RESEARCH ARTICLE

Assessing Medicinal Plant Extracts in Strengthening Anti-Dandruff Shampoo: An Analysis Using Multi-Criteria Decision-Making Techniques

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ABSTRACT

Currently, more than half of the global population grapples with dandruff. The presence of the *Malassezia* fungus significantly contributes to this condition by potentially triggering the production of cytokines in keratinocytes, the cells responsible for synthesizing keratin and activating inflammatory pathways. Given the distress caused by dandruff, considerable efforts are underway to find effective treatments. Numerous studies centered on medicinal plants suggest promising efficacy in addressing this issue. This particular research focuses on conducting a clinical trial to explore the effectiveness of zinc L-pyrrolidone carboxylic acid and pirocton olamine, combined with extracts from six medicinal plants, for dandruff therapy. In this study, a combination of methanolic extracts from alternatives, along with pirocton olamine and zinc-PCA in the form of shampoo, was applied to a group of 30 individuals experiencing dandruff. This treatment regimen was carried out over a span of two months to assess its effectiveness in managing dandruff. Notably, 15 patients with persistent dandruff experienced significant relief within the initial two weeks. Another 12 patients noticed dandruff reduction after 28 days, the majority experienced relief within the first few weeks, and by the end of the fifth week, those remaining also expressed satisfaction with the treatment. These results strongly highlight the impressive effectiveness of medicinal plant extracts in alleviating dandruff, accompanied by minimal side effects, albeit requiring extended treatment duration. The research indicates that blending medicinal plant extracts with both natural and chemical compounds in pharmaceutical formulations shows potential for enhancing the effectiveness of dandruff treatments.

Keywords: Plant extract, Pharmacological properties, Anti-dandruff, ARAS method.

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INTRODUCTION

Dandruff is characterized by an overgrowth of the outer layer of skin on the scalp, often accompanied by itching and redness. The mechanism behind dandruff is believed to involve an enzyme known as lipase.[1] The *Malassezia* fungus, responsible for causing dandruff, the enzyme works to break down sebum into oleic acid, which consists of free fatty acids known for their pro-inflammatory properties. This particular fatty acid demonstrates the capability to permeate the upper layer of the scalp, leading to inflammation and an escalation in the shedding of skin cells, particularly in individuals who are susceptible to these effects. In the present day, numerous chemical treatments exist to combat stubborn dandruff that may not respond well to standard therapeutic remedies.[2] Conversely, many commercially available anti-dandruff products exhibit limited clinical effectiveness. Consequently, there's a growing inclination towards employing medicinal plant extracts in addressing dandruff-related concerns. Several studies have demonstrated the efficacy of extracts derived from *Punica granatum* L., *Rosmarinus officinalis* L., *Matricaria chamomilla* L., *Urtica dioica* L., *Mentha piperita* L., and *Salvia officinalis* L. in either significantly reducing or entirely eliminating scalp dandruff.[3] This study's primary objective was to conduct a clinical trial to evaluate the efficacy of treating dandruff using a combination of the six medicinal plant extracts listed above, zinc L-pyrrolidone carboxylic acid, and piroctonolamine. *P. granatum* L., a member of the Punicaceae family, is one of these extracts, was included,

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boasts a lengthy history of use over thousands of years in treating diverse health issues, particularly dandruff and scalp inflammation. Recognized as a crucial native plant in Iran, it holds considerable importance due to its medicinal properties. Numerous studies have highlighted the pharmacological properties of these compounds, showcasing their potential as anti-itching, antidandruff, anti-inflammatory, and antioxidant agents. Furthermore, these compounds also demonstrate the ability to inhibit enzymes like cyclooxygenase, lipooxygenase, and phospholipase A2.[4]

COX and LOX enzymes are crucial in the conversion of arachidonic acid into prostaglandins and leukotrienes, substances recognized for their role in triggering inflammation. Additionally, tannin, ellagic acid, and phenolic acid present in the plant exhibit antidandruff, antifungal, and antimicrobial properties.[5]

