Impact of Green Technologies on Extraction and Processing of Herbal Ingredients for Skin and Hair Care.

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***Abstract*—Herbal cosmetics have phytochemicals from various plants that give healthy hair and skin providing essential nutrients and biologically active compounds. These formulations are gat high demand compared to conventional cosmetics due to less side effects and natural occurring. Key herbal ingredients like moringa oliefera and Glycyrrhiza glabra have high content of antioxidants, flavonoids, phenolic acids, and other bioactive compounds which are required for skin and hair health. However, conventional methods take long time for extraction and use large amount of solvent. Advanced green extraction methods such as Microwave-assisted extraction (MAE) and Ultrasound-assisted extraction (UAE) give improved efficiency by reducing solvent use, extraction time and energy consumption while enhancing yield and preserving bioactive compounds. This study evaluates the impact of MAE and UAE using environmentally friendly solvents on extracting bioactive compounds from Moringa and Licorice for skincare and haircare applications, focusing on phenolic content and phytochemical profile.**

***Index Terms*—Herbal cosmetics, Moringa Oliefera, Glycyrrhiza Glabra, MAE, UAE, environmentally friendly solvents**

1. INTRODUCTION

Herbal cosmetics are formulation that incorporate phytochemicals derived from diverse botanical sources, influencing skin functions while providing essential nutrients that promotes healthy and radiant skin and hair. The phytochemicals serve a dual purpose: i) they can be employed as cosmetic agent for skincare purpose, and ii) the botanical components contribute biologically active components that support skin and health and provide nutrients essential for nourishment of both skin and hair. The need for herbal cosmetics is growing rapidly compared to conventional cosmetics, due to their reduced side effects. These herbal formulations are favourable because they are obtained from herbs and shrubs. The natural components in the herbs do not possess any side effects, but provide nourishment to the skin and other favourable nutrients. (1) Herbal cosmetics are natural and free from harmful synthetic chemicals. These products are compatible with all skin types, affordable, not tested on animals (2) Herbal ingredients are widely incorporated into skin and haircare products due to their diverse properties such as anti-oxidant, anti-inflammatory, anti-microbial, and anti-aging, skin-lightening and anti-irritant properties. (3)

1.1 Moringa Oliefera: The Moringa tree (Moringa Oliefera) also known as the tree of life, is a source of active ingredients valuable for the cosmetic industry. Due to its wide spectrum of bioactive components, the plant exhibits powerful antioxidant, antibacterial, astringent, toning and anti-inflammatory properties. Leaves are rich in flavonoids like myricetin, quercetin, kaempferol, isorhamnetin, and rutin along with phenolic acids. Fresh leaves provide carotenoids such as lutein, β-carotene, and zeaxanthin, Moringa tree is also characterized by high content of vitamin C and A. These active compounds have shown benefit to the skin health and provides alternatives to synthetic ingredients. (4) Moringa leaves contain many active phytoconstituents, including alkaloids (N-benzyl carbamic acid, Aurantiamide acetate, Nicotine) flavonoids (Isoflavones, Neoflavonoids) phenolic compounds (Gallic acid, Ellagic acid, Salicylic acid, and Quercetin), saponins, coumarins, glycosides, proteins,

steroids and carbohydrates. These bioactive compounds exhibit strong antimicrobial activity, which helps to reduce the growth of dandruff-causing fungi and bacteria on the scalp. [5] Moringa plant consists of active components like phenols, tannins, saponins, and flavonoids. The moringa powder is used as potent solution for promoting hair growth and scalp health. The presence of zinc, iron and essential amino acids in moringa nourishes hair follicles and enhances scalp circulation which encourages stronger, healthier hair growth. Moringa powder can be used in hair mask to nourish the scalp and strengthen hair. Furthermore, moringa powders can be added in shampoos and cleansers to reduce hair fall, cleanse scalp, and enhance overall hair health. Moringa the leaf powder can be also used in skincare, such as face masks and scrubs, as it is packed with vitamins, minerals and amino acids providing detoxifying, and rejuvenating effect, reducing inflammation resulting in brighter complexion. [6]

(https://www.nutritionfact.in/wp-content/uploads/2021/06/moringa.jpg)

