

Comparison of the antioxidant potential of *Rhodiola rosea*, *Arctium lappa*, and *Symphytum officinale* root extracts*

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ABSTRACT

Introduction: Aging of the human body is a process influenced by numerous factors, both environmental and genetic. The initial signs can be observed as early as around the age of 25 and include slowed skin regeneration, the appearance of fine mimic wrinkles, reduced elasticity, and the formation of discolorations. Free radicals play a significant role in intensifying these processes, leading to a phenomenon known as oxidative stress. This condition refers to an imbalance between the presence of free radicals and the body's ability to neutralize them. However, there are various compounds, including antioxidants, that restore balance in the body and prevent the oxidation of cellular structures, thus protecting them from damage. Compounds with antioxidant potential include various vitamins such as C, A, and E, polyphenols, flavonoids, and minerals. Considering the growing interest in natural origin cosmetics that could delay the aging process, this study aimed to investigate the antioxidant properties of root extracts from *Rhodiola rosea*, *Arctium lappa*, and *Symphytum officinale*. These plants have been used for centuries in traditional phytotherapy for various ailments, including skin conditions, yet in the field of cosmetology, they require more extensive research.

Materials and methods: Commercially available root extracts from *R. rosea*, *A. lappa*, and *S. officinale* were used to prepare the

alcoholic extracts. Plant materials were subjected to ultrasound-assisted extraction for 15, 30, or 60 min, using methanol, ethanol, n-propanol, and isopropanol at concentrations of 40%, 70%, and 96/99%. The analysis and evaluation were conducted using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azino[3-ethyl-2,3-dihydrobenzothiazole-6-sulphonate] diammonium salt (ABTS) methods with a spectrophotometer, which allow the determination of the ability of plant extracts to neutralize free radicals.

Results: The highest antioxidant potential was observed in *R. rosea* extracts, particularly after 1-hour extraction using ethanol or methanol. Slightly lower activity was demonstrated by *A. lappa* extracts, and the lowest by *S. officinale*. The ABTS method proved to be more sensitive than DPPH, which may be related to the higher content of phenolic compounds.

Conclusions: The obtained results indicate that extraction time, type of solvent, and plant part are key factors for the effective recovery of antioxidants. The results suggest that the analyzed plants may constitute a valuable component of cosmetic formulations with protective and anti-aging properties for the skin.

Keywords: *Rhodiola rosea*; *Arctium lappa*; *Symphytum officinale*; antioxidant activity; extraction; DPPH; ABTS; skin aging.

INTRODUCTION

Skin aging is a complex process that depends on many factors, both internal and external, such as solar radiation and environmental pollution [1]. One of the important mechanisms accelerating this process is the occurrence of oxidative stress, which is associated with the presence of free radicals [1, 2]. To protect the body from the adverse changes associated with oxidative stress, antioxidants are used. These compounds have a high antioxidant potential, so they are frequently applied in cosmetic and dermatological preparations [2].

Antioxidants are valued for their ability to protect the body's cells from oxidants, which can significantly disrupt the function and structure of tissues and the organs built from them. Their activity based on the scavenging, weakening the activity, and inhibition the formation of free oxygen radicals, which contribute to the degradation of cellular structures and,

consequently, to disrupt collagen and elastin synthesis, resulting in discoloration, loss of firmness, changes in skin tone, and wrinkles appearance [3]. Additionally, antioxidants derived from plants, among others, exhibit anti-inflammatory, anti-bacterial, and soothing properties, which may be important in the context of many skin conditions by supporting wound healing and improving the regeneration of damaged skin [3, 4]. Antioxidants are most often found in herbs, plant juices, fruits, vegetables, and seeds, which are increasingly being added to dietary supplements, drugs, and preparations produced by the pharmaceutical and cosmetic industries. Antioxidants are used to prepare, among others, creams, masks, tonics and sun protection products as ingredients that stimulate skin renewal processes and ensure the stability of cosmetics [4].