Plant Extraction

The plants were meticulously harvested from the specified locations and subsequently dried on sheets within a week, ensuring a clean, dry, and dark environment. The flowers of *P. granatum* (pomegranate), *M. chamomilla* (chamomile), and *S. officinalis* (sage), as well as the leaves of *M. piperita* (peppermint) and *R. officinalis* (rosemary), are commonly used in various herbal preparations and have been studied for their potential medicinal properties.[6] Each of these plants possesses distinct compounds that contribute to their therapeutic effects, ranging from antioxidant and antimicrobial properties to potential anti-inflammatory and soothing effects on the skin and scalp.

As well as the roots of *U. dioica*, were carefully separated and then finely ground. The extraction process employed a soxhlet apparatus, following the method outlined by Tekli *et al.* Furthermore, a rotary evaporation setup was utilized to speed up the evaporation of methanol.[7]

To prepare the extracts, 300 mL of 96% methanol from Merck, Germany, was used to dissolve 15 grams of each powdered plant material. This solution was then shaken for 24 hours using a shaker. Following the required shaking duration, the solvents were filtered through the Whatman no. 1 filter paper. Following the use of the rotary evaporation apparatus set at 90 rpm and 50°C for 15 minutes to evaporate the methanol and decrease the volume to 10 mL for storage in vials at 4°C, the vials containing the methanolic solvents were then left under a hood for 24 hours. This additional time ensured complete evaporation, facilitating the production of pure extracts from the plant materials. Depending on the extract's consistency, dimethyl sulfoxide (DMSO) was utilized to dissolve it and facilitate its combination with other chemicals.[8] Following the use of the rotary evaporation apparatus set at 90 rpm and 50°C for 15 minutes to evaporate the methanol and decrease the volume to 10 mL for storage in vials at 4°C, the vials containing the methanolic solvents were then left under a hood for 24 hours. While multiple creams exist for addressing these issues, the rate of tissue regeneration often remains a limiting factor. After thoroughly examining the root causes and exploring various traditional and non-traditional treatments, there's a realization that modern advancements in cosmetic technology can be combined with herbal wisdom and expertise to develop an innovative product. This fusion aims to bridge the gap and deliver a skin cream that effectively promotes tissue regeneration while leveraging the benefits of herbal knowledge.[9,10]

MATERIALS AND METHODS

The evaluation of a potent antidandruff shampoo fortified with medicinal plant extracts signifies a significant step in addressing hair-related concerns. This evaluation typically involves several key aspects. First, it assesses the efficacy of the shampoo in effectively combating dandruff, potentially through clinical trials on a sample population dealing with this concern. The inclusion of medicinal plant extracts, renowned for their therapeutic properties, is scrutinized for their impact on scalp health and dandruff reduction.[11] Furthermore, the evaluation entails analyzing the formulation's safety, ensuring it doesn't induce adverse effects on hair or scalp. Scientific methods are employed to measure the shampoo's impact on the scalp, such as assessing its effects on inflammation, fungal inhibition, or reduction of scalp sebum. Additionally, the overall user experience, including fragrance, texture, and ease of use, often plays a role in determining the product's market readiness. The assessment of this antidandruff shampoo fortified with medicinal plant extracts encompasses a broad spectrum of scientific, user-centric, and safety-oriented evaluations to ensure its effectiveness and consumer satisfaction.[12,13]

Physicochemical Tests

This study focused on evaluating the effects of six medicinal plants on treating dandruff. Following this investigation, the study also analyzed various physicochemical parameters associated with these plants. These parameters included moisture content, pH (using a 1% aqueous solution), total ash, acid-insoluble ash, as well as the extractives soluble in alcohol and water. In addition, a first phytochemical screening was conducted to determine whether the plant extracts included alkaloids, flavonoids, glycosides, phenols, saponins, and tannins. Precisely 5 grams of powdered substance were weighed and put on a dry, flat petri dish to measure the moisture content. This sample then spent two days being dried in an oven that was heated to 110°C. Following this process, the weight loss was computed as a percentage to ascertain the moisture content.[14]