1.2 Glycyrrhiza Glabra: Glycyrrhiza glabra Linn. Is among the most widely used medicinal herbs, from ancient history of Ayurveda. It has long been valued as a flavoring agent. The word Glycyrrhiza is derived from Greek word glykos(sweet) and rhiza(roots). Commonly known as “liquorice” or “sweet wood,” it belongs to family Leguminosae. The high content of phenolic compounds in ethanolic extract of Liquorice is chiefly responsible for its potent antioxidant activity. The activity is expressed through significant free radical scavenging, hydrogen-donating ability, metal-ion chelation, anti-lipid peroxidation, and reducing properties. Liquorice flavonoids have strong antioxidant properties, which was found to be over 100 times stronger than that of Vitamin E. The extract of liquorice is an effective pigment lightening agent with lesser side effects. Liquiritin in liquorice extract disperse melanin, which induces skin lightening. The antioxidant present in the extract also decrease skin melanin content. Ethanolic extract of Glycyrrhiza Glabra have shown improvement in viscoelasticity and hydration of skin. Synergistic effect of antioxidant, anti-inflammatory and UV protection may provide benefits to the skin. Saponons, alkaloids, tannins present in the hydro-methanolic extract of G.glabra exhibit potent antibacterial activity. Aqueous and ethanolic extracts of liquorice inhibit the growth of S.aureus and S.pyogenes. Hydro-ethanlolic extraction of liquorice roots gives good hair growth promoting properties. After safety and efficacy analysis, it has been concluded that 2% concentration of liquorice extract gives better hair growth promoting activity than 2% minoxidil. [7]

(https://healthjade.com/wp-content/uploads/2017/10/licorice-root.jpg)

1.3 Current challenges in conventional extraction method: The study of bioactive compounds from plant material depends on selection of correct extraction methods. Plant materials are on demand due to their application in pharmaceutical, nutritional and cosmetic application. Many active compounds are present in plant material such as tannins, saponins, flavonoids, phenols, volatile oils, deposited in plant part, which can be extracted using suitable extraction methods. For a long period of time extracts have been prepared using conventional methods like maceration, percolation, decoction, and infusion methods. [8] Conventional methods associated with disadvantages like prolonged extraction time, large number of solvents. These extraction methods however can be used to extract fragrance and aroma oil plants. To face the challenges associated with conventional methods, advanced methods were investigated. The advanced methods include Microwave assisted- extraction

(MAE), Ultrasound-assisted extraction (UAE), and Supercritical fluid extraction (SCF). [8,9]

The relevance of advanced techniques is due to their ability to increase efficiency, decreased extraction time, and limit the use of solvents, resulting in higher yield of bioactive components. The advanced extraction methods often lead to improved selectivity and preserve delicate compounds. These techniques are environment friendly as they do not use any harmful solvents. Overall, importance of advanced extraction methods lies in their ability to optimize extraction parameters, improve productivity and enhance yield of bioactive compounds, with increased purity and bioavailability, making them essential for application in pharmaceutical, nutraceutical and other related industries. Selection of extraction technique is dependent of nature of active compounds, target yield and desired application. Enhancing the extraction parameters like extraction solvent, time, temperature, pressure, power and ultrasonic amplitude can remarkably influence extraction efficiency and quality of compound obtained. [10]

The aim of the research is to study the two green technologies – Ultrasound- assisted extraction (UAE), and Microwave-assisted extraction (MAE), to study their impact on extracting bioactive compounds from Moringa Oliefera and Glycyrrhiza Glabra using environment friendly solvents and to evaluate the total phenolic content and phytochemical profile like tannins, saponins, and flavonoids for application in skin and hair care formulations.

