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Medicinal and aromatic plants traditionally used to treat metabolic diseases in the Rabat region, Morocco

Chaimae EL KOURCHI [1], Oumayma BELHOUSSAINE [1], Hicham HARHAR [1], Abdelhakim BOUYAHYA [2*], Vijay KOTRA [3], Inayat Ur REHMAN [4], Long Chiau MING [5], Pei Lin LUA[6], Mohamed TABYAOUI [1]

1 Department of Chemistry, Faculty of Sciences, Mohammed V University, Rabat, Morocco
2 Department of Biology, Faculty of Sciences, Mohammed V University, Rabat, Morocco
3 Faculty of Pharmacy, Quest International University, Ipoh, Malaysia
4 Department of Pharmacy, Abdul Wali Khan University Mardan, Mardan, Pakistan
5 School of Medical and Life Sciences, Sunway University, Sunway City, Malaysia
6 Faculty of Pharmacy, Universiti Sultan Zainal Abidin, Terengganu, Malaysia
* Corresponding author. E-mail: a.bouyahya@um5r.ac.ma (A.B.); Tel : +212 (0) 5 37 77 18 34

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ABSTRACT: Diabetes and hyperlipidemia are major human health problems due to their high levels of mortality and morbidity. During the last decades, people affected by metabolic diseases are turning more and more to traditional medicine due to the undesirable side effects of hypoglycemic and hypolipidemic drugs. Morocco has a wide floral diversity, which offers a wide range of aromatic and medicinal plants with potential application in the nutraceutical and pharmaceutical market. In this survey, we are going to highlight the medicinal plants used traditionally by the Rabat community for the treatment of metabolic diseases like hypercholesterolemia and diabetes. A total of 475 participants were interviewed in this survey using a semi-structured questionnaire form. The results obtained were interpreted through the ethnopharmacological parameters such as UV, RFC and FUV. The results revealed 83 and 41 floristic species recorded as a remedy against diabetes and hypercholesterolemia, respectively. The most cited species are: *Olea europaea, Solanum melongena* and *Linum usitatissimum.* Leaves and seeds are the most used plant parts, while the oral administration of powder is the most common route of administration. It should also be noted that *Moringa oleifera, Stevia rebaudiana,* and *Panax ginseng* are not used by citizens but only by herbalists as anti-diabetic plants imported from outside Morocco, which implies that the people of Rabat region are not familiar with imported plants and are using the endemic and condiment species. The results of this study pave the way for phytochemical and pharmacological studies to confirm the activity of the highlighted species, and toxicological studies regarding the duration of treatment, dose and interaction with other drugs.

KEYWORDS: Medicinal plants; nutritional plant; plant mixtures; metabolic diseases; etnopharmacological survey

1. INTRODUCTION

Metabolic diseases (MD) represent one of the main sources of death, affecting millions of people each year in the world (in developed and developing countries), thus constituting a negative burden for the government and the community, besides its impact on the individual [1–3]. However, the development of MD including obesity, diabetes mellitus, and cardiovascular diseases, can be attributed to several environmental, lifestyle and epigenetic elements such as physical inactivity, smoking, lack, overconsumption or imbalance of dietary nutrients [4–7].

Diabetes is a worldwide health problem due to its high mortality and morbidity rates. It is an endocrine metabolic disease characterized by an increase (hyperglycemia) or decrease (hypoglycemia) of the blood glucose level. Diabetes is a chronic disease that can occur from a hereditary or environmental source, as well as it can increase the risk of several diseases in affected patients [8–13]. However, there are several classes of diabetes, including type 1 (insulin-dependent), type 2 (non-insulin-dependent) and gestational diabetes[9,12,14,15]. Type 1 diabetes, also called juvenile diabetes because of its constant onset in children, is characterized by a lack or total absence of insulin production due to the destruction of beta cells producing this hormone in the pancreatic islets of Langerhans[12,14,16]. This type of diabetes represents only 5-10% of

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cases while type 2 diabetes affects the majority of diabetics (90-95%). These diabetic patients do not need insulin from an external source, but they just need to follow a balanced diet, moderate physical exercise and take hypoglycemic and hypolipidemic drugs[12,14,17]. Whereas, gestational diabetes (GD) represents hyperglycemia first detected during pregnancy [18]. GD is linked not only to perinatal morbidity[19], but also to an increased risk of diabetes and cardiovascular disease in later life [20,21] and obesity in children[22].

