Ras El Hanout: a theriac of therapeutic plants and spices - Qualitative and quantitative ethnobotanical investigation in the city of Meknes (Morocco)

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Research

Abstract

Background: In Morocco, plants are not traditionally used in isolation, but rather in mixtures, like Ras El Hanout, an ancestral spice theriac from North Africa for culinary and medicinal use. The aim of this project is to preserve and enhance this heritage by means of a qualitative and quantitative ethnobotanical study exploring the ethnopharmacological information about its constituent plants.

Methods: Sixty herbalists from Meknes city were interviewed to collect ethnobotanical and ethnomedicinal information on the *Ras El Hanout* mixture using a semi-structured questionnaire and the free listing technique. A quantitative ethnobotanical study was also carried out by calculating various quantitative indices. In parallel, various databases were consulted to obtain information on the pharmacological activities and active ingredients of its constituent plants.

Results: The results revealed that Ras El Hanout is used as a spice, an aphrodisiac, a tonic and to treat various illnesses. Its composition differs depending on the herbalist and the intended use, and it can contain up to 60 plants. The quantitative study showed that 10 species have a relative frequency of citation value equal to 1, with Cinnamomum cassia being the species with the highest use value (2.967). The highest informant agreement values (0.711) were obtained for the use of Ras El Hanout as an aphrodisiac and tonic.

Conclusions: The species constituting Ras El Hanout are endowed with a range of biological activities thanks to their active ingredients, which explains the typical flavor and therapeutic effects of this mixture. However, to guarantee its safety and effectiveness, pharmacotoxicological studies are necessary.

Keywords: Ras El Hanout, spice, therapeutic properties, mixture, Meknes, Morocco.

Background

Carriers of bewitching fragrances and subtle flavors, symbols of luxury and social distinction, spices have fascinated mankind since the dawn of time. No one can say when the regular use of spices began, or how long ago the trade in these precious commodities began (Birlouez 2012). Undoubtedly, it was more than 4,000 years ago that these plant substances were desired as much as gold and were eagerly sought after, making them the subject of trade between peoples. The remoteness of production areas, the risks associated with long journeys and the increase in the number of people involved are all factors that contribute to the high price of spices (Birlouez 2012).

Derived from the Latin word 'spices' meaning simply species, spices are parts of plants in whole, broken or ground form known for their strong flavor, taste and color, from which no volatile oil or other flavoring principle has been removed. Spices are used for seasoning, perfuming, preserving and coloring, while imparting a particular flavor (Sung *et al.* 2012).

In the past, early practitioners used spices not only to highlight their flavors but also as vectors of benefits for the body, whether in China, India or the Middle East. For over 3,500 years, the benefits of spices such as saffron, aniseed, caraway, cardamom and fenugreek have been mentioned in one of the oldest medical treatises, the Egyptian Ebers papyrus (Birlouez 2012). Today, spices are used in aromatherapy and aromachology because of their active ingredients, which can act on our olfactory system and hence on our whole body (Pons-Guiraud 2004).

From their origins to the present day, spices exhibit great diversity in terms of both botany and parts used; some are derived from fruit or flower buds (cloves), or flowers (saffron); others come from a root or rhizome (ginger, turmeric), a seed (pepper, cumin, fennel, cardamom), or even a bark (cinnamon) (Birlouez 2012). Furthermore, spices are generally made up of fibers, carbohydrates, proteins, gums, ash and volatile and non-volatile aromatic substances. This heterogeneity of constituents gives each spice its own organoleptic and therapeutic characteristics (Raghavan 2007).

In addition, each region of the world is characterized by the use of very specific flavors, and several spice mixtures are used in gastronomy. The Indian subcontinent is famous for its curries or masalas, a blend of up to 15 spices depending on the dish to be seasoned (Cahuzac-Picaud 2012). Other combinations are subtle, such as the French bouquet garni or herbes de Provence, Mexican adobo, Chinese five-spice or Georgian khmeli-suneli. The composition of these delicate flavors cannot overshadow the countless Ras El Hanout blends that characterize North Africa, particularly Morocco (Cahuzac-Picaud 2012). Ras El Hanout is a traditional theriac of warming products and spices (Bellakhdar 1997). In Moroccan dialectal Arabic, it means 'head of the grocery shop', taking its name from its composition, which contains a large number of spices and medicinal plants much in demand in Moroccan cooking and phytotherapy (El Alami *et al.* 2019). For some, Ras El Hanout may also be called Msakhen, while for others the name Msakhen is only used after the addition of other complementary ingredients (Bellakhdar 1997). In Moroccan dialect Arabic, Msakhen means 'warming' (El Alami *et al.* 2019).

With the aim of preserving this socio-cultural heritage as well as these organoleptic and phytotherapeutic practices, while maintaining written documentation of this traditional Moroccan know-how, a qualitative and quantitative ethnobotanical study of the Ras El Hanout blend was carried out among herbalists in the town of Meknes (Morocco). This ethnobotanical study was complemented by documentation on the active principles and biological activities of the various plants making up the Ras El Hanout mixture.

Materials and Methods

Presentation of the study area

Covering an area of 370 km 2, with a legal population of 6,320,79 inhabitants in 2014, Meknes is one of the Kingdom's six major cities (Fig. 1) (H.C.P. 2014). Due to its geographical position, the city serves as a communication hub between the Atlantic plains, the pre-Rif hills, the Middle Atlas, and the high plateaus of the Oriental region. Meknes has a semi-continental Mediterranean climate, with cool, rainy winters and hot, dry summers (H.C.P. 2017). In terms of healthcare, in 2013, the public hospital infrastructure in the city of Meknes consisted of 2 general hospitals, 2 specialized hospitals and 33 health centers (H.C.P. 2017).

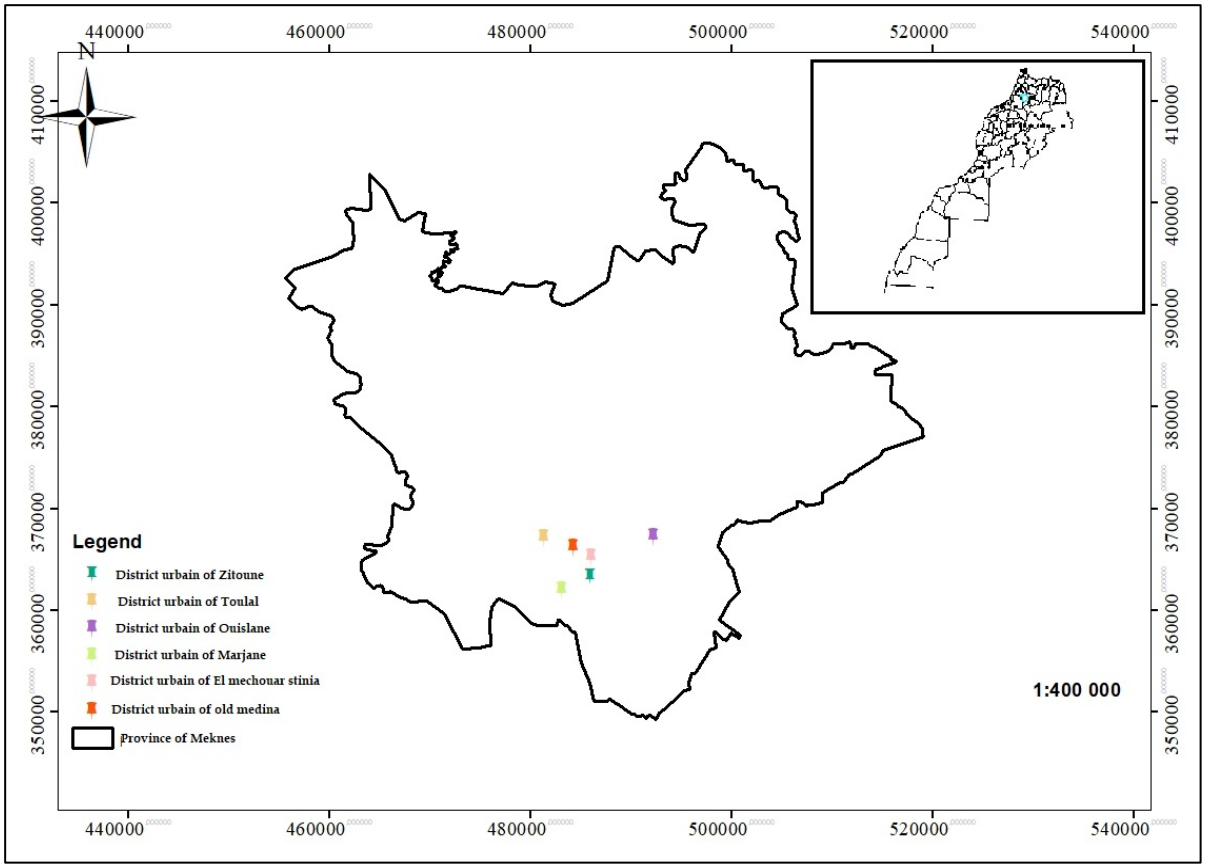

Figure 1. Study area

Research methodology

Sample size

Stratified probability sampling was adopted: the target population was subdivided into strata according to certain characteristics, and individuals were then selected to form a sample that must contain an equal proportion of individuals from each stratum. In our case, the strata were represented by the following urban districts: Ancienne Medina, El Mechouar Stinia, Marjane, Zitoun, Toulat and Ouislane. Each stratum had the same number of respondents, represented by ten herbalists. The sample size was therefore N=60 respondents.

