EXTRACTION OF BIOLOGICALLY ACTIVE COMPOUNDS FROM PLANT WASTE AND THEIR COMPARATIVE ANALYSIS

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Abstract: The main objective of this study is to obtain biologically active compounds from various plant wastes, determine their extraction yield, and investigate the main properties of the obtained extracts. Waste materials of rosemary and pine were selected as the research objects.
The plant materials were first dried and ground, and then bioactive components were extracted using the Soxhlet extraction method. To increase the efficiency of the extraction process and determine optimal conditions, parameters such as temperature, time, and solvent type were systematically studied.
The physicochemical properties of the obtained extracts — including density and refractive index — were determined. In addition, their functional groups were analyzed using infrared spectroscopy, and the results were comparatively evaluated.
Within the scope of the study, the Soxhlet extraction method was applied. Based on the obtained results, the efficiency of the raw material type and extraction method was compared, and the most suitable option was identified.

Keywords: plant waste, biologically active compounds, extraction, rosemary, pine

Introduction

In modern times, as a result of urbanization and the expansion of agricultural activities, the amount of plant-based waste has increased significantly.

These wastes include leaves, branches, food residues, and other plant-derived materials. Studies show that improper mana ment of such waste leads to environmental pollution, loss of valuable resources, and contributes to climate change [1, 3, 4, 5].

Plant-derived wastes, especially agricultural and food industry residues, are considered important sources of valuable biologically active components. Various metabolites such as flavonoids, alkaloids, phenolic compounds, terpenoids, carotenoids, and saponins are present in the peels, seeds, and other parts of fruits and vegetables. These compounds have wide applications in pharmacology, food industry, cosmetology and agriculture [2, 4, 6].

Many studies have proved positive effects of phenolic compounds on human health. They have antioxidant, antimicrobial and anti-inflammatory properties [2, 7, 8, 12, 13]. Flavonoids are secondary metabolites widely distributed in plants, they are pigments and protect plants from ultraviolet radiation. These compounds have antioxidant and anticarcinogenic effects in the human body [9]. Alkaloids are organic compounds containing nitrogen and are found mainly in medicinal plants; well-known examples are morphine, caffeine and nicotine [10]. Terpenoids are the main constituents of essential oils and possess antiseptic, antibacterial, and antifungal properties [11].

Many researchers have obtained biologically active compounds from various plant residues and analyzed their composition using different analytical methods.

In a study conducted by Hongthong, S. and co-authors, steam distillation was applied under the conditions of 100 °C, 90 minutes, and a water-to-biomass ratio of 5:1. The maximum extract yield was observed to be 0.55% (w/w) for lemongrass and bergamot and 0.48% (w/w) for mint. FTIR analysis suggested the presence of functional groups such as aldehydes, alcohols, alkanes and carbonyl compounds in the oils confirming their bioactivity and aromatic potential. Comparative analysis showed lemongrass and bergamot to be the most favorable yields. Furthermore, steam distillation was assessed as a more accessible, cost-effective, safer and sustainable method for community level applications as compared to solvent extraction and supercritical CO_2 methods [14].

A study by Valtcho D. Zheljazkov et al. proved that the yield and chemical composition of sage extraction product depend on the duration of steam distillation. It was determined that the most of the extraction product is achieved in the first 10 min and prolonging the distillation time does not significantly increase the yield. A total of 39 components were identified, with monoterpenes (58.2–84.1%) as the major fraction [15].

This article presents the results related to the extraction of biologically active compounds from various plant wastes, their yield, and the main properties of the obtained extracts. In this study, the term "bioactive compounds" refers mainly to phenolic compounds, terpenoids, and other oxygen-containing secondary metabolites extracted from rosemary and pine wastes.

Experimental part

The stems and leaves of pine tree and rosemary, considered as plant waste, were selected as the research materials. The plant materials were dried and ground prior to extraction. Extraction was performed using a Soxhlet extraction apparatus, with ethanol selected as the solvent. The process was conducted under specified temperature and time conditions. The obtained target products were analyzed using various methods. Specifically, infrared (IR) spectroscopy, density, and refractive index of each extract were determined, and the results were comparatively evaluated.

In the study, rosemary (*Salvia rosmarinus*) and pine (*Pinus sylvestris*) were used as raw materials. Bioactive components from both plant materials were extracted using the Soxhlet extraction method, and the results were comparatively assessed. During the extraction, 15 g of ground raw material was placed into filter paper and introduced into the Soxhlet apparatus. The process was carried out for 8 hours in the presence of 500 ml of ethanol, after which the solvent was removed by distillation.