Dyslipidemia is a disorder in the metabolism of lipids [cholesterol, low-density lipoprotein cholesterol (LDL), high-density lipoprotein (HDL) and triglycerides]. This alteration can result from diet, tobacco exposure, autosomal mutations in LDL receptors that result in elevated LDL cholesterol levels, which can conduct to the development of cardiovascular disease [23,24]. Previous studies conducted in Morocco on the prevalence and risk factors of type 2 diabetes (T2) revealed a group of significant risk factors for chronic complications of T2 in Moroccan patients such as increased duration of diabetes, insulin use, lack of regular exercise, hypertension, hypolipidemic treatment, elevated serum creatinine and elevated low-density lipoprotein cholesterol[25,26].Therefore, because of the difficulty to maintain changes in the way of life, and of the undesirable secondary effects of drugs namely hepatotoxicity and myopathy, people are turning more towards herbal cure as an alternative to manage metabolic diseases. To this end, several studies have reported on the physiological modifications by primary and secondary metabolites contained in functional foods on metabolic diseases, *via* metabolomic analysis [6,27]. These functional foods derive largely from microorganisms, animals, and plants. They encompass a nutrient ratio beneficial to human health and capable of reducing many diseases [28,29]. One example is given by tea polyphenols (*Camellia sinensis* (L.) Kuntze) that reduced level of blood sugar, total cholesterol and LDL-cholesterol [30]. In addition to its rich flavor, coffee (*Coffea arabica* L.) also boasts polyphenols that are known to reduce hyperglycemia, obesity, and the risk of cardiovascular disease [31,32]. Anthocyanins, flavonoids, and resveratrol contained in many fruits and vegetable help to prevent degenerative diseases such as diabetes, hyperlipidemia, hypertension, obesity, and cancer [33–36]. Polyphenols of pomegranate (*Punica granatum* L.) such as ellagitannins and anthocyanins are responsible for hypoglycemic and hypocholesterolemic effects [37].

African health systems have relied on the traditional medicine approach for about two centuries, allowing about 70-80% of patients to be treated with the so-called complementary and alternative medicine [38–40]. According to the statistics yearbook of Morocco published by the High Commission for Planning in 2020, The region has a remarkable floristic richness where natural forest species occupy an area of 355,999 ha, distributed among the different provinces of the region, including natural deciduous species that mark the first place in terms of area (173,357 ha), followed by the matorral type (75,064 ha), then the natural resinous species (66,082 ha). Thus, the natural hardwood species include a specific richness grouping *Quercus suber* L. (133 867 ha), *Quercus ilex* L. (69 918 ha) and *Quercus canariensis* Willd. (239 ha) with the absence of the argan tree (*Argania spinosa* L.) in the region. However, natural resinous species in the Rabat region are limited to *Pinus atlantica* Endl. (65,522 ha) and *Juniperus phoenicea* L. (560 ha). In terms of cultivated area, Morocco has experienced a decline in the cultivation of cereals, where the region of Rabat produces 12,603.3 thousand quintals on an area of 526.4 thousand hectares with the dominance of soft wheat and barley, and occupies the 2nd rank after the region of Fez. In addition, the cultivation of pulses in this region is in continuous evolution, including the cultivation of chickpea and lentils (318.4 and 225.9 Mq). On the other hand, the region has experienced an evolution in the production of sugar and oilseed crops.

Given the enormous popularity of this healing system based on the use of medicinal and aromatic plants, it is important to shed light on the risk from the combination of several plants in a recipe or their interactions with conventional medicines. Therefore, the main objective of this study is to bring together all the achievements and knowledge of citizens and herbalists in the region of Rabat, Morocco, through an ethnopharmacological survey form established in two forms (online and in the field) allowing the recording of the floristic species used by this community for the treatment of metabolic diseases such as diabetes and hyperlipidemia.

2. RESULTS

2.1. Population based profile

This survey involved interviewing a total of 475 participants, including 20 herbalists and traditional healers who were questioned in their stores about the two treated diseases, and 455 people who contributed to the success of this online survey, with 241 and 214 people interviewed about diabetes and hyperlipidemia, respectively.

2.1.1. Herbal practitioners

A total of 20 herbalists were interviewed during the survey in their herbal stores (Table 1).

Table 1. Socio-demographic profile of traditional healers.