Inclusion and exclusion criteria

The inclusion criteria concerned herbalists from the study area who were reputed to be skilled and expert in the practice of herbal medicine or the trade in aromatic and medicinal plants, as such they would be able to provide correct ethnobotanical information and original ideas about medicinal and aromatic plants. However, the exclusion criteria were herbalists who did not originate from the study area and who did not have a reputation in the field.

Data collection and interview methods

In this study, the free listing technique, commonly used in the social and behavioral sciences, ethnozoology and ethnobotany, was adopted (Miranda *et al.* 2007). Respondents were asked to list the plants and other ingredients they use to prepare the *Ras El Hanout* mixture.

A complementary technique was also used: the so-called 'field journal' technique, which consists of using audio recordings to gather information with the permission of the interviewee. This technique has the advantage of saving all the information gathered during a given interview.

The flexible, open-ended interviews were conducted on an individual basis; the surveys were rarely completed in a single visit; sometimes it was necessary to return to the interviewee several times and to show patience and availability in order to gather the information. The interviews were conducted in the local language (Moroccan dialect Arabic) spoken by the herbalists in the study area over a period from January 2022 to August 2022.

The traditional ethnobotanical knowledge of the herbalists surveyed about the Ras El Hanout mixture was documented using a semi-structured questionnaire, with respondents asked to answer closed and semi-closed questions. During each interview, all the necessary socio-demographic information on the respondents was collected, including level of education, age and gender. As for the plants listed, the data collected included the local name of each plant, the part or parts used, the method of preparation and much more.

All informants were first questioned on general points, then on specific issues. Also, in order to limit bias, we tried to be as neutral as possible to avoid making the interviewee uncomfortable or influencing him or her to express an opinion. Similarly, value judgements that might guide the respondent's answers or cause bias on the part of the respondent themselves, such as the tendency to give answers that may be perceived as acceptable, were avoided.

Taxonomic identification of species

The species used by the herbalists surveyed to prepare the Ras El Hanout mixture were sampled, dried, numbered and preserved using the standard method (Jain 1964). Each species was carefully sampled in the study area or in other regions of Morocco, and for species that do not grow in Morocco, samples sold by the herbalists surveyed were used. These samples were compared with those sold by herbalists in the different strata studied for greater accuracy.

The taxonomic identification was carried out in the Laboratory of Environment and Valorization of Microbial and Plant Resources by Professor Laila Nassiri, using the vascular plant identification manuals "Practical Flora of Morocco" (Fennane *et al.* 1999, Fennane *et al.* 2007, Fennane *et al.* 2014). Species and family names have been revised according to the 'Plants of the World online' website (http://plantsoftheworldonline.org/).

All specimens have been deposited for future reference in the herbarium of the 'Environment and Development of Microbial and Plant Resources' research unit, Faculty of Science, Moulay Ismail University, Meknes, Morocco.

Quantitative analysis of ethnobotanical data

The data collected were used to calculate various quantitative indices: use value (UV), family use value (FUV), relative frequency of citation (RFC), informant consensus factor (ICF) and plant part value (PPV).

Use value

The use value (UV) is used to demonstrate the relative importance of locally known plants; this index is calculated using the following formula (Vitalini *et al.* 2013):

$$\mathbf{UV} = \sum_{i=1}^{i=N} \mathbf{Ui/N}$$

Where:

Ui = the number of use reports mentioned by each informant i for a given species

N = the total number of informants interviewed.

Use value of *families*

Family use values (FUV) are used to identify the importance of plant families and are calculated using the following formula (Cadena-González *et al.* 2013) :

$$\mathbf{FUV = (\sum UVS) / Ns}$$

Where:

UVs = the use value of species belonging to the same family;

Ns = the total number of species present in a given family.

Relative frequency of citation

The relative frequency of citation (RFC) shows the local importance of each species and is given by the following formula (Vitalini *et al.* 2013):

$$\mathbf{RFC = FC / N}$$

Where:

FC = the number of informants using a given species;

N = the total number of informants interviewed.

Informant consensus factor

The informant consensus factor (ICF) is used to determine the agreement between informants on the use of plants for specific use categories. It is defined by the formula (Heinrich *et al.*1998):

$$ICF = (N_{ur} - N_t) / (N_{ur} - 1)$$

Where:
Nur = the number of times a particular category of condition was mentioned;
Nt = the number of plants mentioned for the treatment of this particular condition.

The ICF varies from zero to one; a value close to 1 indicates a high intra-cultural consensus, meaning that most informants used the same species to treat the same diseases, and a value close to zero indicates a high variation in species use indicating that informants did not agree on the species used to treat a disease category (Heinrich *et al.* 1998).

Value of plant parts

The plant part value (PPV) was calculated using the following formula:

$$\mathbf{PPV} = \frac{\mathbf{RU\ Plant\ part}}{\boldsymbol{RU}}$$

Where:
RU = the number of uses declared for all parts of the plant;
RU Plant part = the sum of declared uses per plant part.
The part with the highest PPV was the most used by the respondents (Najem *et al.* 2020).

Results and discussion

Socio-demographic data of respondents

All the participants selected for this study answered all the questions in the questionnaire, so 100% of them were respondents. In total, of the 60 herbalists interviewed, 90% were men and only 10% were women, giving a female/male sex ratio of 0.11. The herbalists surveyed in Meknes were spread across all age groups, with an average age of 47.5 years. The upper and lower age limits were 20 and 75 respectively. There is a predominance of people aged between 50 and 60 (43.33%), compared with 10% of people aged under 30. With regard to the respondents' level of education, those with secondary education dominated with a percentage of 43.33%; those with primary education and the illiterate made up 26.67% and 16.67% of all respondents respectively (Table 1).

Table 1. Profile of herbalists interviewed (N=60)

Variables	Categories	Number of respondents	Percentages (%)
Gender	Male	54	90
	Female	6	10
Age	< 30 years	6	10
	30-50 years	9	15
	50-60 years	26	43.33
	> 60 years	19	31.67
Level of education	Illiterate	10	16.67
	Primary	16	26.67
	Secondary	26	43.33
	University	8	13.33

The herbalists surveyed all come from the study area. They are experienced in selling plants and practicing phytotherapy. They are therefore able to provide correct information on the use of plants, particularly medicinal and aromatic plants. Plants are an integral part of their daily lives, and the use of plants and the practice of phytotherapy are often inherited from their parents and/or ancestors. It was clearly observed that the prevalence of men in the field of herbal medicine is significant, which is in line with the results of other studies in other regions (Bachiri *et al.* 2015, Harouak *et al.* 2018). However, it is important to bear in mind that women's knowledge is an original cultural creation, in terms of both knowledge of plants and their medical applications (Najem *et al.* 2020). Moreover, herbalism is mainly practiced by people over the age of 50, reflecting that knowledge of plants and their properties, as well as the practice of traditional medicine, requires experience accumulated over the years (Anyinam 1995). Nevertheless, the attachment of young people to herbalism is proof of the durability of the transmission of knowledge from one generation to the next and the persistence of the traditional use of plants (Najem *et al.* 2020). The proportion of university-educated herbalists is likely to contribute to the improvement of this field; this category of practitioner is certainly better informed about the possible side-effects of plants, synergistic or

asynergistic interactions, the dangers of overdosing and the risks of plant intoxication through abusive or inappropriate therapeutic use, unlike illiterate people who are unable to document and deepen their knowledge of the profession they practise, or to transcribe their knowledge and preserve it in writing (Najem *et al.* 2019).

Formulation of the *Ras El Hanout* mixture

Ethnobotanical investigations carried out among herbalists in the city of Meknes revealed that there is no standard composition for *Ras El Hanout*, and that the plants making up the mixture differ from one herbalist to another and may include up to 60 species (Table 2). As a result, there are several different types of *Ras El Hanout* mixture, depending on its intended use.

