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ISOLATION OF BIOLOGICALLY ACTIVE COMPOUNDS FROM ALOE VERA BIOMASS AND THEIR APPLICATION IN ECOLOGICAL SYSTEMS

Lola Boltayeva, Guzal Akmalova
Tashkent State Technical University named after Islam Karimov
Abdubositkhoja Atakhojayev
Tashkent State Technical University named after Islam Karimov

Abstract. Aloe vera is recognized as a significant medicinal plant due to its rich content of biologically active compounds. This study focuses on the chemical profile of Aloe vera, its bioactive constituents, and the methodologies employed for their extraction. Specifically, extraction techniques targeting polysaccharides, flavonoids, phenolic compounds, and other bioactive molecules present in Aloe vera leaves were examined. The findings indicate that extracts from Aloe vera exhibit notable antioxidant, antibacterial, and regenerative effects. These compounds have diverse applications across pharmaceutical, cosmetic, food, and environmental technology sectors. The results further suggest promising potential for scalable extraction and effective utilization of natural bioactive substances derived from Aloe vera.

Keywords: Aloe vera, biologically active compounds, polysaccharides, extraction methods, antioxidant properties, medicinal plants.

Annotatsiya. Aloe vera o‘z tarkibida biologik faol birikmalarning boyligi sababli muhim dorivor o‘simlik sifatida e’tirof etiladi. Ushbu tadqiqot Aloe vera ning kimyoviy tarkibi, uning biofaol komponentlari hamda ularni ajratib olish usullarini o‘rganishga bag‘ishlangan. Xususan, Aloe vera barglarida mavjud polisaxaridlar, flavonoidlar, fenolik birikmalar va boshqa biofaol moddalarning ekstraksiyasi usullari tahlil qilindi. Olingan natijalar Aloe vera ekstraktlari sezilarli darajada antioksidant, antibakterial va regenerativ xususiyatlarga ega ekanligini ko‘rsatdi. Ushbu birikmalar farmatsevtika, kosmetika, oziq-ovqat va ekologik texnologiyalar sohalarida keng qo‘llanilish imkoniyatiga ega. Tadqiqot natijalari Aloe vera asosidagi tabiiy biofaol moddalarning sanoat miqyosida samarali ajratib olinishi va amaliy qo‘llanilishi istiqbolli ekanligini ko‘rsatadi.

Kalit so‘zlar: Aloe vera, biologik faol birikmalar, polisaxaridlar, ekstraksiya usullari, antioksidant xususiyatlar, dorivor o‘simliklar.

Аннотация. Алоэ вера признано важным лекарственным растением благодаря высокому содержанию биологически активных соединений. Данное исследование посвящено изучению химического состава Aloe vera, его биоактивных компонентов, а также методов их извлечения. В частности, были рассмотрены методы экстракции полисахаридов, флавоноидов,

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фенольных соединений и других биоактивных веществ, содержащихся в листьях Aloe vera. Полученные результаты показали, что экстракты Aloe vera обладают выраженными антиоксидантными, антибактериальными и регенеративными свойствами. Эти соединения находят широкое применение в фармацевтической, косметической, пищевой и экологической отраслях. Результаты исследования также свидетельствуют о перспективности масштабируемого извлечения и эффективного использования природных биоактивных веществ, полученных из Aloe vera.

Ключевые слова: Aloe vera, биологически активные соединения, полисахариды, методы экстракции, антиоксидантные свойства, лекарственные растения.

INTRODUCTION.