Traditional healers	Percentages %
Age	
<20	---
[20-40]	40
[40-60]	50
>60	10
Gender	
Female	5
Male	95
Level study	
Illiterate	5
Primary	45
Secondary	50
University	---
City	
Rabat	50
Temara	25
Salé	10
Kénitra	---
Years' experience	
[5-9]	30
[10-20]	60
>20	10
Origin of information	
Hereditary	63.2
Experience	36.8

The socio-demographic profile of the herbalists showed that all the traditional healers were men; this was due to the fact that in this region, only male traditional healers were listed, as well as women who may not have any encouragement to practice this job especially outside their environment (home and family). However, the age of the participants varies from 20 to 60 years old. The most represented age group was 40-60 years old (50%), followed by 20-40 years old (40%), then 60 years old and above (10%) while the age group under 20 years old was absent. On the basis of experience, 60% of the herbalists had between 10 and 20 years of experience, while 30% of the respondents had between 5 and 9 years, while 10% had more than 20 years of experience (Table 1). The majority of the herbalists had a secondary and primary level of education, with 5% being illiterate. In addition, 63.2% of the informants had knowledge inherited from their families, and 36.8% of the participants based their knowledge on experience gained since they started this work. However, the majority of the traditional healers were accompanied by their parents who have more experience in this field and from where their heritage came.

2.1.2. Local population

A total of 455 informants were interviewed and classified into different demographic categories, as shown in Table 2.

Table 2. Socio-demographic profile of online respondents.

Informant	Diabetes	Hypercholesterolemia
	%	%
Age		
<20	1.7	2.8
[20-40]	62.3	73,8
[40-60]	23.3	19.2
>60	12.7	4.2
Gender		
Men	35.6	31.8
Female	64.4	68.2
Level study		
Illiterate	5.5	3.3
Primary	6.4	1.9
Secondary	11.4	5.1
University	76.7	89.7
City		
Rabat	36	38.3
Témara	12.7	20.1
Salé	36	30.4
Kénitra	5.3	4.2
Khemisset	10	7
Origin of information		
Hereditary	14.4	13.4
Reading	27.2	43.3
Social initiation	52	37.3
Divine revelation	5.6	6
Are you suffering from the disease?		
Yes	19.9	14
No	80.1	86

Generally, the socio-demographic characteristics of the informants appear to be the same in both therapeutic categories. The age group varies from 20 to 60 years. The most representative age range is 20 to 40 years and this may be due to the increased use of online communication by this age group. However, women showed more knowledge in the field of herbal medicine. Thus, the knowledge of the respondents seems to be more argued with their university study levels and the origin of the information and this can be explained by the knowledge of the Moroccan populations regarding the socio-economic level and the knowledge acquired by the ancestors. The majority of the speakers belonged to the following cities: Rabat followed by Salé, then Temara.

In this study, we remarked that women frequently used more (69%) medicinal plants than men (31%). This trend has been observed in other ethnobotanical and ethnopharmacological studies at the regional scale [41–43], as well as at the national scale [40,44–47]. This preponderance of women in the field of herbal medicine can be explained by the fact that they take responsibility within their homes to take care of their families in terms of their health but with means that are available, effective, and less expensive, in line with the knowledge and tricks of Moroccan cooking based on the use of aromatic plants.

2.2. Floristic profile of food and medicinal plants

Morocco, has a remarkable floristic richness due to its geographical position and encompasses about 4500 native species which make it among the richest countries floristically at the scale of the Mediterranean basin [48]. Likewise, the studied area offers a wide ecological diversity characterized by a vast subterranean

forest which in turn presents a very diverse range in terms of aromatic and medicinal plants which provides the citizen of the region with an awareness all around the world of traditional medicine. However, this tradition must be scientifically approved by further studies.

The results obtained inventoried about 98 medicinal plants for the managing of diabetes and hyperlipidemia in the region of Rabat and are presented in Table 3.

The ethnobotanical survey disclosed the presence of 98 floristic species divided into 43 families listed by citizens and herbalists in the region of Rabat as herbal remedies against diabetes and cholesterol. The most cited family was the Fabaceae followed by the Oleaceae and then the Lamiaceae (Figure 1).

In relation to the number of species used for treatments, the Asteraceae family is the most common, with 12 species, followed by the Lamiaceae (10 species) and Fabaceae (9 species). The Oleaceae family presents a higher number of citations with only one species (*Olea europaea*) that represents a remarkable socio-economic, cultural and agronomic resource for Morocco. Families most commonly cited in this study area are generally the major groups belonging to the nine main Moroccan families. These three families, as well as the Asteraceae, Lamiaceae, and Fabaceae, represent the most important floristic groups with medicinal plants in Rabat [115]. Geographically, the flora of Morocco is typically Mediterranean with 1441 endemic species and subspecies taxonomically distributed in 7 main families (Asteraceae, Fabaceae, Lamiaceae, Brassicaceae, Caryophyllaceae, Poaceae, Apiaceae, Scrophulariaceae) [49].