The first mixture is used as a spice and is considered to be the base mixture for the other mixtures. It can contain up to 45 species: *Aframomum melegueta* K. Schum, *Alpinia officinarum* Hance, *Ammodaucus leucotrichus* Coss. et Dur., *Anethum graveolens* L., *Brassica nigra* (L.) W.D. Koch., *Capparis spinosa* L., *Capsicum frutescens* L., *Carum carvi* L., *Ceratonia siliqua* L., *Cinnamomum cassia* (Nees & T. Nees) J. Presl., *Colchicum autumnale* L., *Coriandrum sativum* L., *Corrigiola telephiifolia* Pourr., *Crocus sativus* L., *Cuminum cyminum* L., *Curcuma xanthorrhiza* Roxb., *Elettaria cardamomum* (L.) Maton, *Eruca vesicaria* L., *Foeniculum vulgare* Mill., *Fraxinus excelsior* L., *Glycine max* (L.) Merr., *Illicium verum* Hook. F, *Laurus nobilis* L., *Lepidium sativum* L., *Linum usitatissimum* L., *Myristica fragrans* Houtt., *Nigella sativa* L., *Origanum compactum* Benth., *Pennisetum typhoides* (Burm.) Stapf et Hubb., *Pimenta officinalis* (L.) Merr., *Pimpinella anisum* L., *Piper cubeba* L.f., *Piper nigrum* L., *Piper retrofractum* Vahl., *Punica granatum* L., *Ranunculus bullatus* L., *Rosmarinus officinalis* L., *Rubia peregrina L.*, *Sesamum indicum* L., *Syzygium aromaticum* (L.) Merr. & L.M.Perry, *Thymus* sp., *Trigonella foenum-graecum* L., *Xylopia aethiopica* A. Rich., *Zingiber officinale* Rosc. and *Ziziphus lotus* L.

The other types of mixture are not usually considered to be spices, but rather Moroccan medicinal formulations. Investigations revealed the presence of 3 types of these formulations. For example, there is a combination called *M'sakhen*, which means 'warming'. It is made up of the basic formula mentioned above, to which we add *Pistacia atlantica* Desf., *Ferula assa-foetida* L. and *Smyrnium olusatrum* L. There is another variant of *M'sakhen* called *Saharan M'sakhen* which contains the same constituents as *M'sakhen* amended by the following plants: *Acacia raddiana* Savi, *Androcymbium gramineum* (Cav.) J.C.Manning & Vinn., *Centaurea pungens* Pomel, *Eremophyton chevallieri* (baratte) Beg., *Euphorbia calyptrata* Coss. & Kralik, *Gaillonia reboudiana* Coss. & Dur, *Limoniastrum guyonianum* C. & D. and *Marrubium desertii* DeNoe.

The final medicinal formulation is an aphrodisiac and tonic mixture consisting of the basic formula mentioned above supplemented with the following species: *Cyperus esculentus* L., *Fraxinus angustifolia* Vahl., *Reseda villosa* Coss. and *Urtica pilulifera* L.

Biodiversity of plants used in the preparation of the *Ras El Hanout* mixture

The medicinal and aromatic plants used by herbalists in the town of Meknes to prepare the Ras El Hanout mixture are divided into 31 families, of which the most represented are: the Apiaceae (9 species), the Zingiberaceae (5 species), the Brassicaceae, the Fabaceae and the Lamiaceae, each containing 4 species. The Piperaceae are represented by 3 species. The remaining 25 families are each represented by two or a single plant (Fig. 2).

The plants inventoried belong to 57 genera. The majority of the genera identified (96.49%) are represented by a single species, and only two genera have at least two species each, i.e. 3.51%; these are Fraxinus (2 species) and Piper (3 species) (Table 2 and Fig. 2).

Value of the part of the plant (PPV)

The herbalists interviewed use many different plant parts in the preparation of *Ras El Hanout*, including leaves, flowers, seeds, roots, fruit, resin and many other parts, sometimes even the whole plant. According to the plant part value index (PPV), the main plant part used to formulate the *Ras El Hanout* mixture was the seed (PPV = 0.433), followed by the fruit (PPV = 0.150) and the whole plant (PPV = 0.083) (Table 3).

Table 2. Plant species used in the composition of *Ras El Hanout*

Family	Scientific name	Vernacular name	Specimen number	Part Used	Active principles	Biological activities	RFC	UV
Anacardiaceae	*Pistacia atlantica* Desf.	Lebtem	TRH01	Seeds	1 α-pinene, β-pinene, limonene, terpinolene, camphene, terpinen-4-ol, bornyl acetate, sabinene, p-Mentha-1 (7),8 diene, Δ3-carene, spathulenol, masticadienonic acid, morolic acid, oleanolic acid, Ursonic acid, 3-O-acetyl-3-epiisomasticadienolic acid, gallic acid, Quercetin-3-glucoside, 3-methoxycarpachromene and β-myrcene (Mahjoub *et al.* 2018)	Gastrointestinal benefits, antioxidant, antidiabetic, antihyperlipidemic, anticancer, anticholinesterase hypoglycemic and wound-healing effects (Mahjoub *et al.* 2018)	0.167	0.167
Annonaceae	*Xylopia aethiopica* A. Rich.	Bzar dakar	TRH08	Fruits	Oxoaporphine alkaloids, oxophoebine and liriodenine, alkaloids oxoglaucine, O-methylmoschatoline and lysicamine.kaurane, kolavane and trachylobane diterpenes (Fetse *et al.* 2016)	Antimicrobial, Anti-anaphylactic , anti-inflammatory, antioxidant, antiproliferative, hypolipidemic and analgesic activity (Erhirhie & Moke 2014)	0.633	0.950
Apiaceae	*Ammodaucus leucotrichus* Coss. et Dur.	Lkamoune Soufi	TRH45	Fruits	Perillaldehyde, limonene, guainolide lactone, ammolactone, monoterpenoid 3-hydroxyperiilaldehyde, methylperillate, borneolangelate and γ-decalactone (Idm'hand *et al.* 2020)	Antioxidant, antibacterial, antifungal, antidiabetic, anti-inflammatory, anticholinesterase and cytotoxicity activities (Idm'hand *et al.* 2020)	0.233	0.600
Apiaceae	*Anethum graveolens* L.	Chibt	TRH58	Seeds	Essential oil : carvone, limonene, α-phellandrene (Al-Snafi 2014)	Antibacterial, antifungal, antioxidant, antidiabetic, anti-inflammatory, antispasmodic, hypolipidemic activities (Chahal *et al.* 2017b)	0.333	0.633

Apiaceae	*Carum carvi* L.	karwia	TRH44	Seeds	Carvacrol, carvone, α-pinene, limonene, γ- terpinene, linalool, carvenone, and p-cymene, whereas the major compounds occurring in cumin are cuminaldehyde, limonene, α- and β-pinene, 1,8-cineole, o- and p-cymene, α- and γ-terpinene, safranal and linalool (Johri 2011)	Anti-diabetic, antioxidant, hepatoprotective, antiulcerogenic, antimicrobial, Insecticidal, diuretic, analgesic, renoprotective, molluscicidal, endocrine, anti-cholinesterases, Immunomodulatory properties (Goyal *et al.* 2018)	1.000	2.350
Apiaceae	*Coriandrum sativum* L.	kazbour	TRH36	Seeds	Essential oil, fatty acids, tocol, sterol and carotenoids (Wei *et al.* 2019)	Anxiolytic, antidepressant, sedative-hypnotic, anticonvulsant, memory enhancement, improvement of orofacialdyskinesia, neuroprotective, antibacterial, antifungal, anthelmintic, insecticidal, antioxidant, cardiovascular,hypolipidemic, anti-inflammatory, analgesic, antidiabetic, mutagenic, antimutagenic, anticancer, gastrointestinal, deodorizing, dermatological, diuretic, reproductive, hepatoprotective and detoxification (Esmail Al-Snafi 2016)	1.000	2.967
Apiaceae	*Cuminum cyminum* L.	Lkamoun	TRH25	Seeds	Pinene, cymene, terpinene, cuminaldehyde, oleoresin, thymol (Singh *et al.* 2017)	Antimicrobial, insecticidal, anti-inflammatory, analgesic, antioxidant, anticancer, antidiabetic, antiplatelet aggregation,	1.000	2.750

						hypotensive, bronchodilatory, immunological, contraceptive, anti-amyloidogenic, anti-osteoporotic, aldose reductase , alpha-glucosidase and tyrosinase inhibitory effects, protective and central nervous effects (Al-Snafi 2016)		
Apiaceae	*Ferula assa-foetida* L.	Hentit	TRH19	Resin	Umbelliprenin, galbanic acid, 8-acetoxy-5-Shydroxyumbelliprenin, farnesiferol A, farnesiferol B, farnesiferol C, 10-R-acetoxy-11-hydroxyumbelliprenin, 10-R-karatavicinol, conferol (Iranshahy & Iranshahi 2011)	Antifungal, anti-diabetic, anti-inflammatory, anti-mutagenic and antiviral activities (Iranshahy & Iranshahi 2011)	0.367	0.367
Apiaceae	*Foeniculum vulgare* Mill.	Nafaa	TRH02	Seeds	3-caffeoylquinic acid, 4-caffeoylquinic acid, 1,5-O-dicaffeoylquinic acid, rosmarinic acid, eriodictyol-7-O-rutinoside, quercetin-3-O-galactoside, kaempferol-3-O-rutinoside, and kaempferol-3-O-glucoside. Essential oils: Trans-anethole and estragole, (E)-anethole, fenchone and methyl chavicol (Diao *et al.* 2014, Mimica-Dukić *et al.* 2003, Parejo *et al.* 2004)	Antioxidant, anti-cancer, anti-inflammatory, analgesic, antifungal, hepato-protective, anti-bacterial and estrogenic (Choi & Hwang 2004, Diao *et al.* 2014, Esquivel-Ferriño *et al.* 2012, Kooti *et al.* 2015, Mimica-Dukić *et al.* 2003, Mohamad *et al.* 2011, Wang *et al.* 2012)	1.000	2.550
Apiaceae	*Pimpinella anisum* L.	Hbat Lhlawa	TRH24	Seeds	Isovitexin, Rutin, apigenin 7-glucoside and a luteolin glycoside. Essential oils: trans-anetole, estragole, *γ*-hymachalen, paraanisaldehyde and methyl	Antimicrobial, antifungal, antiviral, anti-inflammatory, muscle relaxant, analgesic, antispasmodic, antiulcer, Anti-diabetic, hypolipidemic	1.000	2.100