Results and Discussion

The analysis of the obtained results indicates that the type of plant used and its morphological parts have a significant impact on the efficiency of the extraction process, as well as on the yield of the obtained extracts (Figure 1).

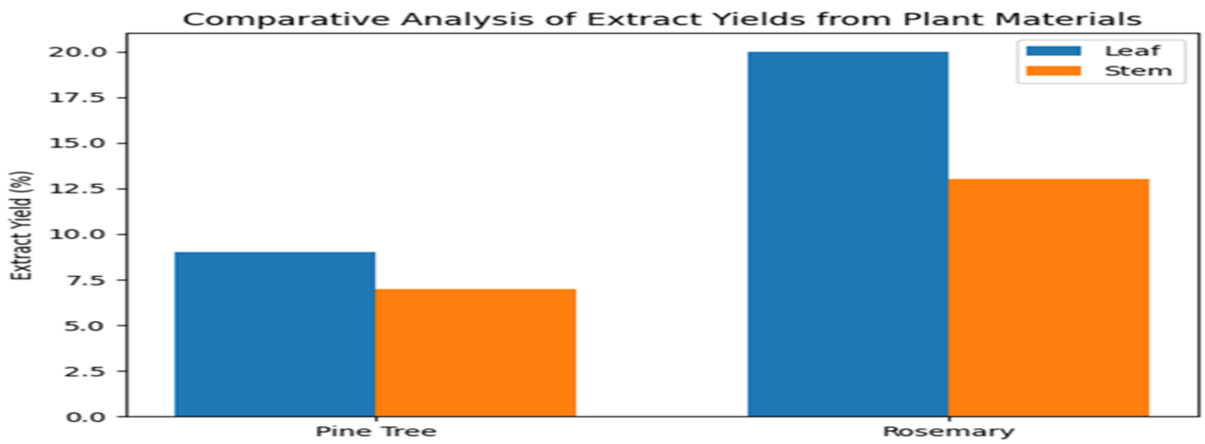

Figure 1. Comparative analysis of extract yields obtained from pine tree (*Pinus sylvestris*) and rosemary (*Salvia rosmarinus*) using leaf and stem materials.

The figure presents a comparative analysis of the extract yields obtained from plant materials. As can be observed, in both pine and rosemary, the extract yield obtained from the leaf parts is higher than that from the stem parts. Specifically, the extract yield from pine leaves was 9.3%, whereas the yield from the stem was 7.3%.

In the case of rosemary, higher yields were observed overall: 20% from the leaves and 13.3% from the stems. In general, both parts of rosemary produced higher extract yields compared to pine.

This difference is due to the chemical composition of the plants, in particular leaf parts, especially in rosemary, are richer in terpenoids and phenolic compounds, which results in higher extraction efficiency.

The chemical composition of the obtained plant extracts was determined using various analytical methods. In order to identify the chemical composition of the extracts, FTIR analysis was carried out (Figure 2).

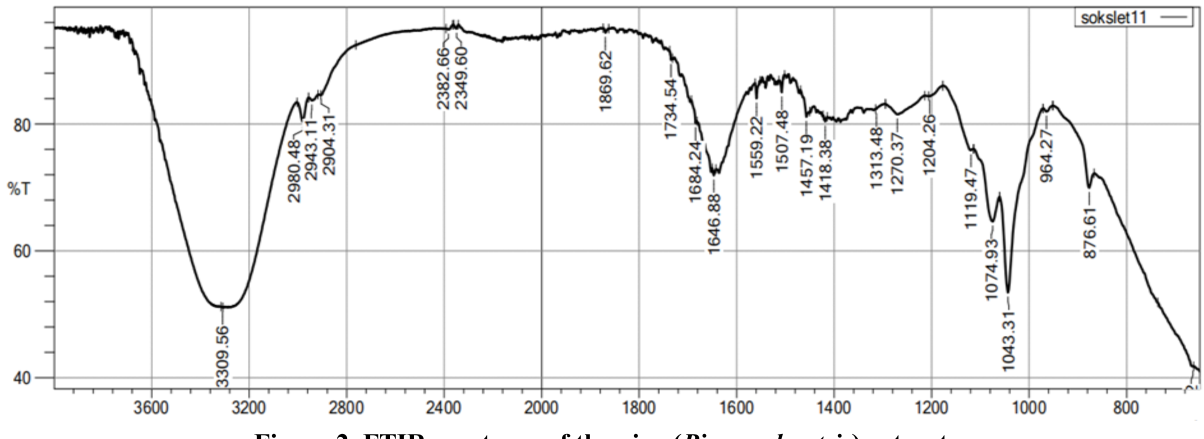

Figure 2. FTIR spectrum of the pine (*Pinus sylvestris*) extract.