However, the climate in Morocco is undergoing a significant change, which is proving to be a hindrance for the development of the forestry and agricultural field. This change is accompanied by an increase in temperature and a decline in annual rainfall, with consequent severe drought. These have direct impacts on water resources, agriculture, human health and economy [116]. In addition to climate change, the overexploitation of natural plant resources has a direct impact on the deterioration of natural areas through the uncontrolled harvesting of plant parts.

In our study, 9 parts of plants are used in phytotherapy including leaves, seeds, fruits, aerial parts, roots, stems, flowers, bark and juice. The survey allowed to classify the plants according to their used parts among which the leaves represent the most used by the practitioners against diabetes and hyperlipidemia with a percentage of 48%, followed by the seeds (34%), the fruits (12%) and the roots (9%) (Figure 2).

While seeds and leaves are found to be preferentially used in the treatment of diabetes, roots and fruits register more uses in recipes treating hypercholesterolemia (Figure 3). This trend has been observed in previous studies reporting the increased use of leaves for treatment of diabetes [44,58,59,74,81], hypercholesterolemia [76], and treatment of diseases with medicinal plants in Morocco [40,89,107,117].

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Table 3. Medicinals and nutritional plants used to manage metabolic diseases in rabat region.

Family	Scientific name	Vernacular name	Used part	Use value	Metabolic diseases**	Moroccan literature relating to Metabolic diseases plants	Literature documented for the uses of metabolic diseases plants outside Morocco
Aloaceae	*Aloe barbadensis* Mill.	Aloe vera	L	0.061	D-Hy	Nd	[49–56]
Amaranthaceae	*Spinacia oleracea* L.	Sabanikh	L	0.018	D	[57,58]	
Anacardiaceae	*Pistacia lentiscus* L.	Drou	Fr	0.009	D	[41,57–65]	Nd
	Ammi visnaga Lam.	Bachnikha	Fr- Ap	0.018	D	[44,45,58,61,62,64,66,67]	Nd
	Coriandrum sativum L.	Kosber	S-L	0.109	D-Hy	[43,47,58,59,64,68–75]	Nd
	Cuminum cyminum L.	Kamoun	S	0.056	D-Hy	[58,59,63,64,74,76]	Nd
	Carum carvi L.	Carwiya	S	0.028	D	[45,57,59,60,64,67,68,71–74,77–80]	Nd
	Foeniculum vulgare Mill.	Nafaa	S	0.028	D	[44,45,57–60,64,67,68,70–81]	Nd
Apiaceae	*Petroselinum crispum* Mill.	Maadnouss	L- Ap	0.028	Hy	[58,59,70,72,74,78,80]	Nd
	Apium graveolens L.	Krafess	R	0.028	Hy	[58,59,70,72,78]	Nd
Araliaceae	*Panax ginseng* C.A.Mey.	Ginseng	R	0.033	D	Nd	[82]
	Artemisia herba-alba Asso.	Chih	Ap	0.123	D-Hy	[44–46,48,58,59,61–63,65,67–69,71–79,81,83–89]	[51,56,57,90,91]
	Artemisia absinthium L.	Chiba	L	0.018	D	[45,46,59–62,64,65,67,68,71–73,77–79,81,83,85]	[55,57,90,92,93]
	Arctium lappa L	Badiana	S	0.028	D		[57]
	Anacyclus pyrethrum L.	Babounj	Fl	0.004	Hy	[59,63,65]	[57]
	Dittrichia viscosa L.	Tarahla	L	0.018	D	[59,63,67,74,78,79,94]	[57]
	Stevia rebaudiana Bertoni.	Stevia	L	0.037	D	Nd	Nd
Asteraceae	*Silybum marianum* L.	Chouka hmar	L - R	0.037	D-Hy	[72]	[95]
	Cynara cardunculus L.	Qoq	L	0.061	Hy	[59,61,65,67,71,72,75–78,83]	[91]
	Taraxacum officinale L.	Pissenlit	L	0.014	Hy	[65,74]	[55,57]
	Helianthus annuus L.	Nawart chams	S	0.023	Hy	[61,65,96]	[57,93]
	Centaurea maroccana Ball.	Tafgha	St	0.028	D	[59]	
	Scolymus hispanicus L.	Guernina	L - R	0.037	D	[59,63,67,78]	[97]
Berberidaceae	*Berberis vulgaris* L.	Aghris	Fr - B	0.004	D	[59,67,72,78]	[51,57,92,93]