One gram of the powdered sample had to be dissolved in 100 mL of distilled water, and the mixture had to stand for eighteen hours in order to determine the pH. Using a pH meter, the filtered sample was then utilized to determine its pH. Regarding the determination of total ash, An estimated 2 to 5 grams of the dried plant material were precisely measured and positioned within a crucible that had been previously ignited and tared for accuracy. The substance was progressively heated to a temperature range of 500 to 600°C until it reached a white coloration. Subsequent to

cooling within a desiccator, the crucible was reweighed, allowing for the calculation of the total ash content as a percentage. In the process of determining acid-insoluble ash, About 25 mL of hydrogen chloride solution (approximately 70 g/mL) was added to the crucible containing the total ash. The combination was covered with a watch glass and gently boiled for approximately 5 minutes.[12]

The liquid that resulted from boiling the crucible containing all of the ash with hydrogen chloride and washing the watch glass in 5 mL of hot water was then added to the crucible containing the mixture. After collecting the insoluble material on ashless filter paper, hot water was used to thoroughly wash it away. The filter paper with the insoluble material was then cautiously put back into the crucible and burned until it reached a constant weight. The crucible, filter paper, and insoluble ash were weighed after cooling in a desiccator so that the acid-insoluble ash content could be computed as a percentage. About 4 grams of air-dried material were precisely weighed in a conical flask with a glass stopper in order to evaluate alcohol-soluble extractives.[7] After macerating this material for 6 hours with frequent shaking in 100 mL of pure alcohol, it was left to stand for 18 hours. In order to prevent solvent loss, the solution was quickly filtered after that. A quarter of a milliliter of the mixture was poured into a tared, flat-bottomed petri dish, and it was allowed to evaporate completely on a water bath that was heated to 105°C for six hours. After that, the substance was allowed to cool in a desiccator for half an hour before being weighed. The alcohol-soluble matter content was determined as a percentage using this measurement.[10]

The observed minor discrepancies in physicochemical and phytochemical results might stem from various factors. These include differences in geographical conditions, soil composition (edaphic factors), environmental variables, cultivation and harvesting periods, collection methods, irrigation sources, fertilizer types used, plant maturity, powdering techniques, and extraction methodologies. Presents the outcomes of the physicochemical study, accounting for these potential influencing factors.[15]

ARAS Method

The additive ratio assessment (ARAS) method is a valuable tool in multi-criteria decision-making (MCDM), designed to streamline complex decision processes.[16.17] The ARAS method, known as the aspiration, registration, analysis, and synthesis method, presents a structured and systematic approach primarily utilized in problem-solving, decision-making, and project management.[18-20] It intricately involves four pivotal steps. Initially, the aspiration stage sets the groundwork by clearly defining and identifying the problem or goal, emphasizing a deep comprehension of what requires achievement or resolution.[21] Following this, the registration phase focuses on meticulous data collection, gathering pertinent information, facts, and figures related to the specific problem or goal at hand. This comprehensive compilation forms the foundation for the subsequent stages.[22-24] Moving into the analysis phase, the amassed data undergoes thorough scrutiny, meticulous examination, and rigorous processing to unveil insights, identify patterns, and discern the root causes or contributing factors associated with the problem or objective.[25-27] Finally, the synthesis stage encapsulates the findings from the analysis, amalgamating them into a cohesive and actionable solution or strategy. It's a culmination of the insights derived to craft a comprehensive approach aimed at addressing the identified problem or accomplishing the preset goal. The ARAS method thus furnishes a systematic framework, fostering a structured and comprehensive approach to unraveling complexities, making informed decisions, and devising effective solutions in various scenarios.[28-30]

Table 1: Alternative

Alternative	*Name of plant*
A1	*P. granatum* L.
A2	*R. officinalis* L.
A3	*Matricaria chamomilla* L.
A4	*U. dioica* L.
A5	*M. piperita* L.
A6	*S. officinalis* L.

