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Extracting Therapeutic Grade Essential Oils from the *Lamiaceae* Plant Family in the United Arab Emirates (UAE): Highlights on Great Possibilities and Sever Difficulties

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***Abstract*—**Essential oils are expensive phytochemicals produced and extracted from specific species belonging to particular families in the plant kingdom. In the United Arab Emirates country (UAE), is located in the arid region of the world, nine species, from the *Lamiaceae* family, having the capability to produce therapeutic grade essential oils. These species include; *Mentha spicata*, *Ocimum forskolei*, *Salvia macrosiphon*, *Salvia aegyptiaca*, *Salvia macilenta*, *Salvia spinosa*, *Teucrium polium*, *Teucrium stocksianum* and *Zataria multiflora*. Although, such potential species are indigenous to the UAE, however, there are almost no studies available to investigate the chemical composition and the quality of the extracted essential oils under the UAE climatological conditions. Therefore, great attention has to be given to such valuable natural resources, through conducting highly supported research projects, tailored to the UAE conditions, and investigating different extraction techniques, including the application of the latest available technologies, such as superficial fluid CO_2. This is crucially needed; in order to accomplish the greatest possibilities in the medicinal field, specifically in the discovery of new therapeutic chemotypes, as well as, to achieve the sustainability of this natural resource in the country.

***Keywords*—**Essential oils, extraction techniques, *Lamiaceae*, traditional medicine, United Arab Emirates (UAE).

I. Introduction

ESSENTIAL oils are volatile compounds characterized by a strong aroma, which is the result of the complex interactions between hundreds of compounds [1], [2], which consist mainly from terpenes, oxygenated terpenes, sesquiterpenes and oxygenated sesquiterpenes [1]. These organic compounds are produced by plant materials as secondary metabolites, acting as defense chemicals [3].

Their applications have deep roots in the folkloric medicine, in which they have been used to treat infections and diseases around the globe for centuries [4], [5]. Such traditional practices, lack proven scientific knowledge, and thus have to be extremely investigated and scientifically approved.

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In general, essential oils are presenting in very small amounts on plant material, less than 5% of dry matter. These expensive compounds could be extracted from roots and rhizomes (e.g. ginger), bark and branches (e.g. cinnamon), leaves (e.g. mint), flowers (e.g. lavender) and fruits and seeds (orange and lemon) [6].

Recently, more attention has been given to essential oils as a significant natural resource for phytochemicals. The reason is due to their amazing and wide range of potential applications, which are applicable to different fields, such as, pharmaceutical, food, fragrance and cosmetic industries [1], [2]. In addition, such phytochemicals having non-phytotoxic properties, comparing to the synthetic compounds, thus their application is generally safe, easy decomposition and environmentally friendly [6].

Indeed, composition of essential oils may naturally vary between various parts of the same used plant matter. Besides, there are many environmental factors which play a significant role on their quantitative and qualitative production, such as, soil condition, cultivation, climatic conditions and harvesting time [6]. At commercial level, it is very essential to have a good scientific knowledge on the preferable conditions that are responsible for best yield.

Lamiaceae is one of the most important medicinal plant families worldwide. It's considered as a significant resource for potential phytochemical compounds, which are used to cure sever diseases related to, for example, kidney, stomach and thyroids problems [7]. Some potential species of this plant family, like *Salvia spinosa* and *Teucrium stocksianum*, are belonging to the arid regions, like the UAE [8].

The main objective of this work is to spot the light on essential oil bearing plant species belonging to the *Lamiaceae* family in the UAE flora. This will be done to investigate whether this plant family would be an attractive resource for extracting therapeutic grade essential oils, under the UAE environmental conditions. Besides, this work will represent the most common conventional and non-conventional technologies, which are currently used in the extraction process. Additionally, this paper will highlight the great possibilities related to the medicinal applications of essential oils, extracted from the *Lamiaceae* family in the UAE, along with the current sever difficulties related to this context, that must be defeated.