In addition, plant-based ingredients are increasingly used in dermocosmetics, which, in addition to their skincare benefits, also have a therapeutic effect and accelerate skin regeneration,

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including in various types of dermatoses and skin inflammations. Their natural origin makes them well-tolerated by the skin and rarely causes adverse effects such as irritation, dryness, or itching. Due to their looking for effective and natural solutions that are less cytotoxic than their synthetic counterparts [5]. Currently, there is growing awareness of the potential of utilizing the anti-aging potential of plants and the biologically active substances they contain. Active compounds with antioxidant properties that can slow down the aging process are present in many plants, including the root of *Rhodiola rosea*, *Symphytum officinale*, and *Arctium lappa*.

Rhodiola rosea L. is a plant belonging to the Crassulacea family. Its natural habitat is high mountain areas, rock crevices and coastal cliffs, which occur mainly in the Arctic regions of Asia and Europe, as well as North America [6].

This plant has been used in traditional medicine for centuries as a substance supporting endurance, mental performance, and overall vitality. Furthermore, *R. rosea* is also valued for its adaptogenic properties, helping the body adapt to high-altitude conditions [7]. It is also effective in alleviating symptoms of both mental and physical stress caused by a busy lifestyle or environmental factors [8]. These effects make the plant useful in dietary supplements and as an ingredient in cosmetics with regenerative and skin-regenerating properties [9]. Furthermore, *R. rosea* has anti-inflammatory and antioxidant properties, which are due to the presence of bioactive compounds such as salidroside, tyrosol, and rosavin. These compounds have strong antioxidant effects, inhibiting inflammatory mediators, including interleukins and tumor necrosis factor alpha (TNF- α) [8]. In addition, the root also contains acids such as chlorogenic and gallic acid. They are responsible for regenerative and antimicrobial effects. Such properties are particularly important in the dermatological context, as the plant used in medicinal preparations can help reduce inflammation resulting from oxidative stress and free radicals [10]. Furthermore, *R. rosea* extracts support the reconstruction of damaged epidermis and improve overall skin condition by improving cell division and increasing cellular resistance to stress-inducing factors. They can also stimulate microcirculation and collagen production, thus oxygenating and nourishing the skin, as well as improving its firmness, thereby reducing the signs of aging. Taking extracts from the root of this plant can also promote immunity to stressful situations and help calm the nervous system, which is also important in the aging process [9, 10].

Symphytum officinale is a perennial plant in the Borage family. It is native to Europe but can also be found in South America and Asia. In Poland, it can be located throughout the country, particularly near wetlands such as lakes, ponds, and rivers. The root of this plant is dark brown, and the secretion of thick mucus can be observed when it is cut [11].

Symphytum officinale root has been used for years in topical preparations to relieve bone, joint, and muscle pain. It owes its properties to a high concentration of active compounds, such as mucilage polysaccharides, glycopeptides, terpene saponins, and phenolic compounds, including caffeic, rosmarinic, and chlorogenic acids [12]. The presence of these substances allows

S. officinale extract to exert a beneficial effect on processes occurring during inflammation. Among other things, it inhibits the production of cyclooxygenase-2 induced by interleukin-1 (IL-1), an enzyme actively involved in the development of inflammation [13]. Furthermore, numerous acids give the plant antioxidant, anti-inflammatory, and protective properties, particularly against free oxygen radicals. Rosmarinic acid has analgesic and astringent properties. An equally important ingredient is allantoin, a urea derivative widely used in the cosmetic and pharmaceutical industries. It belongs to the group of diureides, which are naturally present in mammals and plants, including comfrey root [12, 13]. This substance has a strong regenerative effect on the skin, supports wound healing, stimulates cell growth, as well as moisturizes and soothes inflammation and irritation. This compound does not directly affect the molecular aging processes, but its indirect action is valued in the prevention and alleviation of visible changes that are signs of aging. Aging skin is characterized by a weakening of type III and I collagen synthesis, while allantoin, contained in *S. officinale* root, can increase the production of these compounds by stimulating fibroblasts, ultimately improving skin elasticity, firmness, and elasticity [13]. Additionally, this substance has a gentle exfoliating effect, thus smoothing the surface of the epidermis and lightening discolorations that appear on mature skin. In cosmetic preparations, it is most often used at concentrations 0.1–2%, which allows for a skincare effect without the risk of adverse effects [14]. In addition, polysaccharides, particularly mucilages, are natural prebiotics, or nutrients for symbiotic bacteria that inhabit human skin, such as *Staphylococcus epidermidis* and *Cutibacterium acnes*. These substances support the development of beneficial bacterial flora by inhibiting the growth of pathogens. Furthermore, they support the reconstruction of the hydrolipid barrier of the epidermis by reducing transepidermal water loss. Moreover, the active compounds found in the plant can stimulate Langerhans cells, thereby increasing resistance to pathogenic microorganisms [15].