					cavicol (Kunzemann & Herrmann 1977, Orav *et al.* 2008)	and anticonvulsant activity (Ahmadipour *et al.* 2016, Kunzemann & Herrmann 1977, Orav *et al.* 2008, Tas *et al.* 2006,Tirapelli *et al.* 2007)		
Apiaceae	*Smyrnium olusatrum* L.	Habbet gri	TRH59	Seeds	Isofuranodiene and 1β-acetoxyfuranoeudesm-4(15)-ene (Quassinti *et al.* 2013)	Antiproliferative activity on human tumor cell lines, antioxidant and antimicrobial activities (Quassinti *et al.* 2013)	0.283	0.283
Asteraceae	*Centaurea pungens* Pomel	Neggir	TRH46	Whole plant	Centaureolide A and centaureolide B (Labed *et al.* 2019)	Antimicrobial activity (Labed *et al.* 2019)	0.333	0.333
Brassicaceae	*Brassica nigra* (L.) W.D. Koch.	Khardal aswad	TRH35	Seeds	Glycosinolates (Agrawal *et al.* 2019)	Anticancer, antibacterial, antifungal, antihelminthic activities. Protection against renal and hepatic toxicity, treatment of diabetes, cardiovascular and neurological disorders (Agrawal *et al.* 2019)	0.483	0.967
Brassicaceae	*Eremophyton chevallieri* (baratte) Beg.	Galglan	TRH37	Seeds	-----	-------	0.317	0.317
Brassicaceae	*Eruca vesicaria* L.	Lharra	TRH03	Leaves	Phytol, isothiocyanates, rhodopin (Hassan *et al.* 2021)	Diuretic, vermifuge (Boukerker *et al.* 2016), cytotoxic and antioxidant activity (Hassan *et al.* 2021)	0.500	0.600
Brassicaceae	*Lepidium sativum* L.	Hab rchat	TRH18	Seeds	Glucotropaeolin, 4-methoxyglucobrassicin, esters of caffeic, β-sitosterol, benzylcyanide, calmodulin, sinapoyglucose, p-coumaric, ferulic, quinic acids, protein, mineral, vitamin, 5-4'-dihydroxy	Antibacterial, antioxidant, antifungal, hemagglutinating activity, management of airways disorders, cytotoxic, diuretic, hepatoprotective, hypoglycemic,	0.767	1.850

					7,8,3,5-tetramethoxyflavone, 5-3'-dihydroxy-7,8,4' tetramethoxyflavone, and 5-3'-dihydroxy-6,7,4'-tetramethoxyflavone (Baregama & Goyal 2019)	antiosteoporotic, antiasthmatic, anti-inflammatory and antiarthritic (Baregama & Goyal 2019)		
Capparaceae	*Capparis spinosa* L.	Kebbar	TRH57	Flower bud	Rutin and quercertin, Cappariloside A, stachydrin, hypoxanthine and uracil (Zhang & Ma 2018)	Antiobesity, antihypertensive, antidiabetic, antihepatotoxic, cholesterol-Lowering, antimicrobial, anti-inflammatory (Zhang & Ma 2018)	0.533	1.233
Caryophyllaceae	*Corrigiola telephiifolia* Pourr.	Tasrghinte	TRH43	Root	Saponins and terpenes (Lakmichi *et al.* 2011)	Antidiabetic, antibacterial, diuretic, hypolipidemic and antioxidant Activities (Daoudi *et al.* 2017, Hebi & Eddouks 2019, Hebi & Eddouks 2020; Zakariya *et al.* 2020).	0.450	0.617
Colchicaceae	*Androcymbium gramineum* (Cav.) J.C.Manning & Vinn.	Sgeat lerneb	TRH34	Fruits	Colchicine, 2-demethylcolchicine, 3-demethylcolchicine, and *N*-formyl-*N*-deacetylcolchicine (Ellington *et al.* 2003)	Antibacterial, diuretic, cardiotonic and hypoglycemic activities treatment of respiratory disorders due to cold (Moussaid *et al.* 2012)	0.317	0.317
Colchicaceae	*Colchicum autumnale* L.	Bakbouka	TRH47	Bulbs	Colchicine, colchicoside, 3-demethylcolchicine (Suhail *et al.* 2017)	Purgative, phlegmagogue, constipative, aphrodisiac, analgesic, restoring normal sensation, anaesthetic, anti-gout relieve inflammation and pain of acute gout (Suhail *et al.* 2017)	0.367	0.867

Cyperaceae	*Cyperus esculentus* L.	Habb ezzalam	TRH04	Tubers	Cyperol, anthraquinone ($C_{14}H_8O_2$) (Zhang *et al.* 2022)	Neuroprotective effects, Antioxidant, antimicrobial, antidiabetic, antidiarrheal and anticancer activity (Bezerra *et al.* 2023)	0.500	0.700
Euphorbiaceae	*Euphorbia calyptrata* Coss. & Kralik	Rremada	TRH17	Whole plant	Helioscopinolides A, C, D, and E (Speroni *et al.* 1991)	Antioxidant and antimicrobial activity (Alghazeer *et al.* 2009)	0.317	0.417
Fabaceae	*Acacia raddiana* Savi	Talh	TRH56	Flowers	Apigenin6,8-bis-C-β-D-glucopyranoside (vicenin), Rutin (quercetin 3-O-rutinoside), 1,3-di-O-galloyl-4,6-(-) hexahydroxydiphenoyl-β glucopyranos (Jaouadi *et al.* 2015)	Antimicrobial, antiparasitic, antidiabetic, cardiovascular effects, respiratory effects and anti-inflammatory (Jaouadi *et al.* 2015)	0.300	0.567
Fabaceae	*Ceratonia siliqua* L.	Kharroub	TRH23	Fruits	Phenolic acids such as gallic acid and isoflavones, flavones and flavones and quercetin glycosides (Rtibi *et al.* 2017)	Anti-inflammatory, antimicrobial, anti-diarrheique, antioxidant, anti-ulcer, anti-constipation and anti-absorptive of glucose activities (Rtibi *et al.* 2017)	0.283	0.617
Fabaceae	*Glycine max* (L.) Merr.	Souja	TRH38	Seeds	Glycitin : 4’-hydroxy-6-methoxyisoflavone-7-D-glucoside (Patel 2023)	Chemopreventive, cardioprotective, anti-osteoporosis and anti-diabetic activities. Beneficial effect on acute lung injury, bone, cognitive performance, breast cancer, skin, immune system, enzymes, prostaglandins and taste receptors (Patel 2023)	0.050	0.050

Fabaceae	*Trigonella foenum-graecum* L.	Lhalba	TRH05	Seeds	Galactomannan, diosgenin isoleucine, lecithin and choline, mineral, B-complex, iron, phosphate, para-benzoic acid, vitamins A and D (Olaiya & Soetan 2014).	Antibacterial, antifungal, antiviral antidiabetic, antiplasmodic, hepatoprotective, hypolipidemic, antibacterial, anthelmintic, anti-inflammatory, analgesic activity,antioxidant, anticarcinogenic, antiulcer, antifertility, immunomodulatory effect (Haque *et al.* 2015, Olaiya & Soetan 2014).	0.650	1.850
Iridaceae	*Crocus sativus* L.	Zaafran	TRH16	Stigmas	Apocarotenoids such as crocetin, crocin, safranal (the bio-oxidative cleavage products of zeaxanthin) and picrocrocin (Bukhari *et al.* 2018)	Antioxidant, Cardiovascular effects, Respiratory effects, Anticancer, Anti-inflammatory and analgesic effects, Protective effects, Antidiabetic effects, Dermatological effects (Al-Snafi 2016)	0.717	1.700
Lamiaceae	*Marrubium desertii* DeNoe	Ja'da	TRH33	whole plant	Marrulibacetal A, eohesperidoside, actenoside and forsythoside (Zaabat *et al.* 2010)	Antioxidant, antibacterial, antigenotoxic (Zaabat *et al.* 2010), anti-inflammatory, antipyretic and analgesic (Saad *et al.* 2021)	0.217	0.617
Lamiaceae	*Origanum compactum* Benth.	Zaatar	TRH09	Aerial part	Terpenoids and phenolic acids (Bouyahya *et al.* 2017). Essential oils: Carvacrol, thymol, p-cymene and γ-terpinene (Bouyahya *et al.* 2017)	Antibacterial, antioxidant, antifungal, antitumor, mutagenic and anti-mutagenic and antimalaria activity (Bouyahya *et al.* 2017)	0.650	2.050
Lamiaceae	*Rosmarinus officinalis* L.	Azir	TRH26	Leaves	Rosmarinic acid, camphor, caffeic acid, ursolic acid, betulinic acid, carnosic acid and carnosol	Antibacterial, antidiabetic, anti-inflammatory, antitumor antioxidant,	0.583	1.867