Table 2: Evaluation parameters

Alternative	*Name of plant*
C1	Moisture Content
C2	PH (1% Aqueous)
C3	Total Ash
C4	Acid Insoluble Ash
C5	Water-Soluble Extractive
C6	Alcohol Soluble Extractive
C7	Alcohol Extract Yield
C8	Aqueous Extract Yield

Table 1 presents a range of alternative plants with their respective scientific names. Each of these plants holds distinctive values and applications within various domains. For instance, *P. granatum* L., commonly known as pomegranate, is cherished for its antioxidant properties and its role in promoting heart health. *R. officinalis* L., or rosemary, boasts both culinary significance and potential medicinal properties due to its rich antioxidants. *Matricaria chamomilla* L., known as chamomile, is celebrated for its calming effects and its widespread use in herbal teas and aromatherapy. *U. dioica* L., commonly referred to as stinging nettle, is recognized for its potential anti-inflammatory and diuretic properties. *M. piperita* L., or peppermint, is esteemed for its refreshing flavor and its applications in aiding digestion. *S. officinalis* L., or sage, is valued for its aromatic qualities and potential health benefits, including cognitive enhancement. Each plant in this assortment bears its own distinct set of values, contributing uniquely to various aspects of wellness, cuisine, and therapeutic practices.

Table 2 outlines the evaluation parameters for different alternatives of plants. Each alternative is identified by a specific

name of the plant. The parameters measured for evaluation are crucial indicators of the plant's quality and characteristics. Firstly, 'Moisture Content' (C1) denotes the amount of water present in the plant material, influencing its preservation and storage. 'PH (1% Aqueous)' (C2) indicates the acidity or alkalinity of the plant extract at a specific concentration, which can affect its usability and applications. 'Total Ash' (C3) refers to the residue left after the plant material is completely incinerated, often reflecting the inorganic composition. 'Acid Insoluble Ash' (C4) represents the non-dissolvable residue after acid treatment, offering insights into the insoluble mineral content. 'Water-Soluble Extractive' (C5) measures the components extracted in water, potentially indicating soluble active compounds. 'Alcohol Soluble Extractive' (C6) assesses the components soluble in alcohol, often containing different compounds than water-soluble extracts. 'Alcohol Extract Yield' (C7) and 'Aqueous Extract Yield' (C8) indicate the quantity of extract obtained using alcohol and water as solvents, respectively, providing insights into the extractability of different components based on solvent polarity. Overall, these parameters serve as critical metrics for understanding and comparing the quality, composition, and extractability of various plants, aiding in informed decision-making for their utilization in various applications such as pharmaceuticals, cosmetics, or food products.