Due to its valuable properties, *S. officinale* root is used in both the pharmaceutical and cosmetic industries. Extracts from the plant are commonly used to produce creams and ointments with regenerative and analgesic properties [15]. Thanks to the presence of numerous antioxidants, preparations containing this root delay skin aging, improve skin hydration and elasticity, and reduce the appearance of fine lines and discolorations. Furthermore, the plant can support the treatment of many skin conditions, including atopic dermatitis and acne vulgaris, as it has anti-inflammatory and soothing effects on skin lesions, which is important in the context of these conditions [16].

Arctium lappa is a plant from the Asteraceae family that has been used in folk medicine and herbalism for centuries. It is found primarily in North America, Asia, and Europe. It has been cultivated in China for over 2,000 years and used, among other things, to prepare remedies for headaches, sore throats, and fevers [17]. Moreover, this plant is often used as a food ingredient, particularly its root, flowers, and young leaves. *Arctium lappa* root is valued for its properties in Chinese medicine, making it a valuable ingredient in many medicinal

preparations [18]. This is due to its diuretic properties and its ability to support the body's metabolism by regulating blood glucose levels [17]. Additionally, the raw material is used to produce various ointments for bone and joint pain and creams that accelerate wound healing. The root contains numerous antioxidative compounds, which can include isomers of dicloquinic acid, polysaccharides, including inulin, derivatives of fatty acids, as well as phenols and polyacetylenes. One of the main component of this root is inulin, a fructan, accounting for about 40% of the total dry weight of the raw material [17, 18]. This compound is a humectant, meaning it prevents water loss from the epidermis, so it is used in moisturizing and regenerating products. In addition, inulin is a natural prebiotic that helps maintain normal bacterial flora on the skin. This also strengthens the protective barrier and hydrolipid layer of the skin, as well as reducing the risk of inflammation, which can accelerate the aging process. Polyphenols, including caffeic and chlorogenic acids, also play a significant role [18]. These substances have strong antioxidant properties, combating free radicals responsible for damaging protein structures and genetic material, thus contributing to the appearance of signs of aging. Regular use of products containing antioxidants can significantly improve skin condition by enhancing the synthesis of elastin and collagen, which are responsible for firmness and elasticity. Moreover, the acids contained in the root stimulate circulation, so the formation of swelling is reduced, and the skin regains a healthy and radiant appearance [19].

Furthermore, *A. lappa* root also contains phytosterols, including campesterol and stigmasterol. Both compounds interact with lipid structures in the epidermis, stabilizing them. This reduces transepidermal water loss, thereby reducing skin dryness and making it less susceptible to environmental factors such as wind and pollution [18, 19]. Furthermore, lignans, including arctigenin, play an important role. This substance acts as an antioxidant and has anti-inflammatory properties, supporting natural repair mechanisms, reducing the effects of oxidative stress, and promoting skin regeneration. Additionally, the presence of essential oils and tannins provides soothing, antimicrobial, and toning effects. These properties reduce irritation and accelerate wound healing. Due to the presence of numerous bioactive compounds, burdock extracts are widely used in the preparation of various cosmetic and pharmaceutical preparations [18, 19]. These include creams and ointments that moisturize, soothe pain and irritation, regulate the epidermal barrier, and reduce the effects of free radicals. Root extracts are a common component of cosmetics for sensitive, dry, irritation-prone skin, and skin requiring regeneration and nourishment. For this purpose, alcohol, aqueous, and glycerin extracts, powdered raw material, and oil macerates are most often used. In cosmetic treatments, *A. lappa* is most often used in combination with vitamin C, hyaluronic acid, and peptides to enhance anti-aging potential and comprehensively address skin needs [20].