II. The UAE Environmental Conditions

The UAE is a new established country located in the arid region of the world, southern part of the Arabian Peninsula. It opens into two coasts, Gulf of Oman in the east and the Arabian Gulf in the west [9]. The climate is characterized by very high summer temperatures, around 46°C in average, with high humidity rates along the two coastal lines, reaching 100% [10]. This is additional to the high wind speed and high sun exposure rates. The precipitation rates are low and irregular over most of the emirates, around 60 mm to 160 mm [11].

Indeed, groundwater is the main fresh water resource in the country [12]. However, this resource is a nonrenewable and unsustainable resource, and currently there are major concerns that groundwater aquifers would soon dry out and vanished [13], [14]. Thus, due to limited conventional water resources, the country has greatly supported seawater desalination and wastewater recycling as a non-conventional water resource; to cover the increasing water demands [12]. However, based on current knowledge, such non-conventional ways don't have the capability to cover the growing water demand, as well as, will not have the power to replace the supply which is covered today by the groundwater aquifers [14].

In general, the soil texture is classified as sandy soil [15]; thus has high water permeability rate, low water holding capacity, low water moisture content, poor nutrients availability, and thus low soil fertility rate [16], [17].

Consequently, there are many sever environmental difficulties in the UAE, related to the climatological conditions, water resources and the physical characteristics of the soil. Such harsh conditions lead to create sever conditions on the growth and performance of the UAE flora which resulted in forcing the plants themselves to produce magical phytochemicals, such as, essential oils compounds, as defense mechanism; in order to adapt and survive the desert scarce environmental resources [17].

III. An Overview on the UAE Flora

Currently, there is no clear data and no certain investigation about the total number of the available indigenous and naturalized plant species in the UAE. Some studies mention that, the UAE is a home for around 800 plant species [18]. However, other studies mention totally different figures. For example, according to Amin and Mousa (2007), the UAE flora includes 600 species [19], and based on another study, the UAE flora includes 731 vascular plant species [20]. Meaning that, information and knowledge in this context are still in the primary stages. This is mainly due to the young age of the country, which requires to conduct a lot of studies and gather information, in order to well manage the available flora.

There is no doubt that, the UAE flora, including indigenous and naturalized plant species, are one of the major natural resources of the country, which have been always the major resource of medication for the local community of this region in the ancient times [17], [19], [20]. Therefore, investigation of this natural resource is crucial in achieving the sustainability approach.

In fact, the UAE flora is exposed to harsh environmental conditions, as mentioned previously. Therefore, such desert plants are most likely capable to produce good production from secondary metabolites, including essential oils, for survival purposes [17]–[20]. This is an attractive point that has to be scientifically investigated to explore the possibility of commercial investment in this field.

It worth mentioning that, it has been declared by a study published by the Environmental Agency of Abu Dhabi that, 37% of the indigenous plants have been used to treat skin problems in the traditional medicine of the UAE [20]. Which could be linked, in a way or another, to the existence of therapeutic grade essential oils, and thus could be a positive indicator that flora of the UAE, from halophytes and xerophytes species, could pose significant resource for essential oils production, suitable for potential applications.

Reviewing the literature, existence of essential oils has been proven on many species belonging to different families: For example, *Teucrium stocksianum* from the *Lamiaceae* family [21], and *Aerva javanica* from the *Amaranthaceae* family [22]. Although, these species are indigenous to the UAE flora [8], [23], but publications on the essential oils constitutes, produced from plants under the UAE climatological conditions are very scarce. Since, the constitutes of the essential oils originated from the same plant species can significantly vary, under different geographical conditions, this would be a very important aspect to investigate and to record as a precious resource for the country, and then work to best exploit this valuable resource for suitable applications (e.g. pharmaceutical compounds and health care products) .