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	Raphanus sativus L.	Fjel	R	0.075	D-Hy	[45,58,59,65,67,71,73,78,81]	[55, 57]
	Brassica oleracea L.	Cheflour	L	0.042	Hy	[45,59,63,67,78,96]	[52,57]
Brassicaceae	*Eruca vesicaria* L.	Jarjir	L	0.004	D	[59,67,78]	Nd
	Lepidium sativum L.	Heb rchad	S	0.042	D	[44–46,48,49,59,60,65,67,72–74,77–79,81,83,98]	[56,57,91]
	Brassica rapa L.	Laft	R	0.004	D	[59,63,65,67,78,87]	Nd
Cactaceae	*Opuntia ficus indica* Mill.	Handiya	St	0.047	D	[45,58–60,63,65,71,73,74,77,81,85,98,99]	[53,57,91,100]
Capparacaeae	*Capparis spinosa* L.	Kebbar	Fr	0.004	D	[45,46,59–63,65–68,77–79,81,83–85,101]	[51,56,57,94]
Cistaceae	*Cistus salviifolius* L.	Irgel	Fl	0.009	D	[58–60,65,67]	Nd
Curcubitaceae	*Cucurbita pepo* L.	Geraa khedra	S	0.033	D-Hy	[59,62,63,96,102]	[55,91]
Cupressaceae	*Juniperus phoenicea.*L.	Araar	L	0.037	D-Hy	[45,46,48,59,63,65,67,71,72,77,78,81,83,86,88,101,102]	[51,56,57]
Euphorbiaceae	*Euphorbia officinarum* L.	Daghmouss	St-L	0.090	D	[58,63,65,67,72,74,75,78–80,84,85,96,98]	[55,56]
Ericaceae	*Vaccinium myrtillus* L.	Oleik	Fr	0.004	D	Nd	[103]
	Arbutus unedo L.	Bakhnou	L- Fr	0.014	D	[45,62,63,65,67,68,74,78,79,81]	Nd
	Trigonella foenum-graecum L.	Halba	S	0.374	D-Hy	[42,45,46,48,58–63,65,67,68,70–81,83–86,88,94,98,99]	[51,55,56,90,92,95,104,105]
	Lupinus albus L.	Tirms / Foul gnawa	S	0.099	D	[45,46,48,59,61,65,67,73,74,78,79,83,85,86,102]	[56,57]
	Glycine max (L.) Merr.	Soja	S	0.033	D-Hy	[45,58,65,67,71,73,74,77,78,80,81]	Nd
	Glycyrrhiza glabra L.	Aarq souss	R	0.009	D-Hy	[44,59,60,65,67,76,78]	[56,93]
Fabaceae	*Ceratonia siliqua* L.	Kharoub	S – L	0.014	D	[44,58–60,65,67,71,73–76,78,81]	[91,106]
	Senna alexandrina Mill.	Senameki	L	0.004	D	Nd	Nd
	Cicer arietanum L.	Homes	S	0.004	D	[59,67,73,78,81]	[105]
	Medicago sativa L.	Fessa	L	0.004	D	[59,63,67,71,75,78,81,88]	Nd
	Arachis hypogaea L.	Kawkaw	S	0.004	D	[59]	Nd
Gentianaceae	*Centaurium erythraea Rafn.*	Guesset haya	Fl	0.028	D	[45,59,61–65,67,72,74,78,79,94,107]	[57,91,97]
Juglandaceae	*Juglans reiga* L.	Gargaa	S	0.014	Hy	[45,48,59,60,63,65,67,68,70,72,76,78,86]	[93,95,97,103,108,109]
	Salvia officinalis L.	Salmiya	L – Ap	0.194	D-Hy	[44,46,48,58–60,62,63,65,67–69,71–81,83–86,89,94,96,98,99]	[56,57,91]
	Salvia hispanica L.	Chia	S	0.014	D	Nd	Nd
	Origanum compactum Benth.	Zaatar	L – Ap	0.085	D-Hy	[42,44–46,48,59,61,63–65,67–69,72,73,78,79]	[57]
	Thymus vulgaris L.	Zaitra	L – Ap	0.028	D	[44,46,48,59,63,67,71–73,76–79,84,98]	[56,90]
	Marrubium vulgare L.	Merriwt	L – Ap	0.052	D	[42,44–46,48,58–60,62,63,65,67–75,77–79,81,83–86,89,94,96]	[51,56,57,91]
	Rosmarinus officinalis L.	Azir	L – Ap	0.085	D-Hy	[44–46,59,60,62–65,67,68,71–74,76–79,83,89,96,98,102]	[56,57,90,91,97]