Plant antioxidants are designed to neutralize free radicals, which aggravate oxidation processes in human tissues and thus accelerate the degeneration of many structures, leading to accelerated aging. This process is crucial in the context of

the appearance of signs of aging, such as wrinkles, discoloration, and changes in facial tone and contour. Currently, there is a growing awareness of the possibility of exploiting the anti-aging potential of plants and the biologically active substances they contain. Active compounds with antioxidant properties that can slow the aging process are present in many plants, including the root of *R. rosea*, *S. officinale*, and *A. lappa*. For this reason, we decided to investigate and determine the antioxidant potential of alcoholic extracts from the roots of selected plants, such as *R. rosea*, *S. officinale*, and *A. lappa*. An ultrasound-assisted extraction method, categorized as one of the so-called green extraction techniques, was used to obtain the extracts.

The aim of this study was to evaluate:

- the antioxidant potential of alcoholic extracts from the roots of *R. rosea*, *S. officinale*, and *A. lappa* using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) and 2,2'-azinobis[3-ethyl-2,3-dihydrobenzothiazole-6-sulphonate] diammonium salt (ABTS) methods,
- the effect of the alcohol used for extraction (methanol, ethanol, n-propanol, isopropanol) and its concentration on the antioxidant activity of the obtained extracts,
- the effect of extraction time on the antioxidant potential of the obtained extracts.

MATERIALS AND METHODS

The following reagents were applied in this study: DPPH, ABTS, and 6-hydroxy-2,5,7,8-tetramethylchroman-2 carboxylic acid (Trolox) were purchased from Sigma-Aldrich (USA), methanol, isopropanol, n-propanol and sodium persulphate were from Chempur, Piekary Śląskie (Poland) and ethanol was from Lin-egal Chemicals, Warsaw (Poland).

To prepare the extracts *R. rosea* and *S. officinale* roots were purchased from Flos – Zakład Konfencjonowania Ziół in Mokrsko (Poland), whereas *A. lappa* roots were from Kawon-Hurt, Krajewice (Poland).

To prepare the extracts 4 short-chain alcohols, i.e. methanol, ethanol, n-propanol, and isopropanol were applied. The alcohols were used in 3 concentrations: 40% (v/v), 70% (v/v) or undiluted. To obtain the extracts ultrasound-assisted extraction, classified as a green extraction technique, was applied as described previously [21, 22]. Shortly: to 0.5 g raw material in stoppered glass test tubes 10 cm³ of alcohol was added. The tubes were stoppered and put into ultrasonic bath (frequency 40 kHz) for 15, 30 or 60 min (Sonic 0.5, Polsonic, Warsaw). After extraction the extracts were separated by filtration, transferred into plastic tubes and tightly closed. They were stored in a dark place at room temperature until further analysis [21, 22]. A total of 108 extracts were prepared, 36 from each raw material.

To evaluate antioxidant potential of the obtained extracts 2 frequently applied spectrophotometric methods, i.e. DPPH and ABTS. The procedure was similar to that described in previous reports [23, 24]. Antioxidant potential of the obtained extracts, determined using the above-mentioned methods, was presented as radical scavenging activity (%RSA) expressed as a percentage [22,

24]. All the extracts were evaluated in triplicate. Calibration curve for determination antioxidant potential vs. standard concentration for DPPH and ABTS methods were characterized by good correlation coefficients of 0.994 and 0.984, respectively.