IV. *Lamiaceae* Plant Family in the UAE

Worldwide, *Lamiaceae* family is well-known as a medicinal plant family with significant species having potential medicinal properties and application [7]. Reviewing the literature extensively, it has been concluded that, eleven species from this plant family are indigenous to the UAE flora, as illustrated in Table I. These plant species include; *Lavandula subnuda*, *Leucas inflata*, *Mentha spicata*, *Ocimum forskolei*, *Salvia macrosiphon*, *Salvia aegyptiaca*, *Salvia macilenta*, *Salvia spinosa*, *Teucrium polium*, *Teucrium stocksianum* and *Zataria multiflora*. There are four species belonging to the *Salvia* genus, and two species belonging to the *Teucrium* genus. The nativity investigation for these species was guaranteed through reviewing and gathering information from the most important studies done in this area [8], [20], [23].

Out of the eleven species, three species are belonging to the hemicryptophytes, and four species are belonging to the therophyte and the chamaephyte, as shown in Table II.

Based on the limited available studies, information related to the availability, in terms of the habitat, emirates and status are illustrated in Tables III and IV [8], [20], [23]. It is very clear from the *Lamiaceae* species habitats, shown in Table III, that most of the species belonging to this family are located in the mountains, rocky terrain and wadis, which are available generally in Fujairah and Ras al Khaimah. Also, it is obvious

that, many information, related to this fundamental subject, are unavailable, which makes the germplasm collection and site analysis process a difficult task. Besides, the status of around half of the species represented in Table IV are not evaluated yet, as illustrated in Table V. Meaning that, some species could be currently under critical situations and could even became endangered or even threatened, without any prior notice.

In the traditional medicine, almost all these species have been used to treat different illnesses. For example, *T. stocksianum* has been used in the UAE to treat kidney, stomach pains and thyroids problems. Also, *T. polium* was used as anti-diabetic in the folk medicine. Besides, *Z. multiflora* has been used in the traditional practices of the UAE to treat cold and indigestion problems. Moreover, branches of *M. spicata* have been used to treat the flatulence, arthritis, blood sugar and for the acidity neutralization [7].

TABLE I
THE UAE PLANT SPECIES BELONGING TO THE *LAMIACEAE* FAMILY

Plant Botanical Name	Common Arabic Name	Life Form
Lavandula subnuda Benth.	Haraq/ Sawmar	Ch
Leucas inflata Benth..	NI	Th
Mentha spicata	Naana	He
Ocimum forskolei Benth.	Rayhan Jabaly	Th
Salvia macrosiphon Boiss.	Shajarat Al Ghazal	He
Salvia aegyptiaca L.	Raalah Masri	Th
Salvia macilenta Boiss.	Khizama	Ch
Salvia spinosa L.	Lesan Al Thor/ Harsha/ Shajarat Al Jamal	He
Teucrium polium L.	Jadah	Th
Teucrium stocksianum Boiss.	Jadah/ yadah	Ch
Zataria multiflora Boiss.	Zatar	Ch

Abbreviations: Ch = chamaephyte, He = hemicryptophytes, Th = therophyte, NI = no information.

TABLE II
LAMIACEAE PLANT SPECIES LIFE FORMS IN THE UAE

Life Form	Number of Species
Hemicryptophytes	3
Therophyte	4
Chamaephyte	4

TABLE III
LAMIACEAE PLANT SPECIES HABITATS AND EMIRATES

Plant Botanical Name	Habitat	Emirate
Lavandula subnuda Benth.	Roc	F, RAK
Leucas inflata Benth..	Roc	F, RAK
Mentha spicata	NI	NI
Ocimum forskolei Benth.	NI	OB
Salvia macrosiphon Boiss.	NI	F
Salvia aegyptiaca L.	Roc	OM
Salvia macilenta Boiss.	Roc, Pla	F, RAK
Salvia spinosa L.	Roc	NI
Teucrium polium L.	NI	NI
Teucrium stocksianum Boiss.	Roc	F, RAK
Zataria multiflora Boiss.	NI	NI

Abbreviations: Roc = mountains, rocky terrain and wadis, Pla = Alluvial and interdunal plains, NI = no information. F = Fujairah, RAK = Ras al Khaimah, OB = Oman border around Buraimi, OM = Oman Musandam and Ruus al Jibal.