					Essential oils: camphor, 1,8-cineole, α-pinene, borneol, camphene, β-pinene and limonene (Andrade *et al.* 2018, Kompelly *et al.* 2019)	analgesic, anti-infectious, antidepressant, neuroprotective, cholinergic, antiproliferative, hepatoprotectivity (Andrade *et al.* 2018, Kompelly *et al.* 2019)		
Lamiaceae	*Thymus* sp.	Ziitra	TRH15	Aerial parts	thymol, p-cymene, caryophyllene, α-pinene, β-myrcene, thymyl methyl ether, carvacrol, β-pinene, α-cadinol and 3-carene (Al-Maqtari *et al.* 2011)	Anti-inflammatory, antibacterial, antiviral, antioxidant (Prasanth Reddy *et al.* 2014)	0.500	1.550
Lauraceae	*Cinnamomum cassia* (Nees & T. Nees) J. Presl.	Lkarfa	TRH22	Bark	Hydrocinnamaldehyde, Benzaldehyde, 3-Phenylpropyl Acetate, N-Heptadecane, 2-Hexadecanone (Ranasinghe *et al.* 2013)	Antimicrobial, antiparasitic, antioxidant, effects on blood pressure, glycaemic control and lipids (Ranasinghe *et al.* 2013)	1.000	2.967
Lauraceae	*Laurus nobilis* L.	Asayt Sidna Moussa	TRH32	Leaves	1, 8-cineole, α-pinene, β- pinene, sabinene, limonene and linalool (Chahal *et al.* 2017a).	Antiviral, antibacterial, antifungal,wound healing, neuroprotective, antioxidant, antiulcerogenic, anticonvulsant, antimutagenic, anticholinergic (Patrakar *et al.* 2012).	0.883	1.333
Linaceae	*Linum usitatissimum* L.	Zriaat alkattane	TRH06	Seeds	Linolenic acid, linoleic acid, lignans, cyclic peptides, polysaccharides, alkaloids, cyanogenic glycosides (Shim *et al.* 2014)	Antioxidant, cardio-protective, laxative and protective effects on digestive health (Shim *et al.* 2014)	0.450	0.500
Lythraceae	*Punica granatum* L.	Rman	TRH48	Flowers	Luteolin, naringenin, kaempferol, quercetin, naringenin, caumestrol,	Antioxidant, anticarcinogenic, and anti-inflammatory properties,	0.750	2.317

					ellagic acid and gallic acid (Shaygannia *et al.* 2016)	treatment and prevention of cancer, cardiovascular disease, diabetes, dental conditions, erectile dysfunction, bacterial infections and antibiotic resistance, and ultraviolet radiation-induced skin damage, brain ischemia, male infertility, Alzheimer's disease, arthritis, and obesity (Jurenka 2008)		
Myristicaceae	*Myristica fragrans* Houtt.	Lgouza	TRH39	Seeds	Macelignan, meso-dihydroguaiaretic acid, myristicin and malabaricone C (Ha *et al.* 2020)	Anti-infammatory, analgesic, antioxidant, Antibacterial, antifungal, Anti-obesity, antidiabetic, Anticancer and chemopreventive activity, Hepatoprotective, Cardioprotective and Neuropharmacologic efects (Ha *et al.* 2020)	1.000	2.000
Myrtaceae	*Pimenta officinalis* (L.) Merr.	Nwiwira	TRH55	Seeds	Gallic acid, eugenol, 1,8-cineole, α-humulene, β-caryophyllene and cadinic derivatives (Premachandran & Murthy 2022)	Antihyperlipidemic, antibacterial and antioxidant activity (Sandigawad 2010, Shyamala *et al.* 2005)	0.833	2.033
Myrtaceae	*Syzygium aromaticum* (L.) Merr. & L.M.Perry	Lqronfil	TRH07	Flower bud	Eugenol, eugenyl acetate, β-caryophyllene (Mittal *et al.* 2014)	Antibacterial, antifungal, antioxidant, anticarcinogenic, analgesic, anti-inflammatory, antithrombotic, anesthetic (Mittal *et al.* 2014)	0.950	2.567
Oleaceae	*Fraxinus angustifolia* Vahl.	Taslent	TRH20	Fruits	Esculetin, esculin, fraxin, and fraxetin (Sarfraz *et al.* 2017)	Anticancer, anti-inflammatory, antioxidant,	0.667	1.267

						antimicrobial, neuroprotective, hepatoprotective, antiallergic, skin regenerating and diuretic (Sarfraz *et al.* 2017)		
Oleaceae	*Fraxinus excelsior* L.	Lsan Attir	TRH31	Seeds	Ligstroside, formoside and oleoacteoside (Kołtun-Jasion *et al.* 2023)	Antioxidant, analgesic, antipyretic, anti-rheumatic, anti-inflammatory and hypoglycaemic activity (Kołtun-Jasion *et al.* 2023)	0.683	1.617
Pedaliaceae	*Sesamum indicum* L.	Zenjlane	TRH14	Seeds	Lignan : Sesamol (Miraj & Kiani 2016)	Antidiabetic, anticancer, antioxidant, cardioprotective, neuroprotective, anti-inflammatory, hepatoprotective, nephroprotective, wound healing, antimicrobial, antifungal, antibacterial, profertility potential, antinociceptive activity (Mili *et al.* 2021)	0.067	0.100
Piperaceae	*Piper cubeba* L.f.	Lkbbaba	TRH10	Seeds	Piperine Essential oils: Sabinene, β-elemene, cubebol, (-)-cubebin and (-)-hinokinin (Kumar 2021)	antimicrobial, anti-inflammatory, antibacterial, antioxidant, anti-cancerous, hepatoprotective, nephroprotective and antileishmanial activity (Kumar 2021)	0.917	2.583
Piperaceae	*Piper nigrum* L.	Lbzar	TRH40	Seeds	Piperine, piperic acid, piperlonguminine, pellitorine, piperolein B, piperamide, piperettine, and (-)-kusunokinin (Takooree *et al.* 2019)	antimicrobial, antioxidant, anticancer, analgesic, anticonvulsant, neuroprotective, hypoglycemic,	1.000	2.500

						hypolipidemic, and anti-inflammatory activities (Takooree *et al.* 2019)		
Piperaceae	*Piper retrofractum* Vahl.	Melwi f ksatou	TRH49	Fruits	Piperine, chavicin, palmatic acid, tetrahydropiperic acid, 1-undecylenyl-3, 4- methylledioxy benzene, piperidine, N-isobutyldeka-trans-4- dienamid, and sesamin Essential oils: germacrene D, tetramethylcyclo, undec-8-ene, Ar-turmerone and benzyl benzoate (Leliqia & Wardani 2021)	antimicrobial, antioxidant, cytotoxic, analgesic, androgenic, aphrodisiac, antihyperlipidemic, antihyperuricemic, lowering leukocyte count, antileishmanial and immunostimulant effects (Leliqia & Wardani 2021)	0.683	1.900
Plumbaginaceae	*Limoniastrum guyonianum* C. & D.	Zeyyat	TRH30	Root	Gallocatechin, epigallocatechin and epigallocatechin-3-*O*-gallate (Trabelsi *et al.* 2012)	Hypoglycaemic, hypolipidemic, antioxidant and renoprotective (Benkhaed *et al.* 2022)	0.383	0.383
Poaceae	*Pennisetum typhoides* (Burm.) Stapf et Hubb.	Illane	TRH50	Seeds	Total phenolic compound and condensed tannins (Salar & Purewal 2016)	Anticancer, antioxidant, cardiovascular activity, anti-hypercholesterolemic, hypolipidemic and antidiabetic (Pei *et al.* 2022)	0.300	0.333
Ranunculaceae	*Nigella sativa* L.	Sanouge	TRH11	Seeds	Thymoquinone, thymohydroquinone, dithymoquinone, p-cymene, carvacrol, 4-terpineol, t-anethol, sesquiterpene longifolene, α-pinene and thymol (Ahmad *et al.* 2013)	Antimicrobial, antioxidant, immunomodulator, pulmonary-protective activity and anti-asthmatic effects, antidiabetic, anticancer, analgesic, anti-inflammatory, spasmolytic, bronchodilator, hepato-protective, renal protective, gastro-protective, cardiovascular activity, anti-	0.650	1.150