Statistical analysis

The results are expressed as arithmetical mean \pm standard deviation. To establish calibration curves linear regression parameters and correlation coefficient of antioxidant activity vs. trolox concentration were estimated. The correlation between the antioxidant activities determined using both above-mentioned methods was also analyzed. All the calculations were done using the Excel program for Windows (Microsoft Office).

RESULTS

Figure 1 presents the mean (\pm SD) antioxidant activity expressed as %RSA and evaluated with the DPPH method of *R. rosea* root extracts prepared in 4 short-chain alcohols at 3 concentrations. The extracts were obtained after ultrasound-assisted extraction for 15, 30, or 60 min. The highest activity of 91.3 ± 0.2 %RSA was found for extracts in undiluted n-propanol after 15 min extraction. In contrast, the lowest antioxidant potential of 41.2 ± 0.9 %RSA was observed for extracts in 70% (v/v) methanol after 30 min extraction.

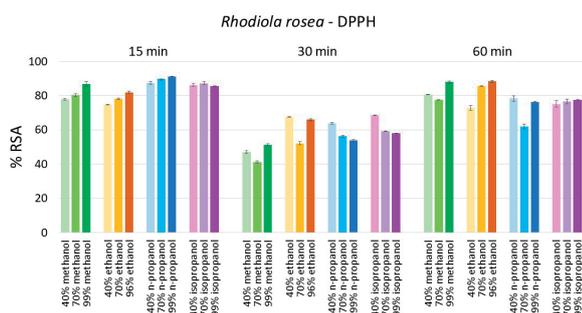


FIGURE 1. Mean antioxidant activity expressed as % radical scavenging activity (%RSA) of *Rhodiola rosea* root alcoholic extracts determined using the DPPH method (vertical lines represent standard deviations)

Figure 2 shows the mean (\pm SD) antioxidant activity expressed as %RSA and evaluated with the ABTS method of *R. rosea* root extracts prepared in 4 short-chain alcohols at 3 concentrations. The highest activity of 74.3 ± 3.8 %RSA was found for extracts in 40% (v/v) methanol after 30 min extraction, whereas the lowest one of 31.4 ± 0.5 %RSA was also found also in 40% (v/v) methanol, but after 15 min extraction.

Figure 3 presents the mean (\pm SD) antioxidant activity expressed as %RSA and evaluated with the DPPH method of *S. officinale* root extracts prepared in 4 short-chain alcohols at 3 concentrations. The extracts were obtained after ultrasound-assisted extraction for 15, 30, or 60 min. The highest activity of 45.2 ± 1.3 %RSA was found for extracts in undiluted methanol after 15 min extraction. In contrast, the lowest antioxidant potential of 15.2 ± 0.3 %RSA was observed for extracts in 40% (v/v) n-propanol after 30 min extraction.

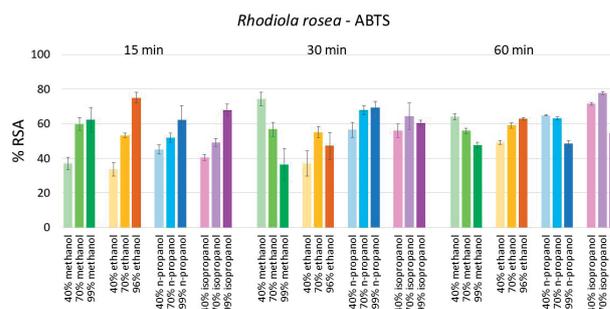


FIGURE 2. Mean antioxidant activity expressed as % radical scavenging activity (%RSA) of *Rhodiola rosea* root alcoholic extracts determined using the ABTS method (vertical lines represent standard deviations)