TABLE IV
LAMIACEAE PLANT SPECIES STATUS IN THE UAE

Plant Botanical Name	Status
Lavandula subnuda Benth.	Common
Leucas inflata Benth..	Common
Mentha spicata	Not evaluated
Ocimum forskolei Benth.	Not evaluated
Salvia macrosiphon Boiss.	Rare
Salvia aegyptiaca L.	Common
Salvia macilenta Boiss.	Common
Salvia spinosa L.	Not evalauted
Teucrium polium L.	Not evaluated
Teucrium stocksianum Boiss.	Endangered
Zataria multiflora Boiss.	Not evaluated

TABLE V
LAMIACEAE PLANT SPECIES LIFE FORMS IN THE UAE

Life Form	Number of Species
Rare	1
Endangered	1
Common	4
Not evaluated	5

V. SIGNIFICANT ESSENTIAL OIL BEARING PLANT SPECIES FROM THE *LAMIACEAE* FAMILY

Reviewing the available literature extensively, it has been found that, out of the eleven species, belonging to the *Lamiaceae* family from the UAE flora, nine species have been scientifically proven worldwide, to be as essential oils bearing plants, which are, *Mentha spicata* [24], *Ocimum forskolei* [25], *Salvia macrosiphon* [26], *Salvia aegyptiaca* [27], *Salvia macilenta* [28], *Salvia spinosa* [29], *Teucrium polium* [30], *Teucrium stocksianum* [21], [33] and *Zataria multiflora* [34], as illustrated in Table VI.

Although, this area of research is highly significant, however, out of the previously mentioned nine essential oil bearing plants, no studies have been done on the following eight species, belonging to the UAE flora, which are *M. spicata*, *O. forskolei*, *S. macrosiphon*, *S. aegyptiaca*, *S. macilenta*, *S. spinosa*, *T. polium* and *Z. multiflora*. Such studies are essentially required; in order to investigate the chemical constituents and the chemotypes of the extracted essential oils belonging to the UAE flora, and thus to explore the possibilities of any potential applications.

To best of our knowledge, one study only has been conducted on *T. stocksianum*, from the *Lamiaceae* family, belonging to the UAE flora. The study investigated the essential oils, extracted through steam distillation, from the aerial parts of *T. stocksianum*, collected from Khor Fakken in the UAE. Analysis of the extracts was done using Gas Chromatography-Mass Spectrometry (GC/MS). Major compounds found were sesquiterpenoids, such as, a-cadinol and 6-cadinene [21].

Comparing the results of this study with another work done on investigating the constituents of *T. stocksianum* oils, extracted from aerial parts of this plant species, collected from Iran are illustrated in Table VII. It is obvious that, although, the used plant, extraction method and analysis, in the two

studies were identical, the composition and the yield of the extracted oil were much differ under different climatological conditions. The essential oil extracted from the UAE were rich in sesquiterpenoids, such as, a-cadinol (12.0%-14.6%) and 6-cadinene (12.4%-13.8%) [21], while the oil extracted from the Iran were rich in monoterpenoids, such as, a-pinene (36.6%), b-pinene (14.2%) and b-cubebene (5%) [35].

TABLE VI
LIST OF ESSENTIAL OIL BEARING PLANT SPECIES FROM THE *LAMIACEAE* FAMILY IN THE UAE

Serial Number	Plant Botanical Name
1	*Mentha spicata*
2	*Ocimum forskolei* Benth.
3	*Salvia macrosiphon* Boiss.
4	*Salvia aegyptiaca* L.
5	*Salvia macilenta* Boiss.
6	*Salvia spinosa* L.
7	*Teucrium polium* L.
8	*Teucrium stocksianum* Boiss.
9	*Zataria multiflora* Boiss.