II. GREEN EXTRACTION TECHNIQUES

Green extraction methods have gained demand in recent years due to less time requirement, less solvent, less energy requirements, and more recovery of phytochemicals. Green extraction methods are based on principles such as selection of renewable plant sources like fruits and vegetable peels, use of green solvents, energy saving, obtaining safe, plant-based extracts and simplified process. [11] The green extraction methods support sustainable environmentally friendly extraction. These methods reduce the harm caused by traditional methods. Microwave- assisted extraction (MAE), Ultrasound-assisted extraction (UAE), Supercritical fluid extraction (SCF), Enzyme-assisted extraction (EAE), Subcritical water extraction (SWE), Pressurized liquid extraction (PLE) are some types of green extraction methods. [12]

2.1. Ultrasound- assisted extraction:

Ultrasound-assisted extraction is widely used method for extracting bioactive compounds from plant material. It can be used to disrupt plant cell walls, improving solvent ability to penetrate the cells and obtain higher yield. Ultrasound frequency from 20kHz- 200kHz can increase permeability of cells and produce cavitation. UAE can be used on low operating temperatures, which maintains high quality extracts. [13] UAE is considered as clean technology, and has gained demand due to low use of solvents, extraction time and low environment impact. [14]

UAE has been studied for extraction of compounds such as pectin, polyphenols, oils from fruits, vegetables. Ultrasound- assisted extraction method applies thermal, mechanical and cavitation effect produced by ultrasonic to the extraction process. This method can enhance the penetration of solvents into cells leading to improved mass transfer. Additionally, ultrasonic method can disrupt the cell walls, facilitating the release of cellular contents. Benefits of UAE methods include high extraction rate (disruption of plant cell tissues leading to rupture of desired components), short extraction time, maintaining higher extraction efficiency, low extraction temperature which maintains the integrity of actives in plant materials, and the method is simple and easy to use. Drawback of UAE is the generation of 65dB noise by ultrasonic equipment during operation. [15]

2.2. Microwave- assisted extraction (MAE):

MAE is modern method used to extract natural products from plants by using microwave energy, with solvents. Microwaves heat solvent and plant material quickly at frequencies between 300MHz and 300GHz. This heating causes moisture inside plant cells to evaporate, which creates pressure making cell walls burst. [13] When cell breaks, solvent can get inside easily and dissolve more bioactive compounds, giving better extraction yield. Many factors affect MAE, such as microwave power, temperature, time of extraction, and how much solvent is used. The benefit of MAE is that it saves money, uses less solvent, works quickly, and uses low power. Disadvantage is that if solvent is nonpolar, extraction might not work well. [12] MAE is useful for extracting wide range of plant materials like saponins, polyphenols, sterols and flavonoids. It is

noteworthy that MAE is most beneficial for capturing phytochemicals that are substantially lost using conventional methods. [13] It works better than traditional methods, especially for compounds that are lost during conventional extraction process. For example, Curcuma oil which can break down during usual extraction, was successfully extracted by MAE in about 30 mins at 160 watts with a good yield. MAE is easy and flexible method that can extract delicate, volatile compound in short period of time [10]

III. MATERIALS AND METHOD

3.1. Materials

Plant materials: Dried Moringa oliefera and Glycyrrhiza glabra powders were obtained from local herbal supplier.

Chemicals & Solvents: Three solvent systems were prepared for extraction. Aqueous solvent (distilled water), Hydro glyceryl, and Hydroethanolic solvent (Ethanol: water- 70:30). All reagents and solvents were freshly prepared prior to extraction.

3.2. Extraction Methods: Each plant material was extracted using two extraction techniques- MAE & UAE with each solvent type.

a. Microwave- assisted extraction: Approximately 5g of plant powder was mixed with 100ml of solvent (solid to solvent ration 1:20 w/v) in Erlenmeyer flask. The extraction was carried out under optimized conditions. Microwave power- 300W, time- 3 minutes. Mode- Intermittent radiation (30s on, 10s off to prevent overheating). After extraction, the mixture was filtered through Whatman filter paper, and evaporated on water bath.

b. Ultrasound- assisted extraction: For ultrasonic extraction, 5g of plant powder was mixed with 100ml of solvent (solid to solvent ration 1:20 w/v) in conical flask. The mixture was extracted in an ultrasonic bath. Extraction time- 3mins, Temperature- 40-50 °C. The mixture was filtered and the filtrate was evaporated using water bath. The extracts were stored in suitable container for further analysis.