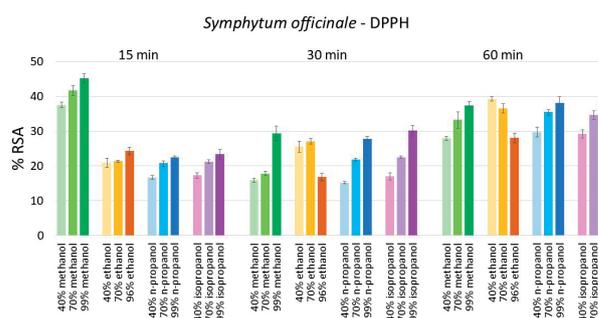


FIGURE 3. Mean antioxidant activity expressed as % radical scavenging activity (%RSA) of *Symphytum officinale* root alcoholic extracts determined using the DPPH method (vertical lines represent standard deviations)

Figure 4 shows the mean (\pm SD) antioxidant activity expressed as %RSA and evaluated with the ABTS method of *S. officinale* root extracts prepared in 4 short-chain alcohols at 3 concentrations. The highest activity of 66.0 ± 0.4 %RSA was found for extracts in 99% (v/v) methanol after 15 min extraction, whereas the lowest one of 36.9 ± 2.1 %RSA was found in 40% (v/v) methanol after 60 min extraction.

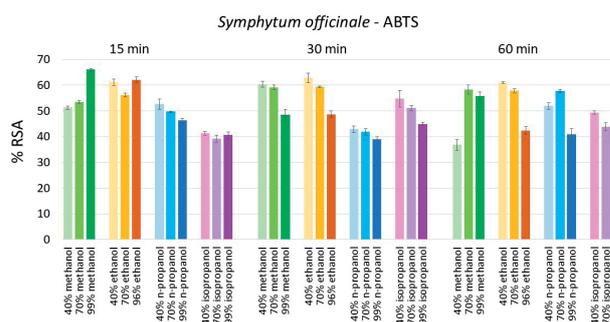


FIGURE 4. Mean antioxidant activity expressed as % radical scavenging activity (%RSA) of *Symphytum officinale* root alcoholic extracts determined using the ABTS method (vertical lines represent standard deviations)

Figure 5 presents the mean (\pm SD) antioxidant activity expressed as %RSA and evaluated with the DPPH method of *A. lappa* root extracts prepared in 4 short-chain alcohols at 3 concentrations. The extracts were obtained after ultrasound-assisted extraction for 15, 30, or 60 min. The highest activity of 86.8 ± 0.3 %RSA was found for extracts in 40% methanol after 15 min extraction.

In contrast, the lowest antioxidant potential of 43.5 ± 0.3 %RSA was observed for extracts in 40% (v/v) n-propanol after 60 min extraction.

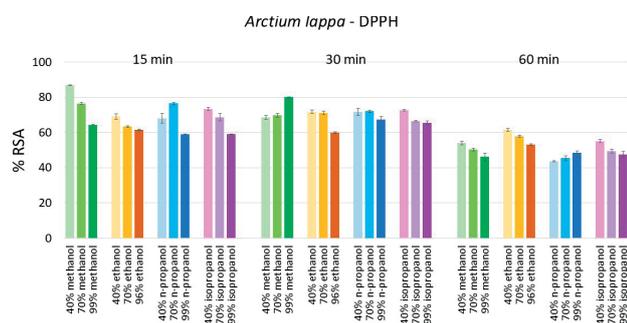


FIGURE 5. Mean antioxidant activity expressed as % radical scavenging activity (%RSA) of *Arctium lappa* root alcoholic extracts determined using the DPPH method (vertical lines represent standard deviations)

Figure 6 shows the mean (\pm SD) antioxidant activity expressed as %RSA and evaluated with the ABTS method of *A. lappa* root extracts prepared in 4 short-chain alcohols at 3 concentrations. The highest activity of 53.3 ± 1.3 %RSA was found for extracts in 40% (v/v) methanol after 15 min extraction, whereas the lowest one of 24.5 ± 1.2 %RSA was found in 40% (v/v) n-propanol after 60 min extraction.