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Lamiaceae	*Ocimum basilicum* L.	Lahbeq	L	0.009	D	[59,63,72]	[53,57,97]
	Mentha officinalis L.	Naanaa	L – Ap	0.018	D-Hy	[46]	Nd
	Lavandula angustifolia L.	Khezama	L	0.018	D	[45,58,59,64,65,71,72,77,78,89,98]	[57]
	Origanum majorana L.	Merdedouch	L	0.014	D	[59,72,75,77,79]	[57]
	Cinnamomum cassia Blume	Qarfa	B	0.175	D-Hy	[46,59,61,63,65,67,73,76,78,83,94]	[56,57,91,95]
	Persea americana Mill.	Avocat	Fr-L	0.009	D	[59,60,65,72,83,85]	[52,54,100,110]
Lauraceae	*Laurus nobilis* L.	Rand	L	0.037	D-Hy	[59,60,67,78]	[57]
	Nerium oleander L.	Defla	L	0.004	D	[45,46,48,59,61–64,67–69,71,74,75,77–81,83,87,99]	[51,57]
Liliaceae	*Allium cepa L.*	Basla	R	0.004	D	[44–46,48,59,60,62–65,67,71–73,76,77,81,83,85,98]	[50,52,54–57,95,104,105,111]
	Allium sativum L.	Toma	R	0.085	D-Hy	[45,46,58–60,63,65,67,68,71,72,75,76,78,79,81,83,89,94,98]	[50,53–56,91,95,97,104,105,111,112]
Linaceae	*Linum usitatissimum* L.	Zariat ketan	S	0.322	D-Hy	[44,46,59,60,63,65,67,76,78,79,96,98,99,102]	Nd
Lithraceae	*Punica granatum* L.	Roman	Fr-L	0.004	D	[46,58–61,63–65,67,72,73,77,78,80]	[50,56,57,91,97,100]
Malvaceae	*Hibiscus sabdariffa* L.	Karkadil	L	0.009	D	[59,67,78]	Nd
	Eucalyptus globulus L.	Eucalyptus	L	0.104	D	[45,46,59,62–65,71,73,74,77,80,81]	[56,57,78,111]
Myrtaceae	*Eugenia caryophyllata*	Qronfel	L-Fl	0.004	D	[44,45,62,65,67,74,78,81,83]	Nd
	Morus alba L.	Toute	L	0.009	D	[59,63,65,83,96,102]	[50,54,55,97]
Moraceae	*Ficus carica* L.	Kermouss	L	0.014	D-Hy	[45,58–60,63,65,67,68,73,74,77,78,80,81,96,98,102]	[55,57,91,100]
Moringaceae	*Moringa oleifera* Lam.	Moringa	L	0.014	D	Nd	[54,55,100,104]
Oleaceae	*Olea europea* L.	Zaytoun	L	0.521	D-Hy	[44,46,48,58–62,64,65,67,68,70–81,83,85–87,89,98,99,113]	[53,55–57,90,91,97,106]
Poaceae	*Avena sativa* L.	Choufan	S	0.009	D	[59,63,76,78,79]	[95]
	Triticum durum Desf.	Zraa	S	0.004	D	[59,61,65,67,78]	Nd
	Hordeum vulgare L.	Cheir	S	0.037	D	[59–61,64,65,67,71,78,86,98]	[56,105]
	Lolium perenne L.	Zouane	S	0.023	D	[46,59,67,71,72,77,78,81,85]	Nd
	Pennisetum glaucum L.	Ilane / Bachna	S	0.104	D-Hy	[59,71,78]	Nd
	Zea mays L.	Dera	S	0.004	Hy	[59,60,62,65,76,81]	[54,55,104]
	Stipa tenacissima L.	Halfa	Ap	0.004	Hy	[61]	Nd
Plantaginaceae	*Plantago ovata* Forsk.	Katona	S	0.004	D	[81]	Nd
Portulacaceae	*Portulaca oleracea* L.	Rejla	L	0.075	Hy	[59,65,67,71,78,101]	[93,97,108]
Ranunculaceae	*Nigella sativa* L.	Sanouj	S	0.009	D	[44–46,48,59,60,62,63,65,67,68,71–75,77–79,81,83–85,89,98]	[55–57,90,91,109]
Rhamnaceae	*Ziziphus lotus* Lam.	Nbeg	S-L	0.014	D	[58–60,65,67,68,73–75,77–81,83,86,98]	[55–57]
	Prunus cerasus L.	Heb mlouk	S	0.009	D	Nd	[93,109]
	Prunus amygdalus	Louz	S	0.028	D	[58–62,65,67,68,71–74,77,78,81,86,98]	[55,57]