Extracts of Moringa Oliefera

Extracts of Glycyrrhiza Glabra

IV. EVALUATION PARAMETERS

1. Extraction yield: Extraction yield is calculated using following equation:

Extraction Yield (%) = Weight of raw material / Weight of dried extract×100

2. Qualitative tests:

- Phytochemical screening for Moringa extracts:

a. Tests for flavonoids (Lead acetate test): Small portion of extract was treated with few drops of dilute ammonia solution, followed by addition of lead acetate solution. Development of yellow colour indicates presence of flavonoids. [14]

b. Test for saponins (Froth test): 5ml of extract was diluted with 5ml of distilled water in test tube and shaken vigorously for 30 seconds. The formation of stable and persistent foam indicates presence of saponins. [15]

c. Test for tannins (Lead acetate test): A few drops of lead acetate solution were added to extract. The appearance of yellow or white precipitate indicates presence of tannins. [16]

- Phytochemical screening for Liquorice extracts:

a. Test for flavonoids (Lead acetate test): 0.5g of plant extract was heated with small volume of double distilled water, followed by addition of 1ml

of 10% lead acetate solution. The yellow colour indicates presence of flavonoids. [17]

b. Test for saponins (Froth test): About 0.5g of extract was dissolved with 10 ml of distilled water, for about 30 seconds. Appearance of stable foam indicates presence of saponins. [17]

c. Test for tannins: A few drops of lead acetate solution were added to extract. The formation of white or yellow precipitate confirmed presence of tannins. [17]

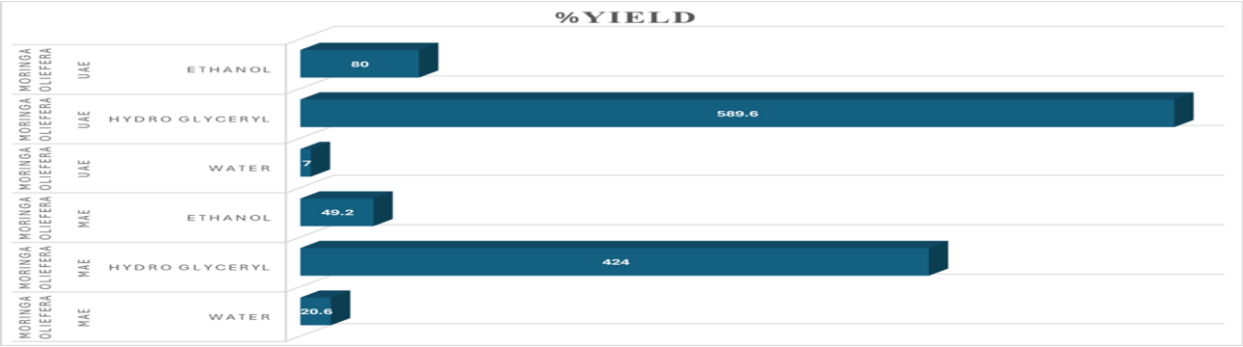
3. Quantitative tests:

a. Total- Phenol content: Total phenol content was measured using modified Folin- Ciocalteu method. In this method, 80µL of sample extract was mixed with 80µL of Folin- Ciocalteu reagent and 80µL of 10% Sodium carbonate solution. After keeping for 1 hour, the absorbance was measure at 630nm for liquorice and 750nm for moringa. The TPC was them calculated as mg per gm of dry weight using calibration curve made with tannic acid. [18]