Table 3 presents findings from a physicochemical analysis of various plants, highlighting essential parameters. For instance, A1 indicated a moisture content of 7.04%, a pH of 4.5 in a 1% aqueous solution, total ash content at 3.55%, and acid insoluble ash of 0.13%. Its water-soluble extractive was recorded at 30.11%, while the alcohol-soluble extractive stood at 20.4%. Both alcohol and aqueous extract yields were 28.1%. Similarly, A2 displayed a moisture content of 8.3%, pH of 5.6, total ash content at 4.10%, and acid-insoluble ash of 0.21%. Its water-soluble extractive was 23.4%, with an alcohol-soluble extractive of 10.7%. The alcohol and aqueous extract yields were 41 and 37.1%, respectively. A3 showcased a moisture content of 10%, pH of 6.7, total ash content at 3.2%, and acid-insoluble ash of 0.44%. Its water-soluble extractive was 30.1%, with an alcohol-soluble extractive of 12%. The alcohol extract yield was 32.7%, while the aqueous extract yield was 25.5%. A4 demonstrated a moisture content of 9.3%, pH of 6.31, total ash content at 5.1%, and acid-insoluble ash of 0.26%. Its water-soluble extractive was 21.8%, with an alcohol-soluble extractive of 9.25%. The alcohol and aqueous extract yields were 31 and 29.6%, respectively. A5 presented a moisture content of 11.1%, pH of 6.98, total ash content at 7.2%, and acid-insoluble ash of 0.36%. Its water-soluble extractive was 22%, while the alcohol-soluble extractive was 15.25%. The alcohol and aqueous extract yields were 34 and 23%, respectively. Finally, A6 depicted a moisture content of 10.4%, pH of 6.92, total ash content at 2.32%, and acid-insoluble ash of 0.15%. Its water-soluble extractive was 23.56%, while the alcohol-soluble extractive was 14.6%. Both the alcohol and aqueous extract yields were reported as 18.6%.

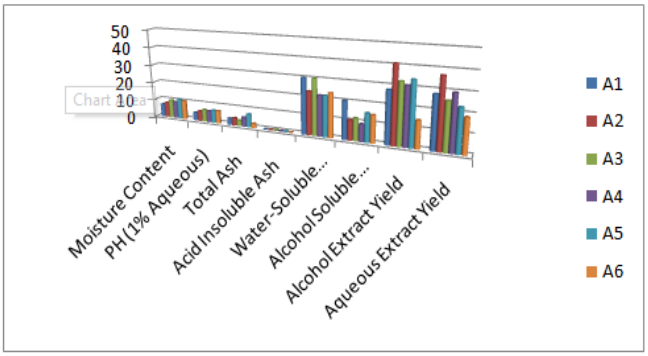

Figure 1: Results of the physico-chemical studies

Table 3: Findings from the physico-chemical research

Alternative	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
A1	7.04	4.5	3.55	0.13	30.11	20.4	28.1	28.1
A2	8.3	5.6	4.10	0.21	23.4	10.7	41	37.1
A3	10	6.7	3.2	0.44	30.1	12	32.7	25.5
A4	9.3	6.31	5.1	0.26	21.8	9.25	31	29.6
A5	11.1	6.98	7.2	0.36	22	15.25	34	23
A6	10.4	6.92	2.32	0.15	23.56	14.6	14.6	18.6

Figure 1 show values that provide comprehensive insights into the physicochemical composition and properties of each plant, elucidating their potential applications in various fields including pharmaceuticals, food, and herbal medicine.

Table 4 highlights the maximum values obtained for various parameters among the studied plants. The maximum moisture content recorded was 11.1%, observed in both A5 and at the maximum value. A pH of 6.98, representing the highest acidity in the 1% aqueous solution, was also shared by A5 and the maximum value. The highest total ash content, at 7.2%, was found in A5 as well as at the maximum. The acid-insoluble ash of 0.44% was another parameter reaching its peak in both A3 and the maximum value. Moreover, the maximum water-soluble extractive of 30.11% was seen in A1 and aligned with the maximum. For alcohol-soluble extractives, A1 and A2 matched the maximum at 20.4%. The maximum alcohol extract yield of 41% was again shared by A2 and the maximum value, while the highest aqueous extract yield of 37.1% was mirrored by both A2 and the maximum. These comparisons highlight the specific plants that contributed the highest values for each parameter and demonstrate the variability in these characteristics across the studied plant samples.