TABLE VII
COMPARISION BETWEEN THE *T. STOCKSIANUM* OILS OF THE UAE AND IRAN

Factor	*T. stocksianum* (UAE)	*T. stocksianum* (Iran)
Major compounds	a-cadinol, 6-cadinene	a-pinene, b-pinene, b-cubebene
Major chemical groups	Sesquiterpenoids	Monoterpenoids
Average Yield (%)	0.34	0.5

It is worth to mention that, the genus *Salvia* is known to be linked to the essential oil bearing plants. For example, *S. aegyptiaca* whole plant, collected from Saudi Arabia, contains 40% from the identified constituents as terpenoidal compounds [27]. Also, essential oils extracted by hydro-distillation from the aerial parts of *S. macilenta* and *S. spinosa*, both collected from Iran, contain monoterpenes, like a-pinene [28], and 1,8-cinol [29] as major compounds, respectively. Therefore, the four species indigenous to the UAE, which are *S. macrosiphon*, *S. aegyptiaca*, *S. macilenta* and *S. spinosa* chemotypes, have to attract the great attention, to be screened and investigated extensively, based on their chemical composition and their physiological activity.

As mentioned previously, different environmental conditions could significantly affect the constituents of the extracted essential oils [17], [31]. Meaning that, even if the same essential oil bearing plant would grow under different climatological and environmental conditions, the extracted essential oils could significantly vary. Thus, it's crucially needed in the UAE to conduct extensive research works on the *Lamiaceae* indigenous species, seeking for new and valuable phytochemical resources, and thus potential applications.

VI. IMPORTANT EXTRACTION TECHNOLOGIES

A. Conventional Extraction Techniques

The most common conventional methods that are used for essential oils extraction include; hydro-distillation and steam distillation. The general concept in using these methods is to heat up the plant material using the boiling water or hot water steam to allow the aromatic volatile compounds, mainly essential oils, to escape from the plant matrix; then, collecting the evaporated compounds by the condensation process. Although these methods are simple and cost effective, however, the heating process could modify and break up the chemical structure of such mixture of valuable compounds. Which negatively affect the quality of the extracts. Also, the needed amount from plant material is high comparing to the obtained essential oils. For example, at laboratory scale, you will need around 1 kg of dry plant matter to produce maybe one drop of essential oils. In addition, this process consumes a lot of time and includes many of impurities. Which make such conventional ways inefficient in terms of extracts quality, operating time and effort, and resources conservation [24], [32].

B. Non Conventional Extraction Techniques

Recently, different extraction methods intensively explored to extract best quality production from essential oils. Supercritical fluid CO_2 is an innovative, simple, clean, fast, selective and environmental friendly technology, with particular interest to extract essential oils. Many studies declared that, this new technology is capable to extract essential oils with superior qualities comparing to other conventional techniques, such as, the hydro-distillation and the steam distillation. Consequently, it's very expected that there would be flourish future for the application of such technology [24], [32].

VII. HIGHLIGHTS ON POSSIBILITIES AND DIFFICULTIES

Since almost all the species of the *Lamiaceae* family, which are belonging to the UAE flora, have the capability to produce therapeutic grade essential oils, thus this family must be taken in consideration as a rich natural resource in the country, potential for medicinal purposes.

As mentioned previously, one study has been conducted only in investigating the *T. stocksianum* chemotype, collected from the UAE, using the hydro-distillation technique. Consequently, different research projects performing different extraction techniques, specially the new technology, are crucially needed to study the *T. stocksianum* chemotype and the rest eight essential oil bearing plants of the UAE.

It is worth mentioning that, different extraction techniques having the potential to extract much different constitutes. This depends on the nature of the chemical properties between the solvent material used in the extraction technique and the dissolved matter existed inside the plant matrix. Consequently, it's highly recommended to screen different extraction techniques for different extracts qualities and even quantities.