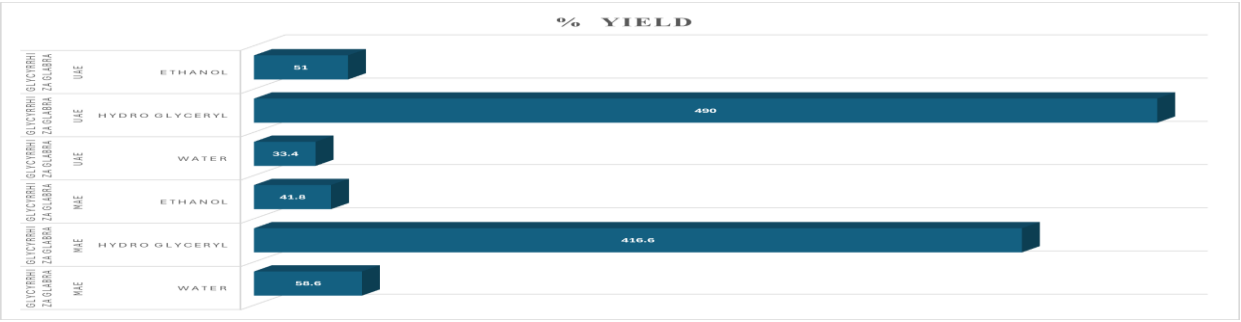
V. RESULTS

5.1 Extraction yield

Sr. No.	Plant Material	Extraction Method	Solvent	%Yield
1	Moringa Oliefera	MAE	Water	20.6
2	Moringa Oliefera	MAE	Hydro glyceryl	424
3	Moringa Oliefera	MAE	Ethanol	49.20
4	Moringa Oliefera	UAE	Water	7
5	Moringa Oliefera	UAE	Hydro glyceryl	589.60
6	Moringa Oliefera	UAE	Ethanol	80
7	Glycyrrhiza Glabra	MAE	Water	58.60
8	Glycyrrhiza Glabra	MAE	Hydro glyceryl	416.6
9	Glycyrrhiza Glabra	MAE	Ethanol	41.80
10	Glycyrrhiza Glabra	UAE	Water	33.40
11	Glycyrrhiza Glabra	UAE	Hydro glyceryl	490
12	Glycyrrhiza Glabra	UAE	Ethanol	51



% yield of Moringa Oliefera

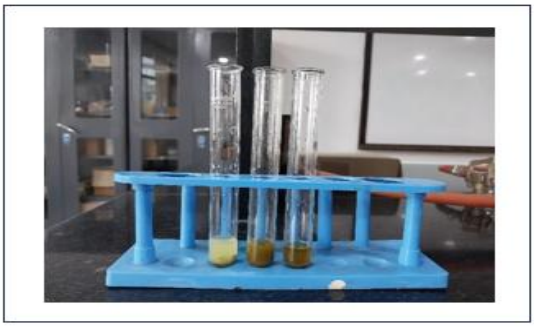


% yield of Glycyrrhiza Glabra

5. 2 Qualitative tests:

Sr. No.	Plant Material	Extraction Method	Solvent	Flavonoids	Saponins	Tannins
1	Moringa Oliefera	MAE	Water	-	-	+
2	Moringa Oliefera	MAE	Hydro glyceryl	+	+	+
3	Moringa Oliefera	MAE	Ethanol	+	+	+
4	Moringa Oliefera	UAE	Water	-	-	+
5	Moringa Oliefera	UAE	Hydro glyceryl	+	-	+
6	Moringa Oliefera	UAE	Ethanol	-	-	+
7	Glycyrrhiza Glabra	MAE	Water	+	+	+
8	Glycyrrhiza Glabra	MAE	Hydro glyceryl	-	+	-
9	Glycyrrhiza Glabra	MAE	Ethanol	+	+	+
10	Glycyrrhiza Glabra	UAE	Water	+	+	+
11	Glycyrrhiza Glabra	UAE	Hydro glyceryl	-	+	-
12	Glycyrrhiza Glabra	UAE	Ethanol	+	+	+

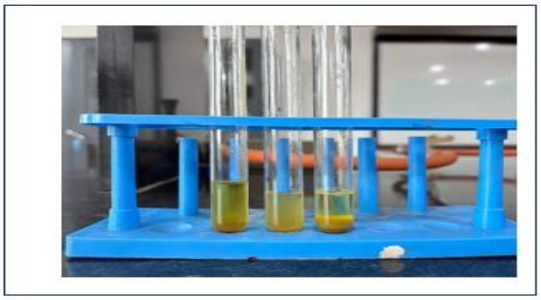
Further tests were performed, and the corresponding images have been added