						schistosomiasis (Ahmad *et al.* 2013)		
Ranunculaceae	*Ranunculus bullatus* L.	Wdan Alhalouf	TRH21	Root	Glycosylated flavonoids and phenolic acid (Lemoui *et al.* 2022)	Acetylcholinesterase inhibitory, antibacterial and hemostatic properties (Lemoui *et al.* 2022)	0.283	0.383
Resedaceae	*Reseda villosa* Coss.	Sbib lakhruf	TRH27	Seeds	kaempferol 3-O-α-rhamnoside, kaempferol 7-O-β-glucoside, quercetin 3-O- α -rhamnoside, 4'-O-methylkaempferol 3-O- β -glucosyl-7-O- α-rhamnosides, 3-O- β -glucosyl-7-O- α -rhamnoside, 7-O- α -rhamnoside, quercetin-7-O- α -rhamnosyl-3-O- β -glucoside, 8-O-methylkaempferol 3-O- β-glucosyl-7-O- α -rhamnoside and kaempferol-3-O- α -rhamnosyl-7-O- α -rhamnoside (Berrehal *et al.* 2010)	Antioxidant activity (Berrehal *et al.* 2010)	0.283	0.283
Rhamnaceae	*Ziziphus lotus* L.	Nbag	TRH41	Fruits	polyphenols, cyclopeptide alkaloids, dammarane saponins, vitamins, minerals, amino acids, and polyunsaturated fatty acids (Abdoul-Azize 2016)	Antimicrobial, antifungal, anti-inflammatory, antioxidant, immunomodulatory, antidiabetic, hypoglycemic, antiulcerogenic, gastroprotective, analgesic and antispasmodic (Abdoul-Azize 2016)	0.350	0.600
Rubiaceae	*Gaillonia reboudiana* Coss. & Dur	Fessyet echikh	TRH52	whole plant	-----	-----	0.300	0.300
Rubiaceae	*Rubia peregrina L.*	Lfoua	TRH54	Root	Pseudopurpurin, rubiafolic acid, β-Sitosterol, ursolic acid (Singh & Geetanjali Chauhan 2004)	Antioxidant and antimicrobial (Özgen *et al.* 2003)	0.317	0.850
Schisandraceae	*Illicium verum* Hook. F	Badyana	TRH12	Fruits	Cis-anethole, Trans-anethole, shikimic acid, limone, α-pinene,	Antioxidant, antimicrobial, antifungal, anthelmintic,	0.450	1.417

					safrol, β-phellandrene, α-terpineol, and farneso (Patra *et al.* 2020)	insecticidal, secretolytic, antinociceptive, antiinflammatory, gastroprotective, sedative properties, expectorant and spasmolytic, and estrogenic effects (Patra *et al.* 2020)		
Solanaceae	*Capsicum frutescens* L.	Sudaniya	TRH28	Fruits	Capsaicins, dihydrocapsaicin and nordihydrocapsaicin (Batiha *et al.* 2020)	Antimicrobial, antiviral, insecticidal, anthelmintic, larvicidal effects, cardiovascular and antiinflammatory effects (Batiha *et al.* 2020)	0.667	1.117
Urticaceae	*Urtica pilulifera* L.	Hurriga mziraa	TRH51	Seeds	Lectins (Abo-elmatty *et al.* 2013)	Diuretic, antiasthmatic, anti-inflammatory, hypoglycemic, hemostatic, antidandruff and astringent (Abo-elmatty *et al.* 2013)	0.200	0.283
Zingiberaceae	*Alpinia officinarum* Hance	Khoudnjal	TRH60	Rhizome	Diarylheptanoids (Abubakar *et al.* 2018)	Angiogenesis, anticancer, antimicrobial, vasorelaxation, anti-inflammatory, antioxidant activity it is used for the treatment of cold, gynecological and musculoskeletal diseases, female sterility, rheumatism, diabetes, kidney diseases, respiratory diseases, digestive disorders (Abubakar *et al.* 2018)	0.933	3.017
Zingiberaceae	*Aframomum melegueta* K. Schum.	Lgouza Sahraouia	TRH53	Seeds	Zerumin A and (E)- labda-8(17),12-diene-15,16-dial, 3-(S)-acetyl1-(4'-hydroxy-3',5'-dimethoxyphenyl)-7-(3",4",5"trihydroxyphenyl)	Anti-inflammatory, antimicrobial, anti-allergic, anti-clotting, anti-cancer, antidiabetic, antioxidant,	0.717	1.767

					heptane, dihydrogingerenone, 6-paradol, 6-shagaol, 6-gingerol, oleanolic acid and acarbose (Yu Sheng Toh *et al.* 2019)	hepatoprotective effects (Yu Sheng Toh *et al.* 2019)		
Zingiberaceae	*Curcuma xanthorrhiza* Roxb.	Kharkoum	TRH42	Rhizome	Curcuminoids and terpenoids (Rahmat *et al.* 2021)	Antioxidant, antimicrobial, anti-inflammatory, anticancer and antitumor, antidiabetic, and skincare and hepatoprotective properties (Rahmat *et al.* 2021)	1.000	2.650
Zingiberaceae	*Elettaria cardamomum* (L.) Maton	kaakala	TRH29	Seeds	1,8-cineole, α-pinene, α-terpineol, linalool, linalyl acetate and nerolidol and the ester constituent α-terpinyl acetate (Ashokkumar *et al.* 2019)	Anti-inflammatory, analgesic, antioxidant, antimicrobial, anti-alzheimer, anti-cancer, anti-convulsant, anti-hypercholesterolemic , anti-spasmodic, anxiolytic, cardioprotective, diuretic chemopreventive, gastroprotective, hepatoprotective, immunomodulatory, sedative and stimulatory activity (Ashokkumar *et al.* 2019)	0.450	1.917
Zingiberaceae	*Zingiber officinale* Rosc.	Skinjbir	TRH13	Rhizome	gingerols, zingibain, shogaols, paradols and zingerone (Kumar Gupta & Sharma 2014). Essential oils: zingeberene, curcumene and farnesene (Kumar Gupta & Sharma 2014)	Anti-inflammatory, antimicrobial, antidiabetic, antioxidant, hepatoprotective, hypocholesterolemic, hypolipidemic, anticancer (Kumar Gupta & Sharma 2014)	1.000	2.917