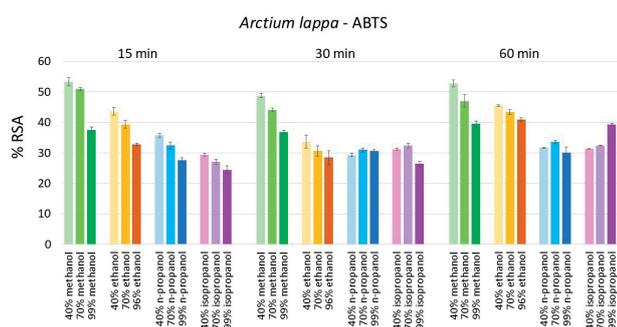


FIGURE 6. Mean antioxidant activity expressed as % radical scavenging activity (%RSA) of *Arctium lappa* root alcoholic extracts determined using the ABTS method (vertical lines represent standard deviations)

To sum up the results of the antioxidant activity determinations assessed using both of the methods applied for all tested raw materials, it should be added that no statistically significant correlation was found between these parameters for each of the tested raw materials.

DISCUSSION

In recent years, there has been a noticeable increase in interest in natural substances that have been shown to delay skin aging. This trend may be due to the growing need to maintain a youthful appearance for many years. More and more people are paying attention not only to aesthetics but also to preventive health care, treating skin care as an important part of overall well-being. Changing consumer attitudes and

growing health awareness mean that consumers are increasingly turning to cosmetics containing natural active ingredients that not only improve the skin's appearance but also support its protective and regenerative functions.

Some of the most commonly used compounds in anti-aging cosmetics are plant-derived antioxidants [2]. These compounds, found in extracts of herbs, flowers, fruits, and tree bark, neutralize free radicals responsible for cell damage and acceleration of aging processes. Examples of such components are polyphenols, flavonoids, vitamins (e.g., C and E), carotenoids, or plant extracts rich in phytonutrients [25]. According to Polumackanycz et al., naturally derived products are proving to be a promising source of compounds that effectively reduce free radicals, thereby reducing the effects of oxidative stress that contributes to accelerated skin aging. The root extracted from *R. rosea* has high antioxidant potential, as it contains significant amounts of phenolic compounds such as rosavin, salidroside, and tyrosol, which have antioxidant effects [26].

Of equal interest are extracts from the roots of *S. officinale* and *A. lappa*, whose antioxidant potential was evaluated by Chociey et al. [27]. They found that the roots of these plants are an important source of polyphenolic compounds, especially acids such as p-coumaric acid and ferulic acid. The presence of these substances makes the plants exhibit health-promoting properties and can be used both topically and orally to regulate blood glucose levels and reduce inflammation. Moreover, extracts from the *S. officinale* root are rich in rosmarinic, p-hydroxybenzoic, caffeic, chlorogenic, and p-coumaric acids. These substances have been shown to have high antioxidant activity in DPPH tests, making them capable of stimulating metabolism and fibroblasts production of collagen and elastin in the skin. Such properties make them attractive for developing skin care formulations [27].

Lin et al. confirmed that ethanol extracts from *A. lappa* have the ability to neutralize superoxide and hydroxyl radicals and also exhibit anti-inflammatory effects, reducing swelling [28]. Alhusaini et al. noted that burdock root contains numerous bioactive compounds, such as arctigenin, diartctigenin, quercetin, chlorogenic acid, and caffeic acid, which contribute to slowing skin aging by reducing the effects of oxidative stress [29].

Taking this into account, it was decided to conduct the study to evaluate the antioxidant activity of *R. rosea*, *S. officinale*, and *A. lappa* roots. For this purpose, extracts were prepared from commercially available raw materials purchased from an herbal store using 40%, 70%, and 96%/99% alcohols (methanol, ethanol, n-propanol, isopropanol) as extractants.