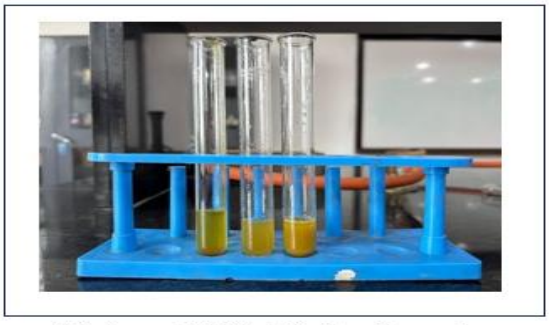
Moringa + MAE + Water

Moringa + MAE + Hydro glyceryl

Moringa + MAE + Ethanol



Moringa + UAE + Water

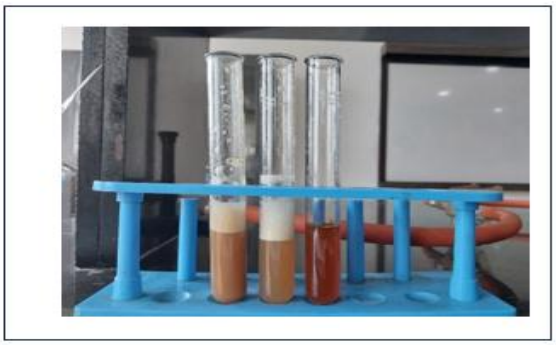


Moringa + UAE + Hydro glyceryl

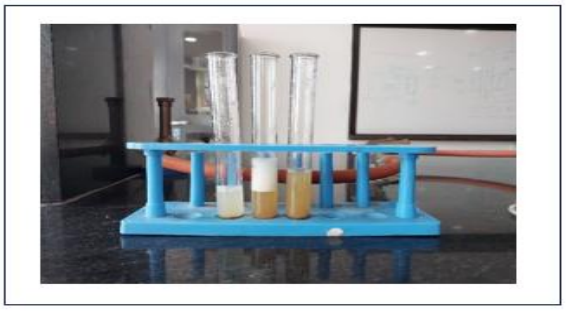
Moringa + UAE + Ethanol

Phytochemical tests for flavonoids, saponins, and tannins in Moringa Oliefera extracts

Liquorice + MAE + Water



Liquorice + MAE + Hydro glyceryl



Liquorice + MAE + Ethanol

Liquorice + UAE + Water

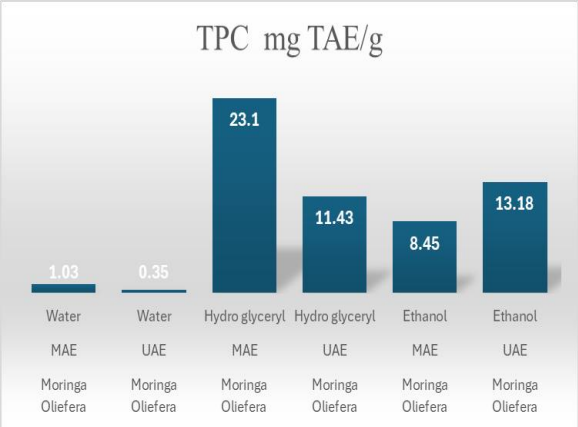
Liquorice + UAE + Hydro glyceryl

Liquorice + UAE + Ethanol

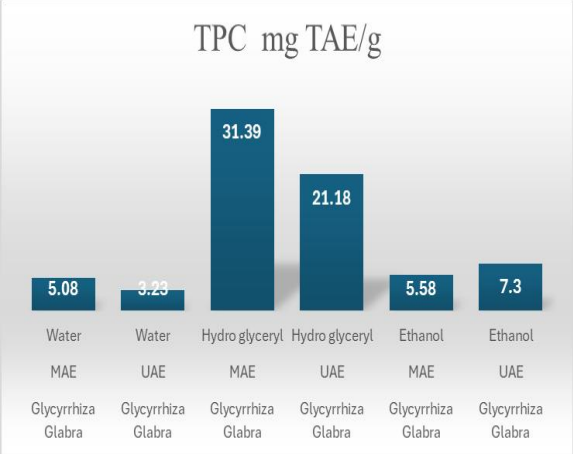
Phytochemical tests for flavonoids, saponins, and tannins in Glycyrrhiza Glabra extracts

5.3 Total phenol content:

Sr. No.	Plant Material	Extraction Method	Solvent	TPC mg TAE/g
1	Moringa Oliefera	MAE	Water	1.03
2	Moringa Oliefera	MAE	Hydro glyceryl	23.10
3	Moringa Oliefera	MAE	Ethanol	8.45
4	Moringa Oliefera	UAE	Water	0.35
5	Moringa Oliefera	UAE	Hydro glyceryl	11.43
6	Moringa Oliefera	UAE	Ethanol	13.18
7	Glycyrrhiza Glabra	MAE	Water	5.08
8	Glycyrrhiza Glabra	MAE	Hydro glyceryl	31.39
9	Glycyrrhiza Glabra	MAE	Ethanol	5.58
10	Glycyrrhiza Glabra	UAE	Water	3.23
11	Glycyrrhiza Glabra	UAE	Hydro glyceryl	21.18
12	Glycyrrhiza Glabra	UAE	Ethanol	7.30