In Table 5, the data has been normalized across the dataset to provide a comparative perspective on the parameters evaluated for each plant. The maximum values for moisture content, pH in 1% aqueous solution, total ash, acid insoluble ash, water-soluble extractive, alcohol-soluble extractive, alcohol extract yield, and aqueous extract yield are denoted and normalized to 1, representing the highest values across the set. For instance, A1 showcased normalized values of 0.1047 for moisture content, 0.102296 for pH, 0.108662 for total ash, 0.065327 for acid insoluble ash, and retained the

Table 4: Maximum value

	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
Max	11.1	6.98	7.2	0.44	30.11	20.4	41	37.1
A1	7.04	4.5	3.55	0.13	30.11	20.4	28.1	28.1
A2	8.3	5.6	4.1	0.21	23.4	10.7	41	37.1
A3	10	6.7	3.2	0.44	30.1	12	32.7	25.5
A4	9.3	6.31	5.1	0.26	21.8	9.25	31	29.6
A5	11.1	6.98	7.2	0.36	22	15.25	34	23
A6	10.4	6.92	2.32	0.15	23.56	14.6	14.6	18.6

maximum normalized values of 0.1662801 for water-soluble extractive and 0.19883041 for alcohol-soluble extractive. The alcohol and aqueous extract yields were 0.126349 and 0.141206, respectively, in comparison to the maximum normalized values. A2 exhibited normalized values of 0.123438, 0.127302, 0.125497, 0.105528, 0.12922465, 0.1042885, 0.184353, and 0.186432 for the respective parameters, closely matching or deviating slightly from the maximum normalized values. Similarly, A3, A4, A5, and A6 demonstrated their normalized characteristics, showcasing their relative positions concerning the maximum values across all parameters. This normalization allows for a standardized comparison, elucidating the variations in these attributes among the different plant samples studied.

Table 6 presents a weighted normalized matrix where the values are not only normalized across the dataset but also weighted based on their importance. The maximum weighted normalized values for moisture content, pH in 1% aqueous solution, total ash, acid insoluble ash, water-soluble extractive, alcohol-soluble extractive, alcohol extract yield, and aqueous extract yield are indicated as 1. These values represent the highest weighted and normalized characteristics across the set. For instance, A1 exhibited weighted normalized values of 0.12564 for moisture content, 0.122755 for pH, 0.130395 for total ash, 0.078392 for acid-insoluble ash, and retained the maximum weighted normalized values of 0.19953612 for water-soluble extractive and 0.23859649 for alcohol-soluble extractive. The alcohol and aqueous extract yields were 0.151619 and 0.169447, respectively, compared to the maximum weighted normalized values. A2 demonstrated weighted normalized values of 0.148126, 0.152762, 0.150597, 0.126633, 0.15506958, 0.1251462, 0.221223, and 0.223719 for the respective parameters, closely resembling or slightly deviating from the maximum weighted normalized values. Similarly, A3, A4, A5, and A6 displayed their weighted normalized characteristics, showcasing their relative positions concerning the maximum values across all parameters while considering their weighted importance. This weighted normalization allows for a nuanced assessment by assigning varying importance to different parameters, offering insights into the comparative significance of these attributes among the different plant samples analyzed.

Table 7 presents Si and Ki values for different plant species. Si values represent the similarity indices of each plant concerning the maximum value, which is denoted as 1. For instance, *P. granatum* L. showcases a Si value of 0.656718, indicating its similarity in specific attributes to the maximum value. Meanwhile, *R. officinalis* L. has a Si value of 0.733188, suggesting a relatively higher similarity to the maximum compared to *P. granatum* L. *Matricaria chamomilla* L. exhibits a Si value of 0.94357, signifying a high similarity to the maximum value among the listed plants. *U. dioica* L. shows a Si value of 0.826681, indicating its similarity to the maximum value. *M. piperita* L. demonstrates a Si value of 1.015843, surpassing the maximum value, possibly indicating a higher similarity or advantageous characteristics in certain