The results of the present study confirm the high antioxidant activity of extracts from the roots of the above-mentioned plants. In our own study, it was found that *S. officinale* root extracts have relatively low to moderate antioxidant activity, depending on the solvent used and the extraction time. The highest level of free radical reduction in the DPPH assay was obtained for the extract prepared in 99% methanol after 15 min of extraction (45.2 ± 1.3 %RSA), while the lowest level was achieved for the extract in 40% n-propanol after 30 min (15.2 ± 0.3 %RSA). Similar levels of antioxidant activity were obtained for ABTS determinations, with the highest values achieved for extracts in 99% methanol after

15 min of extraction (66.0 ± 0.4 %RSA) and the lowest for extract in 40% methanol after 60 min (36.9 ± 2.1 %RSA). These results are confirmed by results of other studies. Sowa et al. evaluated the antioxidant activity of *S. officinale* root extract prepared with 70% ethanol and determined by the DPPH method [30]. Their values were approx. 40–50% in the concentration range of 50–100 µg/mL, which is comparable to the highest activity obtained in this study (45.2 ± 1.3 %). Moreover, they demonstrated that *S. officinale* extract supports the proliferation of skin fibroblasts, suggesting not only antioxidant potential but also regenerative potential, important in the context of dermocosmetic and anti-aging applications [31].

In the present study, the highest antioxidant activity of all extracts analyzed was obtained for *R. rosea* root. After 15 min of extraction, the activity determined using the DPPH method of the extract prepared with 99% (v/v) n-propanol was 91.3 ± 0.2 %RSA, indicating a very strong ability to neutralize free radicals. The lowest result in this group was obtained using 70% methanol and 30 min of extraction (41.2 ± 0.9 %RSA). Also in the ABTS method, *R. rosea* extracts showed the highest activity among all 3 species analyzed – the best result (74.3 ± 3.8 %RSA) was achieved for extracts in 40% methanol after 30 min of extraction. The lowest activity in this test was recorded for the extract obtained with 40% n-propanol after 60 min (43.5 ± 0.3 %RSA). When the ABTS method was used, the highest activity was also achieved for the extract in 40% methanol after 15 min of extraction (53.3 ± 1.3 %RSA), while the lowest for extracts in 40% n-propanol after 60 min (24.5 ± 1.2 %RSA). The results of the studies performed by others also indicate a strong antioxidant potential of burdock root. According to Predes et al., *A. lappa* extracts, prepared in 70% and 96% ethanol exhibit the ability to neutralize free radicals, which is attributed to the content of phenolic acids (such as chlorogenic and caffeic acids) and lignans, such as arctigenin [32]. Additionally, the hydroalcoholic extract of *A. lappa* root evaluated using the DPPH method, achieved activity of approx. 70%, which is reflected in the results obtained in this study, especially when using 40% methanol. The extraction efficiency depended on the type of solvent – lower alcohol concentrations (40%) used for extraction in a shorter time seemed to be the most effective in releasing active compounds [32].

In a comparison of extracts from the 3 tested in the present study roots – *R. rosea*, *S. officinale*, and *A. lappa* – *R. rosea* root showed the highest antioxidant potential, which was confirmed by both own results and literature data. *Arctium lappa* ranked second, while *S. officinale* – despite some favourable biological properties – showed the lowest antioxidant activity, especially after longer extraction and with solvents of lower polarity, suggesting its moderate effectiveness as an anti-aging ingredient. These differences have practical implications for designing cosmetic formulations and, potentially, dietary supplements with antioxidant properties.

To sum up, the study confirms the high antioxidant potential of the root extracts of *R. rosea*, *S. officinale*, and *A. lappa* which may make them suitable raw materials for use in cosmetic and pharmaceutical preparations, particularly in the context of delaying skin aging and protecting against oxidative damage.

CONCLUSIONS

1. Alcohol extracts from all tested plant materials (*R. rosea*, *S. officinale* and *A. lappa*) showed antioxidant activity.
2. *Rhodiola rosea* extracts had the highest antioxidant potential among the tested root extracts.
3. Antioxidant potential depended on the type of solvent used – methanol appears to be the most effective solvent.
4. Extending the ultrasound-assisted extraction time seems to have a positive effect on the antioxidant activity of the obtained extracts.

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