Total Phenol content graph (M. Oliefera)



Total Phenol content graph (G. Glabra)

The study showed that Microwave- assisted extraction (MAE) and Ultrasound-assisted extraction (UAE) successfully extracted bioactive compounds like saponins, tannins and flavonoids from Moringa Oliefera and Glycyrrhiza Glabra using environmentally friendly solvents (water, hydro-glyceryl and ethanol). The hydro-glyceryl solvent gave exceptionally higher extraction yield (>400%), indicating strong extraction efficiency but possibly including residual solvent. Ethanol worked better than water in extracting more compounds. In between the two methods, MAE gave higher extraction yield compared to UAE. The qualitative tests confirmed the presence of flavonoids, saponins and tannins in the extract. The tests performed on extracts confirmed that these useful natural compounds were present in good amount, which is important for skin and hair care products. The results indicate that total phenol content (TPC) varied notably with extraction method and solvent type. Hydro-glyceryl extracts obtained by microwave-assisted extraction (MAE) showed the highest TPC for both Moringa oleifera (23.10 mg TAE/g) and Glycyrrhiza glabra (31.39 mg TAE/g), confirming its superior ability to extract phenolic compounds. Ethanol also demonstrated moderate efficiency, yielding higher TPC than water but lower than hydro-glyceryl extracts, suggesting its role as a good organic solvent for recovering both polar and moderately nonpolar phenolics. Overall, MAE with hydro-glyceryl and ethanol solvents proved to be efficient and sustainable choices for maximizing phenolic recovery important for antioxidant and cosmetic applications.

The advanced extraction methods reduced extraction time and solvent use, while preserving bioactive compounds better than conventional methods.

VI. CONCLUSIONS

The advanced green extraction techniques like MAE and UAE are effective and sustainable alternatives to conventional extraction, giving higher efficiency, less environment impact and better preservation of phytoconstituents. Hydro-glyceryl solvent was effective at extracting active ingredients for skin and haircare cosmetics. The choice of extraction method and solvent significantly impacts yield and phytochemical contents making MAE and UAE with green solvents ideal for optimizing herbal ingredient production. These methods support the growing demand for natural, safe and high- quality herbal cosmetic formulation.

This study demonstrates the potential of microwave and ultrasound-assisted green extraction methods combined with environmentally friendly solvents to produce high- quality bioactive extracts for cosmetic application.

VII. FUTURE PROSPECTS

Future prospects combining these findings and current knowledge include:

1. Optimization of Green Solvents: Hydro-glyceryl solvents, showing superior extraction yields and phenolic recovery, represent a promising solvent class for sustainable, efficient extraction in cosmetics. Research will further optimize solvent blends to maximize bioactive recovery and minimize residual solvent risks.

2. Integration of MAE and UAE Strengths: MAE's rapid, uniform heating offers higher yields and shorter extraction times, while UAE's cavitation improves mass transfer and preserves bioactivity at mild temperatures. Combining these methods (e.g., UMAE - ultrasonic microwave-assisted extraction) could further boost extraction efficiency, bioactive preservation, and scalability for industrial production.
3. Tailored Extraction Protocols: Based on plant matrix and targeted compounds (flavonoids, saponins, tannins), future development will focus on fine-tuning extraction parameters (power, time, solvent ratio) to maximize bioactive content and antioxidant potential, critical for high-quality skin and hair care formulations.
4. Sustainability and Safety: These green methods significantly reduce solvent use, energy consumption, and extraction time compared to conventional techniques, aligning with environmental sustainability goals. Hydro-glyceryl and ethanol, as safer and natural solvent options, also enhance consumer safety and regulatory acceptance.
5. Industrial Scale and Automation: Advances will target scaling these technologies with automated control of extraction parameters, ensuring reproducible, high-quality extracts for commercial cosmetic manufacturing while maintaining cost-effectiveness.

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