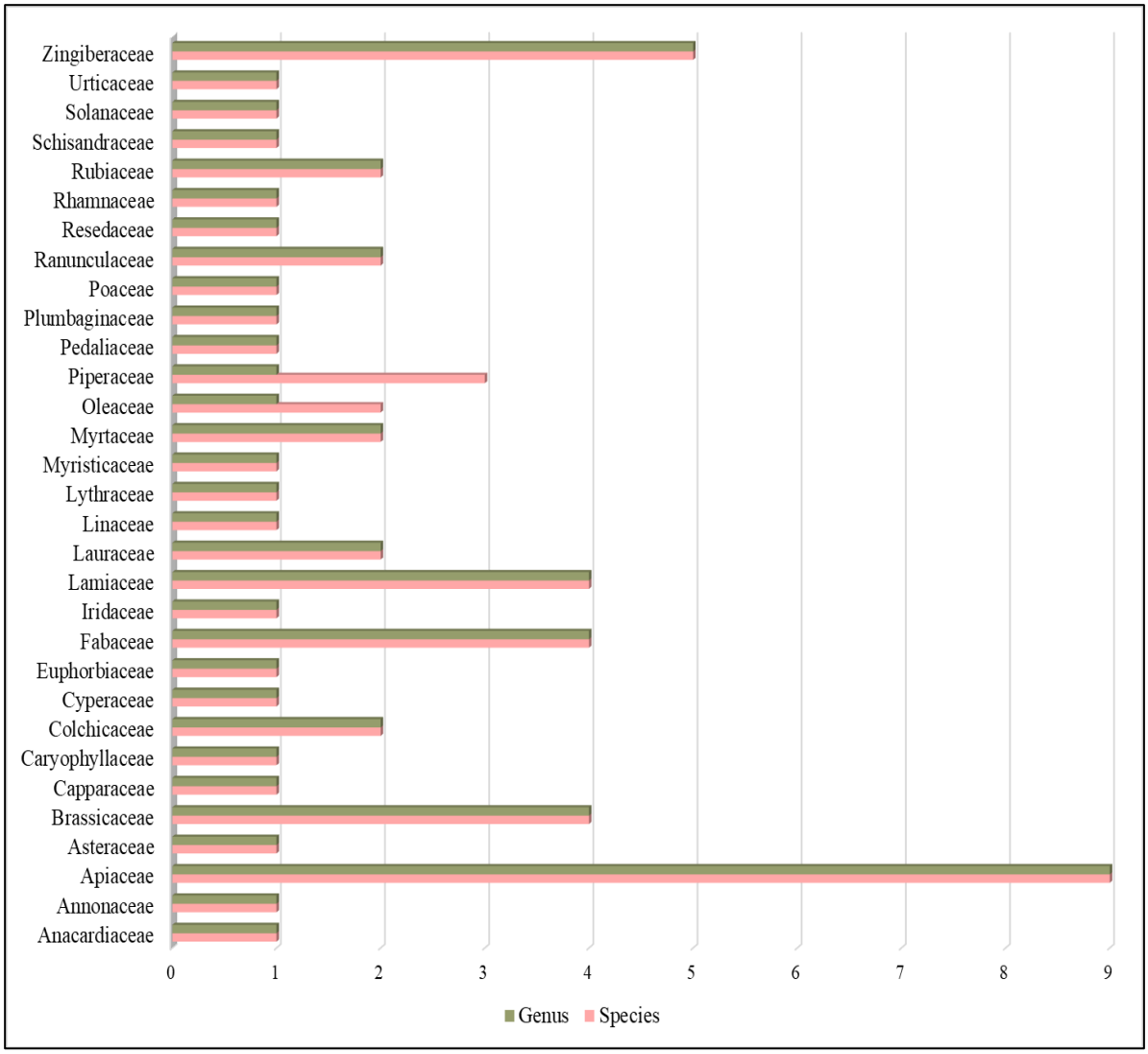

Figure 2. Specific richness of the botanical families inventoried

Table 3. Values of plant parts used in the formulation of *Ras El hanout* mixtures

Plant parts used	Plant part value (PPV)
Seeds	0,433
Fruits	0,150
Risin	0,017
Whole plant	0,083
Flower bud	0,033
Root	0,067
Bulbs	0,017
Tubers	0,017
Flowers	0,017
Stigmas	0,017
Aerial parts	0,033
leaves	0,050
Bank	0,017
Rhizome	0,050

The results of this survey revealed that the formulation of the Ras El Hanout mixture is based in particular on the use of the seeds and dried fruits of medicinal and aromatic plants rather than the leaves. This selection may be justified by culinary traditions, taste preferences and the specific aromatic characteristics sought, as well as by the expected therapeutic effects.

However, certain leaves, such as *Rosmarinus officinalis* L. and *Laurus nobilis* L., are commonly used as spices and identified for their therapeutic effects. In addition, the variety of plant parts used requires careful selection of the appropriate harvesting period for each plant part. Subterranean organs, such as roots, rhizomes and tubers, are harvested during the vegetative dormancy period, in autumn or winter, so that they are richer in active constituents (Leclerc 1999). The barks, on the other hand, are harvested before flowering, during the rising of the sap, that is, from spring to early summer. In contrast, several harvesting periods are possible for the leaves, but the best time is just before flowering (Leclerc 1999). The flowering tops or the flowers alone are picked at their full bloom or even in bud; for example, *Syzygium aromaticum* (L.) Merr. & L.M.Perry. As for the fruits, they should be harvested dry at almost full maturity, but before they detach spontaneously. Regarding seeds, they should be well-matured and have lost most of their natural moisture (Paris & Moyse 1976)

Preparation and administration Methods

The various Ras El Hanout mixtures are theriacs prepared from the different plant parts listed in table 3. These parts are dried in the shade, crushed and sieved before being mixed. They are consumed orally, in powder or infusion form, but are most often added to Moroccan dishes such as Couscous, Mrouzia, Harira (traditional soup), Rfissa, Tride, Tambselt, and Tajine.

Relative frequency of citations (RFC)

The results show that the relative frequency of citation of the species used by herbalists in the study area to formulate the *Ras El Hanout* mixture varies between 0.05 and 1 (Table 2). In fact, 10 species, representing 16.67% of the species used, have a RFC value equal to 1, namely *Carum carvi* L., *Coriandrum sativum* L., *Cuminum cyminum* L., *Foeniculum vulgare* Mill., *Pimpinella anisum* L., *Cinnamomum cassia* (Nees & T. Nees) J. Presl., *Myristica fragrans* Houtt., *Piper nigrum* L., *Curcuma xanthorrhiza* Roxb. and *Zingiber officinale* Rosc. which means that these species are considered useful and are used by all respondents to prepare the *Ras El Hanout* blend (Najem *et al.* 2022). On the other hand, *Glycine max* (L.) Merr had the lowest relative citation frequency (0.05) (Table 2), probably because this species is little known to the respondents or they do not consider it useful for the categories of use of the mixture studied (Tardio & Pardo-de Santayana 2008).

Use value of plant species (UV)

In order to assess the relative importance of the medicinal plants recommended by herbalists in the city of Meknes for the preparation of *Ras El Hanout*, the use value was calculated. This value ranged from 0.05 to 3.017 (Table 2). The species with a high potential for ethnobotanical use are *Cinnamomum cassia* (Nees & T. Nees) J. Presl. (2,967), *Coriandrum sativum* L. (2,967), *Zingiber officinale* Rosc. (2,917), *Piper cubeba* L.f. (2,583), *Cuminum cyminum* L. (2,750), *Curcuma xanthorrhiza* Roxb. (2,650), *Syzygium aromaticum* (L.) Merr. & L.M.Perry (2,567), *Foeniculum vulgare* Mill. (2,550) and *Piper nigrum* L. (2,500). A high use value reflects the importance attributed to a species by respondents due to its various virtues (Najem *et al.* 2019). On the other hand, *Glycine max* (L.) Merr. had the lowest use value (0.05) (Table 2), which can probably be explained by the fact that this plant or its virtues are little known by the respondents.

In fact, the species with the highest use values should be subjected to biochemical, pharmacological and toxicological analyses to identify the active ingredients that will be useful for aromatic or therapeutic purposes. Low-UV plants should not be ignored, to ensure that ancestral knowledge is passed on to future generations (Najem *et al.* 2021).

Use value of botanical families

The families with the highest usage values are the Zingiberaceae (2,453), followed by the Piperaceae (2,327), the Lythraceae (2,317), the Myrtaceae (2,300), the Lauraceae (2,150) and the Myristicaceae (2,000) (Table 4). Some of these families are represented by only one species each and have different use ratios, for example: 120 for the Myristicaceae and 139 for the Piperaceae. The family with the lowest use value is the Pedaliaceae (0.100) (Table 4).

Although certain families are well represented in terms of plants, they do not have a high use value; this is the case for the Apiaceae with 9 species and a family use value equal to 1.622, the Brassicaceae with 4 species and a family use value equal to 0.933, and also the Fabaceae with 4 species and a family use value equal to 0.77. We can therefore deduce that the ethnobotanical value of the use of families does not depend on the number of taxa, but rather on the importance and use value of these taxa. Consequently, families with a high UVF are due to their richness in secondary metabolites, which confer various virtues on them (Najem *et al.* 2021).

Table 4. Family usage values (FUV)

Family	FUV	Family	FUV
Anacardiaceae	0.167	Lythraceae	2.317
Annonaceae	0.950	Myristicaceae	2.000
Apiaceae	1.622	Myrtaceae	2.300
Asteraceae	0.333	Oleaceae	1.442
Brassicaceae	0.933	Pedaliaceae	0.100
Capparaceae	1.233	Piperaceae	2.327
Caryophyllaceae	0.617	Plumbaginaceae	0.383
Colchicaceae	0.317	Poaceae	0.333
Colchicaceae	0.867	Ranunculaceae	0.766
Cyperaceae	0.700	Resedaceae	0.283
Euphorbiaceae	0.417	Rhamnaceae	0.600
Fabaceae	0.771	Rubiaceae	0.575
Iridaceae	1.700	Schisandraceae	1.417
Lamiaceae	1.521	Solanaceae	1.117
Lauraceae	2.150	Urticaceae	0.283
Linaceae	0.500	Zingiberaceae	2.453

***Ras El Hanout* usage categories and the Informant Consensus Factor (ICF)**

To assess the consistency of the information provided by the different informants on the categories of *Ras El Hanout* use and the species used in their formulation, the informants' agreement rate was calculated. The results of the study revealed that the ICF score ranged from 0.081 to 0.711 (Table 5). The highest ICF value (ICF=0.711) was obtained for the use of Ras El Hanout as both an aphrodisiac and a tonic. The lowest value was for the use of *Ras El Hanout* to treat inflammatory diseases (ICF=0.081).

A ICF value close to 1 indicates that there is a high degree of intra-cultural consensus and agreement on the selection of taxa by the informants, in other words, most of the respondents used the same species for the same categories of use (Heinrich *et al.* 1998). Similarly, these high values highlighted the sharing of knowledge between herbalists in the study area (Najem *et al.* 2022). However, a value close to zero indicates a high degree of variation in the use of species, indicating that informants did not agree on the species used to formulate the *Ras El Hanout* mixture for a particular category of use (Heinrich *et al.* 1998).