In recent years, there has been growing interest in the extraction of biologically active compounds from medicinal plants, primarily due to their application in pharmaceutical and biotechnological domains. Naturally derived bioactive substances are valued for their environmental compatibility, biological efficacy, and positive impacts on human health. Hence, advancing technologies to isolate novel biologically active compounds from plant sources holds considerable scientific and applied relevance. Aloe vera (Aloe barbadensis Miller) represents a prominent example of such a plant, widely recognized in traditional and modern medicine. The leaves contain a complex mixture including polysaccharides, vitamins, minerals, enzymes, and phenolic compounds, which collectively contribute to antioxidant, anti-inflammatory, antibacterial, and regenerative functions. The majority of these bioactive components are localized within the leaf gel and can be extracted through various methods. Contemporary approaches often utilize aqueous and alcoholic solvents, ultrasound-assisted extraction, and supercritical fluid techniques, facilitating efficient recovery with improved yields. Products derived from Aloe vera are extensively incorporated in pharmaceuticals, dietary supplements, cosmetics, and environmental remediation technologies. Consequently, a thorough investigation into extraction processes and a broader evaluation of application potential remain pivotal objectives. This study aims to analyze extraction technologies for Aloe vera's bioactive compounds and assess their prospective uses in pharmaceutical and environmental fields.

RESEARCH METHODOLOGY. Mature Aloe vera leaves (Aloe barbadensis Miller) served as the primary material for this investigation. Initial assessment of morphological parameters and external characteristics was conducted through visual inspection. Prior to experimental procedures, leaves were rinsed with distilled water to eliminate dust and surface impurities. The study

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utilized reagents including distilled water, ethanol (96%), methanol, the DPPH reagent (2,2-diphenyl-1-picrylhydrazyl), microbiological media, and standard bacterial strains. Analytical tools and equipment comprised a spectrophotometer, ultrasonic extractor, laboratory dryer, and precision balances.

Method for Obtaining Aloe vera Extract. The internal gel from Aloe vera leaves was carefully separated and homogenized into a uniform mass. This gel was further processed with a grinder to produce a homogeneous suspension. Extraction was performed using both aqueous and ethanol-based solvents under controlled conditions: solvent-to-material ratio of 10:1, temperature maintained between 45 and 50 °C, extraction duration of 2 to 3 hours, and stirring speed at 200 rpm. Upon completion of extraction, the solution underwent filtration, followed by concentration through vacuum evaporation techniques to yield the final extract.

RESEARCH RESULTS AND THEIR DISCUSSION.

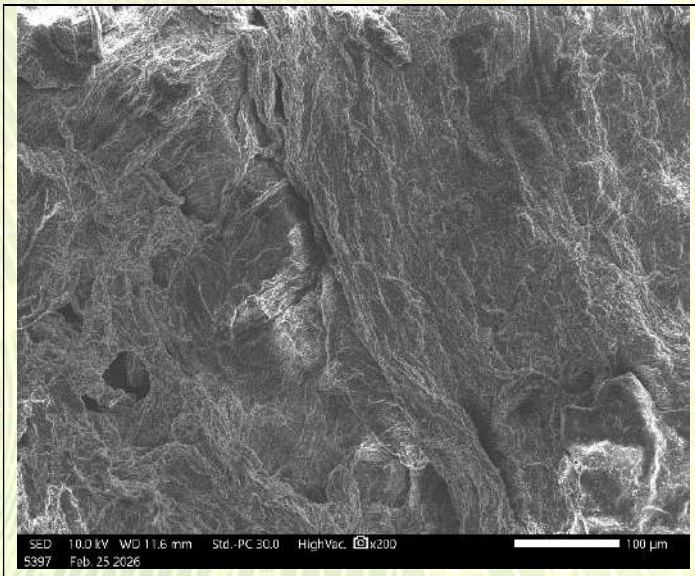


Figure 1. SEM microstructure of an Aloe vera-based biomaterial (×200 magnification). The SEM image reveals an uneven, layered, and fibrous microstructure of the material surface. The structure contains interconnected fibrillar elements, indicating that the biomaterial has a natural polysaccharide-based composition. The surface irregularity suggests the presence of an active surface area suitable for adsorption processes.