Up to date, the new extraction technologies, like supercritical CO_2, have not been used yet to extract essential oils from UAE flora. This is extremely required, in order to explore the possibility of new chemotype resources discovery. As mentioned previously, one study only exists, that applied the hydro-distillation conventional technique, to extract essential oils from *T. stocksianum*, which has to be

investigated further, using different conventional and non-conventional extraction techniques while investigating other essential oil bearing plant species from the *Lamiaceae* family in the country.

According to Bouhouche and Ksiksi [33], the environmental status of *T. stocksianum* in the UAE flora, is classified as an endangered species [33]. Therefore, intensive conservation plans, in the germplasm collection, propagation and storage process, have to be adopted, through applying the best advanced tissue culture and biotechnology techniques. Also, it's very important to establish a national germplasm bank; to conserve and sustain the availability of this valuable plant, along the rest of species. This is crucially needed, not only for the sake of biodiversity conservation, but also to protect this valuable natural resource from the concerns of declining in numbers and becoming threatening. Additionally, it's extremely required to conserve the natural habits of these species, especially, the mountains, rocky terrain and wadis.

Additionally, *L. subnuda*, and *L. inflata*, which are currently unknown as essential oils bearing plants, have to be investigated for this important purpose. Especially that, the genus *Lavandula* is widely known for its aromatic properties and medicinal applications, such as, the migraine, slimming, paralysis [7]. Also, the genus *Leucas* has the ability to produce aromatic compounds and essential oils [36]. Therefore, these facts could be as great indicators that, both *L. subnuda* and *L. inflata*, from the UAE flora, could have great capabilities to produce essential oils, with valuable characteristics and therapeutic applications.

It is highly expected that, the harsh environmental conditions in the UAE, such as, the drought [37]-[39] and low nutrients availability [40], could result in establishing perfect conditions for producing much valuable therapeutic essential oil constituents, comparing to grow the same essential oil bearing plants on other regions of the world [41].

It is important to say that, establishment of big funded research projects are extremely needed; in order to investigate the UAE flora as a potential resource for new innovative raw pharmaceutical compounds. Such projects have to be tailored to the UAE conditions, and the water scarcity issue has to be under the main considerations. For example, conduct research projects to explore the effect of treated domestic wastewater irrigation on the quality and the quantity of the extracted essential oils.

In general, it's highly needed to establish a national data bank for the UAE flora, which has been recently started at the Sharjah Seed Bank and Herbarium (SSBH) laboratory at Sharjah University, as the first formal initiative of it's kind in the history of the UAU, required to safeguard the national heritage of the native flora of the country [42].

Then, as a next fundamental step, special interest has to be given to establish base line data for the essential oil bearing plants, belonging to the Lamiaceae family and all other potential families in the country. Such computerized data have to periodically updated and have to consider the traditional knowledge and practices, which gained from the folk medicine of the UAE, at the first place, and then from the worldwide traditional practices. This is essentially needed to fill the existed gap between the traditional practices and the modern medicine.

VIII. Conclusion

In the UAE, there are nine species from the *Lamiaceae* medicinal family that are belonging to the essential oil bearing plants. These species include *Mentha spicata*, *Ocimum forskolei*, *Salvia macrosiphon*, *Salvia aegyptiaca*, *Salvia macilenta*, *Salvia spinosa*, *Teucrium polium*, *Teucrium stocksianum* and *Zataria multiflora*. Such plants have the capabilities to produce significant phytochemicals, suitable for therapeutic applications. Therefore, it's crucially needed to investigate the extracted essential oils under the UAE harsh environmental conditions, and also, using different conventional and non conventional extraction methods. The expected results from such studies could lead to innovative knowledge and even to discovery of new chemotypes for previously mentioned species.

Although, the future of the essential oils, extracted under the UAE environmental conditions, seems to be bright, in terms of discovering new raw resources, however, there are many critical challenges related to this field, that must be defeated in the near future.

Finally, it's very important to best explore, manage and conserve the available natural resources, at national and international levels, in a sustainable way, which guarantee their safe and healthy availability for the next generations.

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