The spectrum reveals absorption bands of diverse functional groups in the extract. The broad band at 3309 cm-1 corresponds to the stretching vibrations of hydroxyl (O–H) groups, indicating the presence of phenolic compounds and alcohols. In extracts from plant sources, these signals are usually associated with hydroxyl-containing bioactive compounds. The peaks at 2980–2904 cm^{-1} are attributed to stretching vibrations of aliphatic C–H bonds. The intense absorption band observed at 1646 cm-1 is assigned to carbonyl (C=O) group which indicates the presence of ester, aldehyde or ketone type compounds. This indicates the presence of oxygen containing organic compounds in the extract. The bands in the region 1457–1418 cm-1 are attributed to the deformation vibrations of CH_2 and CH_3 groups which indicate the presence of aliphatic chains.

The intense bands at 1313-1204 cm-1 and 1119-1043 cm-1 are attributed to C-O and C-O-

C bond vibrations. FTIR study showed that extract contains a high amount of hydroxyl, carbonyl, aromatic and ether functional groups. This is consistent with the presence of phenolic compounds, terpenoids and other bioactive compounds in the extract and suggests its possible antioxidant and antimicrobial properties.

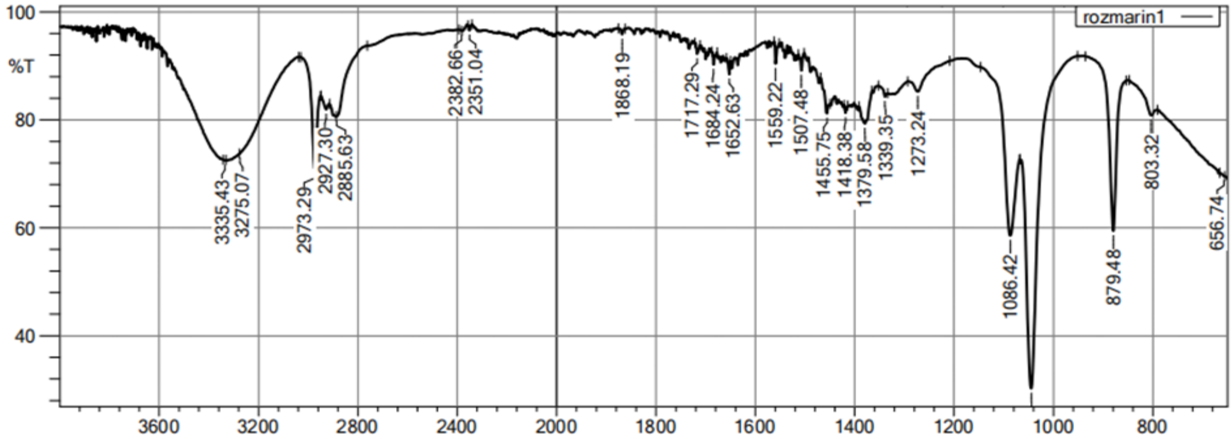

Figure 3. FTIR spectrum of rosemary (*Salvia rosmarinus*) extract.

FTIR analysis was performed to determine the chemical composition of the extract of rosemary (Figure 3). The main absorption bands of the spectrum show the presence of different functional groups. The wide bands at 3275–3335 cm−1 are due to the stretching vibrations of hydroxyl (O–H) groups. As stated above, these peaks are characteristic of phenolic compounds and alcohols confirming the presence of phenolic compounds in the rosemary extract, as the bands are more intense than in the previous sample indicating a higher content of phenolic substances in rosemary. The peaks in the range of 2973–2885 cm^{-1} correspond to the vibrations of aliphatic C–H bonds, which is a common feature of both extracts, but more pronounced in the case of rosemary extract. The peak at 1652 cm^{-1} is associated with carbonyl (C=O) groups and indicates the presence of ester, aldehyde or ketone compounds. The existence of oxygen-containing organic compounds is confirmed in both the samples. The bands in the range of 1455–1379 cm^{-1} are associated with the deformation vibrations of CH_2 and CH_3 groups, indicating the existence of aliphatic chains. The strong peaks at 1273 and 1086 cm^{-1} are related to C–O and C–O–C bond vibrations, indicating the presence of alcohol and ether compounds. The FTIR spectra of the two extracts show similar functional groups, although the hydroxyl and aromatic-related peaks are more intense in the rosemary extract, indicating that it is richer in phenolic and other bioactive components, whereas the pine extract is distinguished by a higher content of aliphatic and resinous components. These results confirm that Soxhlet extraction yields a higher-quality and more bioactive-rich extract from rosemary raw material.