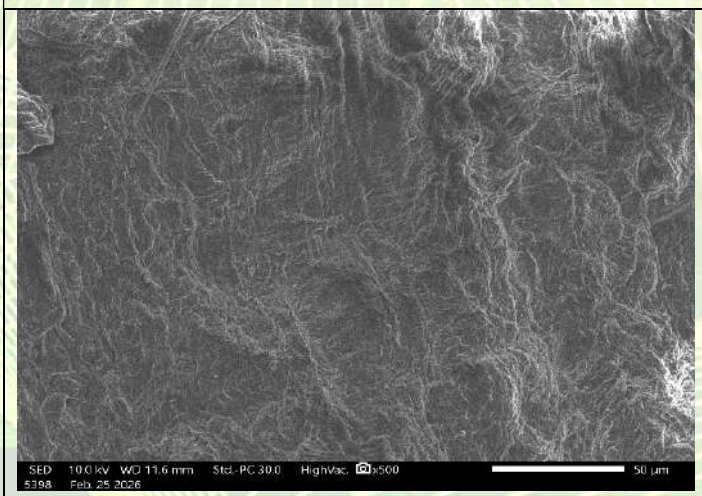
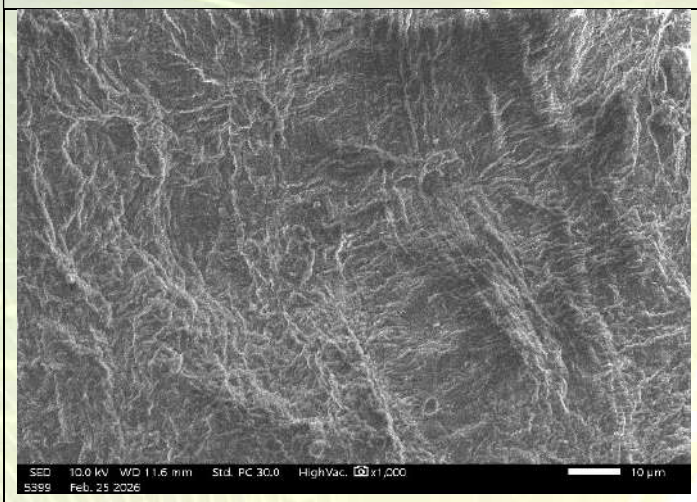


Figure 2. SEM image of the biopolymer matrix (×500 magnification). The image shows the formation of microchannels and a fibrous branched structure on the material surface. Such a microstructural configuration facilitates mass transfer and diffusion processes. This

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	condition may enhance the adsorption and biological activity properties of the material.
	**Figure 3. Fibrous microstructure of the biomaterial (×1000 magnification).** SEM analysis shows the presence of clearly visible microfibers on the material surface. The fibers are interconnected, forming a three-dimensional structure. Such a structure enhances the mechanical strength and active surface area of the biomaterial.