Rosaceae	Stokes						
	Rosa damascena Mill.	Lward beldi	Fl	0.009	Hy	Nd	[55]
Rubiaceae	*Coffea arabica* L.	Qahwa	S	0.023	D	[76]	[91]
	Citrus limon Burm.	Hamed	Fr	0.014	D-Hy	[59,60,76]	[52,55,94]
Rutaceae	*Citrus maxima* Burm.	Ranj	Fr	0.018	Hy	[59]	Nd
Salicaceae	*Salix alba* L.	Safsaf	L	0.004	D	[59,65,74,83,87]	[103]
Sapotaceae	*Argania spinosa* L.	Argane	S	0.009	D	[44,58–60,63,65,71,72,75,80]	Nd
Solanaceae	*Solanum melongena* L.	Danjal	Fr	0.227	Hy	[76]	Nd
Theaceae	*Camellia sinensis* (L.) Kuntze	Atay	L	0.028	D-Hy	[58,59,65,67,71,72,81]	[57,91]
Tiliaceae	*Tilia europea* L.	Zayzafoun	L	0.014	Hy	Nd	Nd
Urticaceae	*Urtica dioica* L.	Hariga	St – L	0.014	D	[45,58,59,61–63,65,67,68,74–77,79,81,101]	[57,91,93,95,109,114]
	Zingiber officinale Roscoe	Skinjbir	R	0.099	D-Hy	[44,59,60,62,67,72,73,75,76,78,79,83,99]	[54,56,57,91,104]
Zingiberaceae	*Curcuma longa* L.	Kharqom	R	0.066	D-Hy	[44,75,76]	[54,104]

* Used part; L: leaves, S: seeds, Fr: fruits, Ap: aerial parts, R: roots, St: stems, Fl: flowers, B: bark.
** Metabolic Diseases; D: Diabetes, Hy: Hypercholesterolemia

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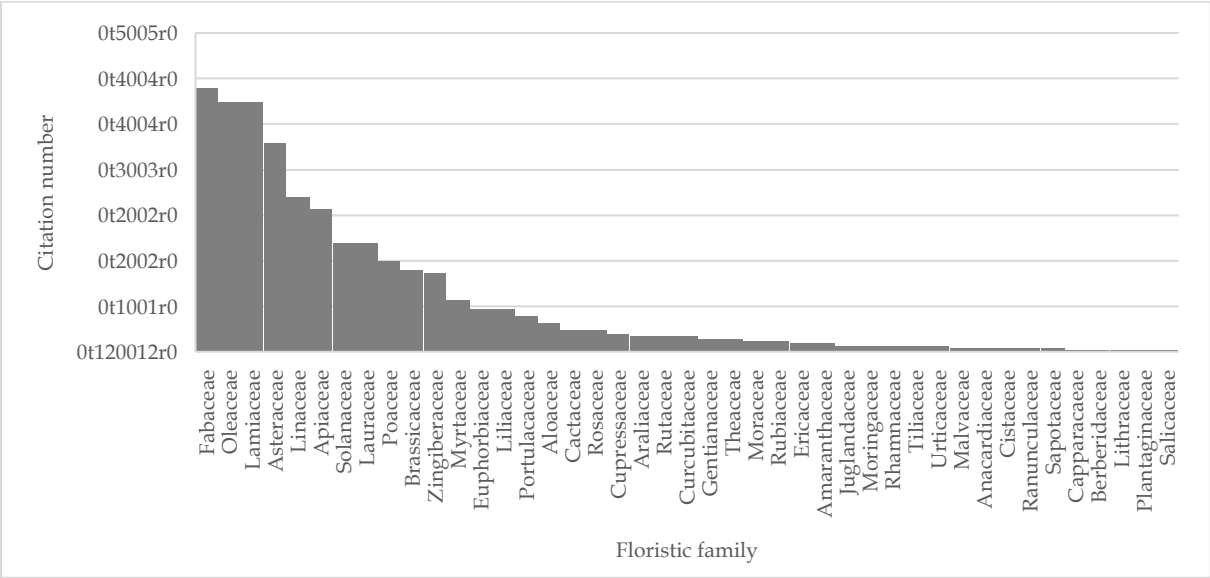

Figure 1. Number of citation of families.