Table 5: Normalized for data set

	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
Max	0.16508	0.15867	0.22038	0.22110	0.166280	0.198830	0.18435	0.18643
A1	0.1047	0.10229	0.10866	0.06532	0.166280	0.198830	0.12634	0.14120
A2	0.12343	0.12730	0.12549	0.10552	0.129224	0.104288	0.18435	0.18643
A3	0.14872	0.15230	0.09794	0.22110	0.166224	0.116959	0.14703	0.12814
A4	0.1383	0.14344	0.15610	0.13065	0.120388	0.090155	0.13938	0.14874
A5	0.1650	0.15867	0.22038	0.18090	0.121493	0.148635	0.15287	0.11557
A6	0.1546	0.15730	0.07101	0.07537	0.130108	0.142300	0.06564	0.09346

Table 6: Weighted normalized matrix

	C1	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*	*C8*
Max	0.19809	0.19040	0.26446	0.26532	0.1995361	0.2385964	0.22122	0.22371
A1	0.12564	0.122755	0.130395	0.078392	0.19953612	0.23859649	0.151619	0.169447
A2	0.148126	0.152762	0.150597	0.126633	0.15506958	0.1251462	0.221223	0.223719
A3	0.178465	0.182769	0.117539	0.265327	0.19946985	0.14035088	0.176439	0.153769
A4	0.165973	0.17213	0.187328	0.156784	0.14446653	0.10818713	0.167266	0.178492
A5	0.198096	0.190407	0.264463	0.217085	0.14579192	0.17836257	0.183453	0.138693
A6	0.185604	0.18877	0.085216	0.090452	0.15612989	0.17076023	0.078777	0.112161

Table 7: Si and Ki values

Name of plant	*Si*	*Ki*
max	1.117829	1
P. granatum L.	0.656718	0.587494
R. officinalis L.	0.733188	0.655903
M. chamomilla L.	0.94357	0.844109
U. dioica L.	0.826681	0.739542
M. piperita L.	1.015843	0.908765
S. officinalis L.	0.706172	0.631735

Table 8: Ranking

P. granatum L.	6
R. officinalis L.	4
M. chamomilla L.	2
U. dioica L.	3
M. piperita L.	1
S. officinalis L.	5

parameters. *S. officinalis* L. has a Si value of 0.706172, indicating its similarity concerning the maximum value. On the other hand, Ki values represent the Kiara indices, denoted relative to the maximum value, which is set as 1. For instance, *P. granatum* L. displays a Ki value of 0.587494, showcasing its relative closeness or similarity to the maximum Ki value. *R. officinalis* L. demonstrates a Ki value of 0.655903, indicating its relative Kiara index concerning the maximum. *M. chamomilla* L. displays a Ki value of 0.844109, suggesting a relatively higher Kiara index compared to the maximum. *U. dioica* L. exhibits a Ki value of 0.739542, showcasing its Kiara index concerning the maximum. *M. piperita* L. showcases a Ki value of 0.908765, suggesting a higher Kiara index in certain parameters compared to the maximum. *S. officinalis* L. demonstrates a Ki value of 0.631735, indicating its Kiara index concerning the maximum value.

Figure 2 show Si and Ki values allow for a comparison of the similarity and relative indices of each plant concerning the maximum across various parameters, providing insights into their characteristics and attributes in comparison to the highest values in the dataset.

In Table 8, each plant species is associated with a ranking based on certain criteria or characteristics evaluated within the dataset. *M. piperita* L. holds the top ranking, designated as 1, suggesting it exhibits characteristics or qualities that are considered the most favorable or prominent among the listed plants. *M. chamomilla* L. holds the second rank, followed by *U. dioica* L. at the third position. *R. officinalis* L. holds the fourth rank, while *S. officinalis* L. is ranked fifth. Lastly, *P. granatum* L. is ranked sixth among the listed plant species. These rankings provide a hierarchical order based on the evaluated criteria or attributes and signify the relative standing of each plant species within the dataset.