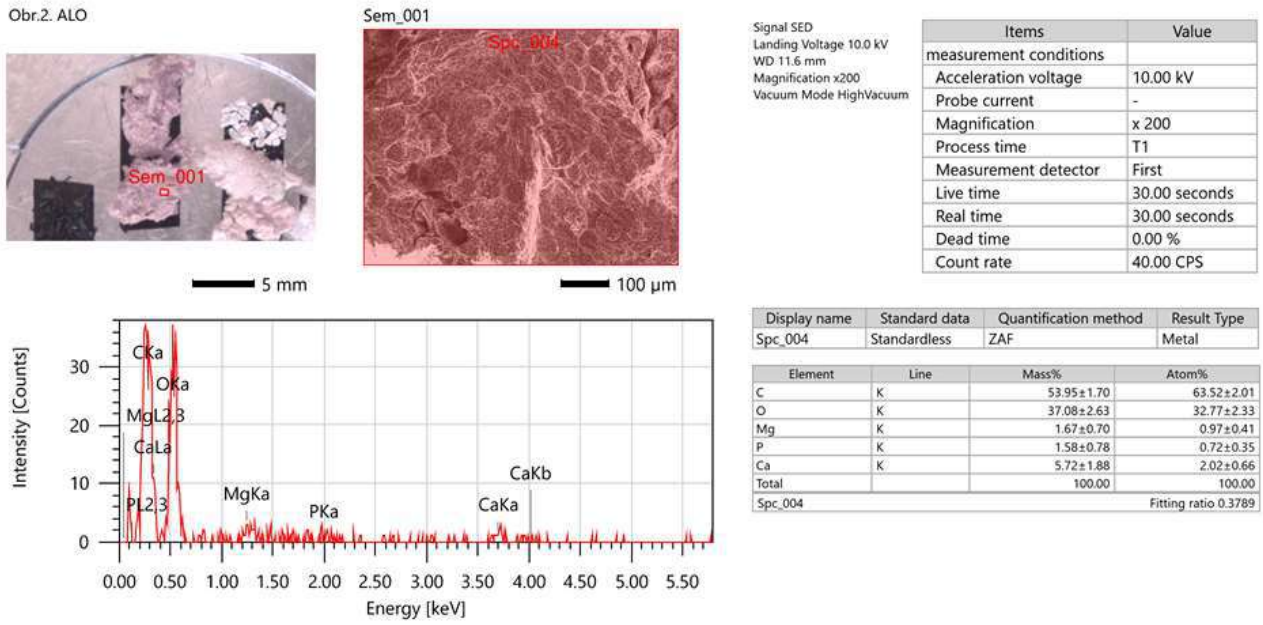


Figure 4. SEM image and EDS elemental analysis of the Aloe vera-based sample, showing the surface morphology and elemental composition of the material (×200 magnification).

The SEM image reveals that the surface of the Aloe vera-based sample presents an irregular and fibrous microstructure. The observed layered and fibrillar features suggest a composition primarily based on natural polysaccharides. This microstructural arrangement likely enhances the material's surface area, thereby facilitating adsorption processes. EDS spectral analysis identifies carbon (C),

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oxygen (O), phosphorus (P), magnesium (Mg), and calcium (Ca) as the principal elements. Quantitative data indicate that carbon accounts for 53.95 wt.% and oxygen for 37.08 wt.%, consistent with an organic biopolymeric framework. The detection of calcium and magnesium implies the presence of mineral constituents or inorganic compounds of biological origin, while phosphorus is presumably associated with phosphate compounds inherent to the plant biomaterial. Collectively, SEM–EDS results suggest the Aloe vera-based material comprises a complex microstructure integrating an organic polymeric matrix with mineral components. This structural complexity potentially broadens the scope of its application in adsorption, biological, and environmental technologies.