Comparative Analysis of Physicochemical Properties

In order to evaluate the quality of the extracts, their density and refractive index were determined. The obtained results indicate that the physicochemical properties vary depending on the type of raw material and the extraction conditions. The pine extract obtained by Soxhlet method showed a density of 0.946 g/cm3 whereas the rosemary extract density was 0.844 g/cm3.The lower density of the rosemary extract is explained by the prevalence of lighter and more volatile components in its composition, especially essential oils and terpenoids. The refractive index analysis showed that the pine extract has a value of 1.3652 and the rosemary extract has a value of 1.3831. The higher value of the refractive index of rosemary extract indicates that it contains the higher amount of optically dense compounds with aromatic and phenolic components. Hence, the comparative analysis indicates a lower density but higher optical activity and higher bioactive compounds content for the rosemary extract, while the pine extract has a relatively higher density and can be considered as a system dominated by resinous and aliphatic compounds. These results are in accordance with the FTIR analysis results and give a full picture of the chemical composition of the extracts.

Conclusion

As a result of the study, extracts from raw materials of rosemary and pine were obtained by the method of Soxhlet extraction. The results showed that the type of raw material has a significant influence on the yield and physicochemical properties of the extracts. The rosemary extract was characterized by a higher yield and a greater optical activity, while the pine extract had a higher density. FTIR analysis confirmed the presence of various functional groups in both extracts. In conclusion, the results demonstrated that plant wastes are a valuable source of bioactive compounds.

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BİTKİ TULLANTILARINDAN BİOLOJİ AKTİV BİRLƏŞMƏLƏRİN EKSTRAKSİYASI VƏ ONLARIN MÜQAYİSƏLİ TƏHLİLİ

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Xülasə. Bu tədqiqatın əsas məqsədi müxtəlif bitki tullantılarından bioloji aktiv maddələrin əldə edilməsi, onların çıxım dərəcəsinin müəyyənləşdirilməsi və alınan ekstraktların əsas xüsusiyyətlərinin araşdırılmasıdır. Tədqiqat obyekti kimi rozmarin və iynəyarpaqlı şam ağacının tullantıları seçilmişdir.

Bitki materialları əvvəlcə qurudulmuş və xırdalanmış, daha sonra isə müxtəlif ekstraksiya üsulları vasitəsilə bioaktiv komponentlər ayrılmışdır. Ekstraksiya prosesinin səmərəliliyini artırmaq və optimal şəraiti müəyyən etmək məqsədilə müxtəlif temperatur, vaxt və həlledici parametrləri sistemli şəkildə tədqiq edilmişdir.

Alınmış ekstraktların fiziki-kimyəvi göstəriciləri — sıxlıq, refraksiya göstəricisi müəyyən edilmiş, həmçinin infraqırmızı spektroskopiya üsulu ilə onların funksional qrupları analiz olunmuş və nəticələr müqayisəli şəkildə təhlil edilmişdir.

Tədqiqat çərçivəsində Soxhlet üsulu tətbiq olunmuş, əldə edilən nəticələr əsasında xammal növü və ekstraksiya metodunun səmərəliliyi müqayisə edilərək ən uyğun variant müəyyən edilmişdir.

Açar sözlər: bitki tullantıları, bioloji aktiv maddə, ekstraksiya, rozmarin, şam ağacı.

ЭКСТРАКЦИЯ БИОЛОГИЧЕСКИ АКТИВНЫХ СОЕДИНЕНИЙ ИЗ РАСТИТЕЛЬНЫХ ОТХОДОВ И ИХ СРАВНИТЕЛЬНЫЙ АНАЛИЗ

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Основной целью данного исследования является получение биологически активных веществ из различных растительных отходов, определение их выхода и изучение основных свойств полученных экстрактов. В качестве объектов исследования были выбраны отходы розмарина и хвойного дерева сосны. Растительное сырьё предварительно высушивалось и измельчалось, после чего биологически активные компоненты извлекались с использованием различных методов экстракции. С целью повышения эффективности процесса экстракции и определения оптимальных условий были систематически исследованы параметры температуры, времени и типа растворителя.
Физико-химические показатели полученных экстрактов — плотность и показатель преломления — были определены, а также проведён анализ функциональных групп с использованием метода инфракрасной спектроскопии, результаты которого были сопоставлены.
В рамках исследования применялись метод Сокслета. На основании полученных результатов был проведён сравнительный анализ эффективности типа сырья и метода экстракции, в результате чего был определён наиболее оптимальный вариант.
Ключевые слова: растительные отходы, биологически активные вещества, экстракция, розмарин, сосна.