Figure 3 outlines the rankings assigned to each plant species based on specific criteria assessed in the dataset. *M.*

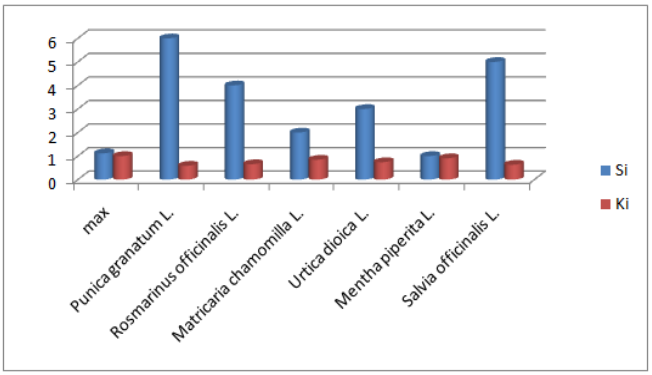

Figure 2: Si and Ki values

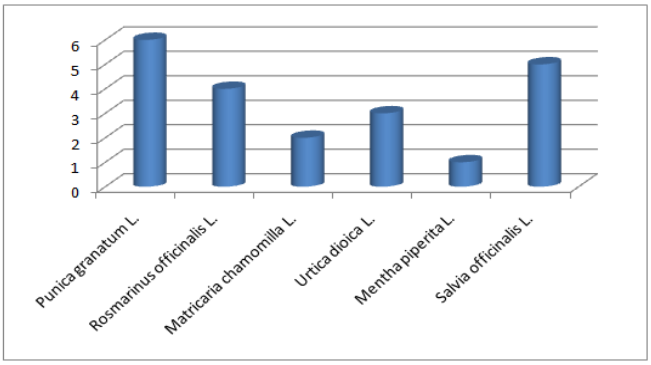

Figure 3: Ranking

piperita L. secures the highest rank, labeled as 1, indicating its prominent characteristics or qualities compared to the other listed plants. *M. chamomilla* L. follows closely with the second rank, and *U. dioica* L. claims the third position. *R. officinalis* L. obtains the fourth rank, while *S. officinalis* L. holds the fifth position. Lastly, *P. granatum* L. is positioned sixth among the listed plant species. These rankings establish a clear order based on the evaluated criteria, offering insight into the relative standing of each plant species within the dataset.

CONCLUSION

The evaluation of various plant species through multiple criteria provides a nuanced understanding of their diverse attributes and characteristics. In Figure 3, the rankings assigned to each plant species offer a hierarchical order based on these criteria, showcasing their relative strengths and qualities within the dataset. *M. piperita* L. emerges as the top-ranked species, signifying its prominent traits among the listed plants. *M. chamomilla* L. and *U. dioica* L. follow closely, highlighting their considerable attributes. *R. officinalis* L., *S. officinalis* L., and *P. granatum* L. complete the rankings, each demonstrating distinct qualities within the evaluated criteria. These findings not only aid in understanding the comparative advantages of each plant species but also provide valuable insights for informed decision-making, especially in fields such as herbal medicine, agriculture, or product development, where the selection of plant species plays a pivotal role. The analysis of various plants (A1 to A6) revealed distinctive characteristics in terms of moisture content, pH levels, ash content, extractives,

and yield of extracts. These plants displayed varying levels of moisture content ranging from 7.04 to 11.1%. The pH values fluctuated between 4.5 and 6.98, indicating differences in acidity or alkalinity within these plant samples. Total ash content varied from 2.32 to 7.2%, suggesting diverse mineral compositions among the plants. Furthermore, the plants exhibited variability in their extractive properties, with water-soluble extractives ranging from 21.8 to 30.11% and alcohol-soluble extractives spanning from 9.25 to 20.4%. This variance indicates differing solubilities of bioactive compounds in water and alcohol across these plant samples. The yields of alcohol and aqueous extracts diverged significantly among the plants, showcasing varying extraction efficiencies. Overall, these findings underscore the diverse physicochemical profiles of these plants, highlighting their potential disparity in bioactive compounds and extractive yields, which could influence their medicinal or therapeutic applications.

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