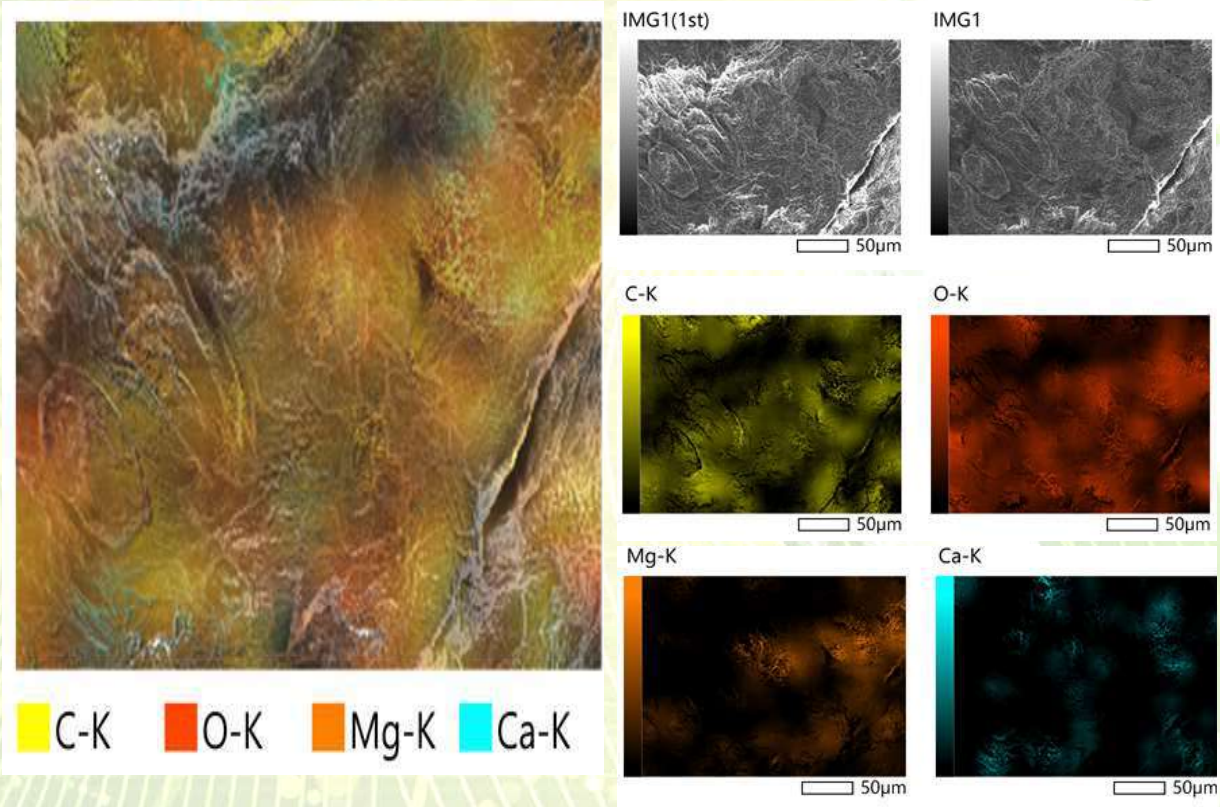


Figure 5. SEM–EDS elemental mapping and microstructure of the surface of the Aloe vera-based biomaterial.

Figure 5 illustrates the SEM image alongside EDS elemental mapping of the Aloe vera-based biomaterial's surface. The images confirm a surface characterized by unevenness, fibrous texture, and layered morphology, which suggests an elevated surface area conducive to adsorption. Elemental mapping identifies carbon, oxygen, magnesium, and calcium as predominant elements. Carbon and oxygen display a widespread and relatively uniform distribution over the surface, corroborating the organic polysaccharide-based nature of the material. In contrast, magnesium and calcium are localized in specific regions, pointing to the incorporation of mineral or inorganic components derived from plant biomass. The heterogeneous distribution of these elements may influence the physicochemical

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characteristics of the biomaterial, with implications for its adsorption capacity and catalytic behavior. Overall, SEM–EDS elemental mapping supports the conclusion that the Aloe vera-derived biomaterial features a heterogeneous microstructure composed of an organic biopolymer matrix interspersed with mineral phases, underscoring its suitability for applications in environmental remediation, adsorption technologies, and biotechnology.