Table 5. Informant agreement values by category of *Ras El Hanout* use in the city of Meknes, Morocco

Use categories	Nur	Nt	ICF
Spices	60	45	0.254
Digestive diseases	40	24	0.410
Inflammatory diseases	38	35	0.081
Cold-related diseases	52	46	0.118
Genital diseases	30	13	0.586
Aphrodisiac and tonic	46	14	0.711
• Nur: the number of times a particular category of use was mentioned; • Nt: the number of plants used in each category			

Classification of the spices making up the *Ras El Hanout* mixture

It is not easy to select criteria for classifying spices; they belong to different plant families, and within these families, different parts of the plant may give rise to spices (Redhead 1990). Nevertheless, it is interesting to group spices according to their organoleptic properties (color, odor, aroma and flavor), particularly in the field of gastronomy (Richard 1992).

The *Ras El Hanout* mixture, a spice theriac, is very popular in North Africa, particularly in Morocco, and is used to season traditional dishes. Its distinctive feature is its very specific flavor, due to the combination of different classes of spices. It contains spices with a hot, pungent flavor (*Capsicum frutescens* L., *Piper nigrum* L., *Zingiber officinale* Rosc. and *Brassica nigra* (L.) W.D. Koch.), spices with coloring power (*Crocus sativus* L. and *Curcuma xanthorrhiza* Roxb.), spices with lemony terpenic notes (*Coriandrum sativum* L.), spices with a warm spicy note (*Cuminum cyminum* L., *Cinnamomum cassia* (Nees &

T. Nees) J. Presl., *Carum carvi* L., *Anethum graveolens* L. and *Trigonella foenum-graecum* L.), spices with a phenolic odor (*Cinnamomum cassia* (Nees & T. Nees) J. Presl., *Pimenta officinalis* (L.) Merr. and *Syzygium aromaticum* (L.) Merr. & L.M.Perry), aniseed-scented spices (*Pimpinella anisum* L.), floral-scented spices (*Coriandrum sativum* L.) and even fresh-smelling herbs (*Laurus nobilis* L., *Elettaria cardamomum* (L.) Maton and *Rosmarinus officinalis* L.) and terpenic-scented herbs (*Myristica fragrans* Houtt. and *Zingiber officinale* Rosc.) (Richard 1992). The accumulated know-how of Moroccan herbalists, particularly those in the study area, ensures the harmonisation of the different tastes and flavours of the spices making up this mixture. Used sparingly, *Ras El Hanout* adds variety and flavour to traditional Moroccan dishes, whetting the appetite and encouraging greater consumption.

Evaluation of the pharmacological activity of certain plant species in the *Ras El Hanout* mixture

In addition to the organoleptic quality of this spice blend, the medicinal plants used by herbalists to prepare *Ras El Hanout* have a wide range of medicinal and therapeutic properties. The virtues of the spices are due to their richness in secondary metabolites, known as active principles, which act directly on the body (Al-Gabbiesh *et al.* 2015).

The plants making up the *Ras El Hanout* blend contain a large number of active ingredients such as flavonoids, terpenes, saponins, tannins, coumarins, alkaloids, quinones, lipids, glycosides, steroids, essential oils and many other active ingredients (Table 2). These compounds have a wide range of biological and pharmacological activities, including antimicrobial, anti-inflammatory, analgesic, antioxidant, anticancer, antidiabetic, antiplatelet aggregation and hypotensive activities, bronchodilator, antihyperlipidemic, healing, diuretic, renoprotective, immunomodulatory, anxiolytic, antidepressant, sedative-hypnotic, anticonvulsant, gastrointestinal, estrogenic, reproductive and many others (Table 2).

The recommendation of one plant or another by the herbalists surveyed is based mainly on their accumulated experience and not on scientific evidence. Consequently, a bibliographical search was carried out using different databases in order to verify the ethnobotanical virtues attributed to this mixture.

The extract of certain plants in this blend has a positive effect on sexual function in humans and laboratory animals. For example, extracts of *Aframomum melegueta* K. Schum. significantly increase the penile erection index and the frequency of intromission and ejaculation (Kamtchouing *et al.* 2002). Similarly, the aphrodisiac efficacy of extracts of *Syzygium aromaticum* (L.) Merr. & L.M.Perry extracts has been shown to markedly increase mounting frequency, intromission frequency, erections and all penile reflexes, significantly reducing the post-ejaculatory interval (Tajuddin *et al.* 2004). These results support claims that the *Ras El Hanout* mixture containing these plants has traditionally been used to treat sexual disorders and as an aphrodisiac.

This mixture is also recommended by the herbalists surveyed to treat inflammatory diseases. Studies on the anti-inflammatory effects of *Foeniculum vulgare* Mill. have shown that this plant has inhibitory effects on acute and sub-acute inflammatory diseases and type 4 allergic reactions. It also reduces the activities of superoxide dismutase (SOD) and catalase (CAT). It significantly increases plasma levels of HDL cholesterol. On the other hand, it reduces levels of malondialdehyde (MDA), a marker of lipid peroxidation. These results demonstrate the effectiveness of *Foeniculum vulgare* Mill. against inflammation (Kooti *et al.* 2015). Similarly, *Xylopia aethiopica* A. Rich. exhibits anti-inflammatory power, inhibiting tumour necrosis factor alpha (TNF-α) in THP-1 macrophages, and significantly reducing levels of interleukin-6 (IL-6). The plant also showed inhibitory activity against 5-lipoxygenase (5-LOX). Analysis of the phenolic compounds in *Xylopia aethiopica* A. Rich. identified eight constituents, including kaempferol-3-O-rutinoside (8), which was found to contribute significantly to anti-inflammatory effects, particularly through its action on 5-LOX (Macedo *et al.* 2020).

The efficacy of *Nigella sativa* L. and its main bioactive constituent on the tract were explored. Administration of the extract of this plant led to a reduction in the enzymatic activity of the brush border membrane in isolated vesicles. In addition, an improvement was observed in enzymatic and non-enzymatic parameters of the antioxidant defence of the intestinal mucosa (Shahid *et al.* 2018). In addition, the fruit and resin of *Pistacia atlantica* Desf. have beneficial effects on upper and lower gastrointestinal disorders. The resin is a stomach tonic and is used in cases of dyspepsia, stomach ulcers, esophagitis and gastritis. *Pistacia atlantica* Desf. has antibacterial properties against a large number of Gram-positive and Gram-negative bacteria involved in gastrointestinal diseases. Pinene, the main active component of *Pistacia atlantica* Desf., has antibacterial properties against Helicobacter pylori. Also, it has been shown that the acid fractions of *Pistacia atlantica* Desf resin have significant inhibitory effects against *Escherichia coli*, *Salmonella typhimurium*, *Bacillus cereus* (Mahjoub *et al.* 2018). These results confirm herbalists' claims about the use of *Ras El Hanout* to treat gastrointestinal disorders.

Conclusion

The ethnobotanical and ethnopharmacological survey carried out among herbalists in the city of Meknes, as part of the project to promote *Ras El Hanout* theriac, revealed the importance of this mixture, as evidenced by the fact that all the herbalists surveyed knew about it and recommended it. As well as improving the taste and flavour of traditional dishes, the *Ras El Hanout* mixture can be considered a source of useful substances for human health. In fact, it is frequently recommended by herbalists in the study area for the treatment and prevention of a number of illnesses, such as cold-related disorders and sexual and reproductive dysfunctions. The results revealed that there is no standard composition for this blend, and that the plants that make up the mixture differ depending on the herbalist and the intended purpose and may include up to 60 species. The most frequently cited spices in this blend are *Carum carvi* L., *Coriandrum sativum* L., *Cuminum cyminum* L., *Foeniculum vulgare* Mill., *Pimpinella anisum* L., *Cinnamomum cassia* (Nees & T. Nees) J. Presl., *Myristica fragrans* Houtt., *Piper nigrum* L., *Curcuma xanthorrhiza* Roxb. and *Zingiber officinale* Rosc.

The plants in this blend are renowned for their flavour and therapeutic properties, and their innumerable benefits are due to the diversity of secondary metabolites they contain and their wide range of pharmacological and medicinal properties. We can therefore assume that spices, both in cooking and in the field of health, have not yet revealed all their benefits or sometimes their harms, so this work may present an avenue for scientific research in the field of pharmacology, biochemistry and toxicology.

In addition, the *Ras El Hanout* mixture is a traditional ancestral socio-cultural heritage. As such, this work is a written record of the ingredients of this mixture and its ethnomedicinal use, which will help to preserve the traditional knowledge of local herbalists and ensure that these traditional practices are passed on from one generation to the next.

Declarations

List of abbreviations: Not applicable.

Ethics approval and consent to participate: All participants gave their prior consent knowing the reason for the study.

Consent for publication: Oral permission was taken from all participants.

Availability of data and materials: The data was not deposited in public repositories.

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