kinazy białkowej aktywowanej przez AMP (AMPK) w regulacji metabolizmu mięśni szkieletowych. Post Hig Med Dosw 2010;64:513-21.
34. Naimi M, Tsakiridis T, Stamatatos TC, Alexandropoulos DI, Tsiani E. Increased skeletal muscle glucose uptake by rosemary extract through AMPK activation. Appl Physiol Nutr Metab 2015;40(4):407-13.
35. Wen YJ, Yin MC. The anti-inflammatory and anti-glycative effects of rosmarinic acid in the livers of type 1 diabetic mice. Biomedicine (Taipei) 2017;7(3):37-41.
36. Bakirel T, Bakirel U, Keleş OU, Ulgen SG, Yardibi H. In vivo assessment of antidiabetic and antioxidant activities of rosemary (*Rosmarinus officinalis*) in alloxan-diabetic rabbits. J Ethnopharmacol 2008;116(1):64-73.
37. Labban L, El-Sayed Mustafa U, Ibrahim YM. The effects of rosemary (*Rosmarinus officinalis*) leaves powder on glucose level, lipid profile and lipid perodoxation. Int J Clin Med 2014;5(6):297-304.
38. Al Shawabkeh MJ, Al Jamal A. Effect of rosemary on fasting blood glucose, hemoglobin A1c and Vitamin B12 in healthy person and Type 2 diabetic patients taking glucomid or/and metformin. Natl J Physiol Pharm Pharmacol 2018;8(1):1-4.
39. Alfonso MS, de O Silva AM, Carvalho EB, Rivelli DP, Barros SB, Rogero MM, et al. Phenolic compounds from Rosemary (*Rosmarinus officinalis* L.) attenuate oxidative stress and reduce blood cholesterol concentrations in diet-induced hypercholesterolemic rats. Nutr Metab (Lond) 2013;10(1):19.
40. Selmi S, Rtibi K, Grami D, Sebai H, Marzouki L. Rosemary (*Rosmarinus officinalis*) essential oil components exhibit anti-hyperglycemic, antihyperlipidemic and antioxidant effects in experimental diabetes. Pathophysiology 2017;24(4):297-303.
41. Stefanon B, Pomari E, Colitti M. Effects of *Rosmarinus officinalis* extract on human primary omental preadipocytes and adipocytes. Exp Biol Med 2015;240(7):884-95.
42. Kowalska K. Naturalne związki zaangażowane w kontrolę masy tkanki tłuszczowej w badaniach in vitro. Post Hig Med Dosw 2011;65:515-23.
43. Bustanji Y, Issa A, Mohammad M, Hudaib M, Tawah K, Alkhatibi H, et al. Inhibition of hormone sensitive lipase and pancreatic lipase by *Rosmarinus officinalis* extract and selected phenolic constituents. J Med Plant Res 2010;4(21):2235-42.
44. Chacińska M, Zabielski P, Grycel S, Błachnio-Zabielska A. Udział kwasów tłuszczowych i tkanki tłuszczowej w indukowaniu insulinooporności mięśni szkieletowych. Post Hig Med Dosw 2016;70:1142-9.
45. Hołysz M, Trzeciak WH. Hormonozależna lipaza/esteraza cholesterolowa z kory nadnerczy – struktura, regulacja i rola w syntezie hormonów steroidowych. Postepy Biochem 2015;61(2):1-9.
46. Abdelhalim A, Karim N, Chebib M, Aburjai T, Khan I, Johnston GAR, et al. Antidepressant, anxiolytic and antinociceptive activities of constituents from *Rosmarinus officinalis*. J Pharm Pharm Sci 2015;18(4):448-59.
47. Machado DG, Bettio LEB, Cunha MP, Capra JC, Dalmarco JB, Pizzolatti MH, et al. Antidepressant-like effect of the extract of *Rosmarinus officinalis* in mice: involvement of the monoaminergic system. Prog Neuropsychopharmacol Biol Psychiatry 2009;33(4):642-50.
48. Machado DG, Cunha MP, Neis VB, Balen GO, Colla AR, Grando J, et al. *Rosmarinus officinalis* L. hydroalcoholic extract, similar to fluoxetine, reverses depressive-like behaviour without altering learning deficit in olfactory bulbectomized mice. J Ethnopharmacol 2012;143(1):158-69.
49. Nematolahi P, Mehrabani M, Karami-Mohajeri S, Dabaghzadeh F. Effects of *Rosmarinus officinalis* L. on memory performance, anxiety, depression, and sleep quality in university students: A randomized clinical trial. Complement Ther Clin Pract 2018;30:24-8.
50. Seyedemadi P, Rahnema M, Bigdeli MR, Oryan S, Rafati H. The neuroprotective effect of Rosemary (*Rosmarinus officinalis* L.) hydro-alcoholic extract on cerebral ischemic tolerance in experimental stroke. Iran J Pharm Res 2016;15(4):875-83.