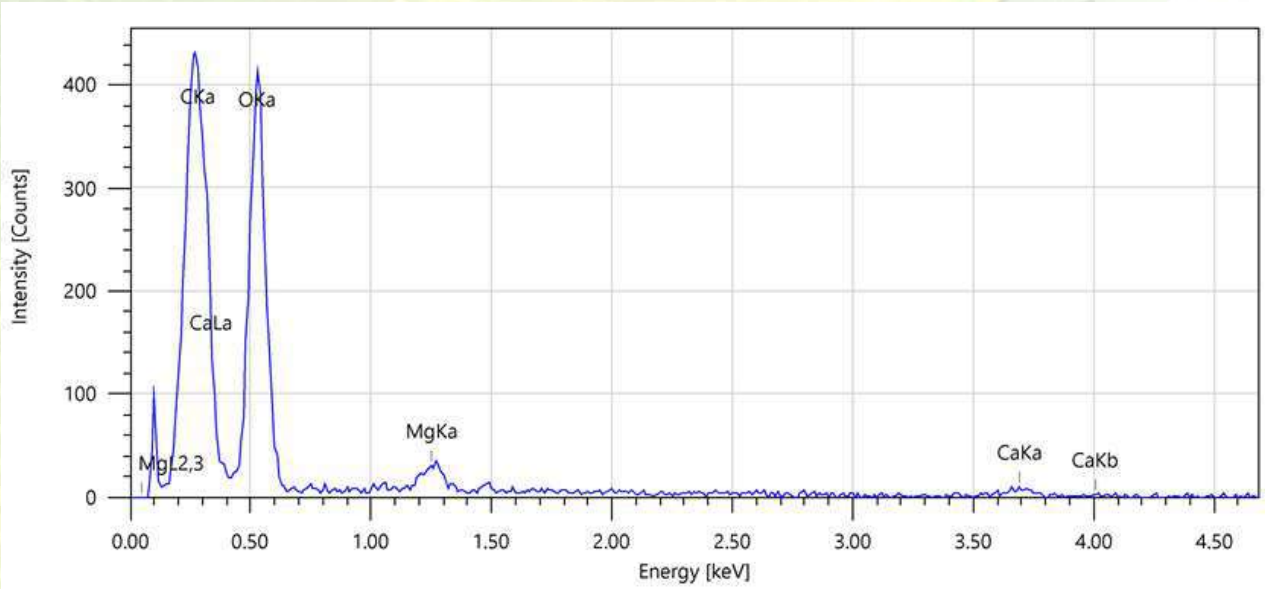


Figure 6. EDS spectrum and elemental composition analysis of the Aloe vera-based sample.

Energy-dispersive X-ray spectroscopy (EDS) analysis revealed that the primary elements present in the sample are carbon (C), oxygen (O), magnesium (Mg), and calcium (Ca). The spectrum exhibited the most intense peaks corresponding to C Kα and O Kα, suggesting that the sample predominantly comprises organic biopolymer constituents. This observation aligns with the known composition of Aloe vera, which is characterized by a high content of polysaccharides and other organic molecules. Furthermore, the detection of Mg Kα as well as Ca Kα and Ca Kβ peaks points to the presence of mineral elements within the biomaterial. These elements likely originate from intrinsic mineral components naturally found in the plant tissue or possibly from inorganic compounds absorbed by the biomass. Collectively, the EDS data confirm that the Aloe vera-derived material possesses a chemically complex matrix containing both organic constituents (carbon and oxygen) and inorganic mineral elements (magnesium and calcium). Such a composition may have a favorable impact on the material's biological activity and adsorption capabilities.

CONCLUSION. In this study, the microstructural features and elemental composition of an Aloe vera-derived biomaterial were characterized using scanning electron microscopy (SEM) and EDS techniques. The findings

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demonstrated that the surface morphology of the material is heterogeneous, exhibiting fibrous and porous characteristics. This microstructure enhances the surface area and thus may facilitate the adsorption of various substances. SEM imaging further revealed fibrillar and laminar features indicative of a biopolymer scaffold originating from plant biomass. Detailed high-magnification observations confirmed the presence of microvoids and fibrous domains on the surface. Elemental mapping showed a uniform distribution of carbon and oxygen throughout the material, underscoring its polysaccharide-rich organic nature. The co-localization of magnesium and calcium suggests that mineral components are also integrated within the matrix. These results indicate that the Aloe vera-based biomaterial consists of a hybrid organic–mineral framework, where its extensive surface area and intricate microstructure could be critical for adsorption and biological interactions. Consequently, this material merits consideration for potential applications in environmental remediation, adsorption technologies, biotechnology, and pharmaceutical fields. Future research should aim to elucidate the physicochemical properties more thoroughly and explore broader practical uses across various industrial and environmental contexts.

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