51. Cornejo A, Aguilar Sandoval F, Caballero L, Machuca L, Muñoz P, Caballero J, et al. Rosmarinic acid prevents fibrillization and diminishes vibrational modes associated to β sheet in tau protein linked to Alzheimer's disease. J Enzyme Inhib Med. Chem 2017;32(1):945-53.
52. Czajkowski P, Nazaruk J. Rola składników naturalnych w zapobieganiu chorobom neurodegeneracyjnym. Geriatria 2014;8:258-63.
53. Amin A, Hamza AA. Hepatoprotective effects of Hibiscus, Rosmarinus and Salvia on azathioprine-induced toxicity in rats. Life Sci 2005;77(3):266-78.
54. Abdel-Wahhab KG, El-Shammy KA, El-Beih NA, Morcy FA, Mannaa FA. Protective effect of a natural herb (*Rosmarinus officinalis*) against hepatotoxicity in male albino rats. Comunicata Sci 2011;2(1):9-17.
55. Sotelo-Felix JI, Martinez-Fong D, Muriel P, Santillán RL, Castillo D, Yahuaca P. Evaluation of the effectiveness of *Rosmarinus officinalis* (*Lamiaceae*) in the alleviation of carbon tetrachloride-induced acute hepatotoxicity in the rat. J Ethnoparmacol 2002;81(2):145-54.
56. Shan W, Gao L, Zeng W, Hu Y, Wang G, Lii M, et al. Activation of the SIRT1/p66shc antiapoptosis pathway via carnosic acid-induced inhibition of miR-34a protects rats against nonalcoholic fatty liver disease. Cell Death Dis 2015;6:e1833.
57. Al-Attar AM, Shawush NA. Influence of olive and rosemary leaves extracts on chemically induced liver cirrhosis in male rats. Saudi J Biol Sci 2015;22(2):157-63.
58. Hayes ES. Spices and herbs. Lore & Cookery. Mineola: Dover Publications; 1980.
59. Commission Regulation (EU) No 723/2013 of 26 July 2013 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council as regards the use of extracts of rosemary (E 392) in certain low fat meat and fish products, OJ EU L 202/8 of 27.7.2013.
60. Commission Regulation (EU) No 1129/2011 of 11 November 2011 amending Annex II to Regulation (EC) No 1333/2008 of the European Parliament and of the Council by establishing a Union list of food additives, OJ EU L 295/1 of 12.11.2011.
61. Reszke R, Reich A. Wybrane składniki pochodzenia roślinnego obecne w kosmetykach dostępnych w Polsce. Forum Dermatologicum 2016;2(2):51-9.
62. Dye J. Aromaterapia. Łódź: Ravi; 2000.
63. Aromaterapia i inne terapie naturalne. Warszawa: REA; 2006.
64. Lewkowicz-Mosiej T. Odmładzające zioła – twój sposób na witalność i długowieczność. Białystok: Vital; 2014.
65. Moss M, Cook J, Wesnes K, Duckett P. Aromas of rosemary and lavender essential oils differentially affect cognition and mood in healthy adults. Int J Neurosci 2003;113(1):15-38.
66. Sayorwan W, Ruangrungsi N, Piriyapunyporn T, Hongratanaworakit T, Kotchabhakdi N, Siripornpanich V. Effects of inhaled rosemary oil on subjective feelings and activities of the nervous system. Sci Pharm 2013;81(2):531-42.
67. Zdrojewicz Z, Minczakowska K, Klepacki K. Rola aromaterapii w medycynie. Fam Med Prim Care Rev 2014;16(4):387-91.
68. Savoini G, Cattaneo D, Paratte R, Varisco G, Bronzo V, Moroni P, et al. Dietary rosemary extract in dairy goats organically managed: effects on immune response, mammary infections and milk quality. Ital J Anim Sci 2003;2(Suppl 1):548-50.
69. Boutoial K, Ferrandini E, Rovira S, García V, Belén López M. Effect of feeding goats with rosemary (*Rosmarinus officinalis* spp.) by-product on milk and cheese properties. Small Rumin Res 2013;112(1-3):147-53.
70. Nieto G, Díaz P, Bańón S, Garrido MD. Dietary administration of ewe diets with a distillate from rosemary leaves (*Rosmarinus officinalis* L.): Influence on lamb meat quality. Meat Sci 2010;84:23-9.
71. Morán L, Andrés S, Bodas R, Prieto N, Giráldez FJ. Meat texture and antioxidant status are improved when carnosic acid is included in the diet of fattening lambs. Meat Sci 2012;914):430-4.
72. Moñino I, Martinez C, Sotomayor JA, Lafuente A, Jordán MJ. Polyphenolic transmission to Segureño lamb meat from ewes' diet supplemented with the distillate from Rosemary (*Rosmarinus officinalis*) leaves. J Agric Food Chem 2008;56(9):3363-7.
73. Liotta L, Chiofalo B, Lo Presti V, Piccolo D, Chiofalo V. Rosemary extract (*Rosmarinus officinalis* L.) supplementation into the diet of Nero Siciliano pigs: effects on lipid oxidation. Ital J Anim Sci 2007;6 Suppl 1:306-8.