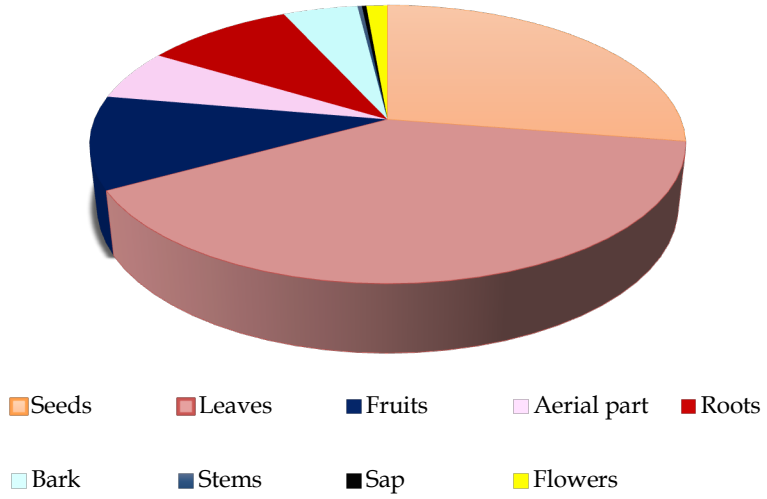

Figure 2. Used part of the listed plants.

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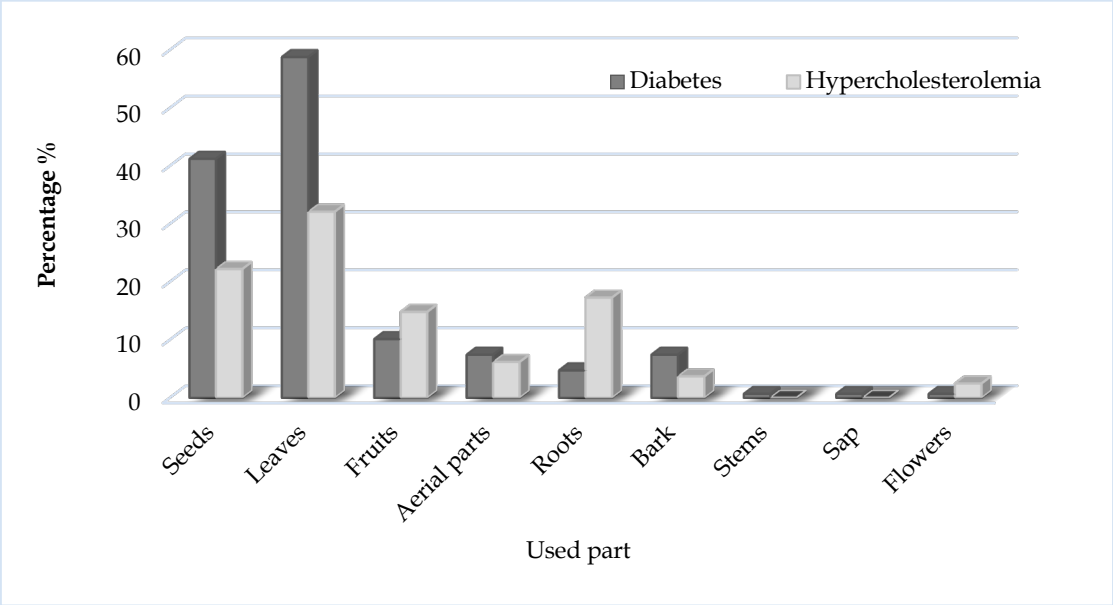

Figure 3. Used part of plants according to the use categories.

2.2.1. Floristic diversity according to use category

As previously mentioned, this survey allowed us to identify 98 plant species suggested for healing the two diseases (diabetes and hypercholesterolemia), of which 26 plants are listed to treat both diseases at the same time and 72 species are cited in the two categories of diseases divided between diabetes (57) and hypercholesterolemia (15) (Figure 4).

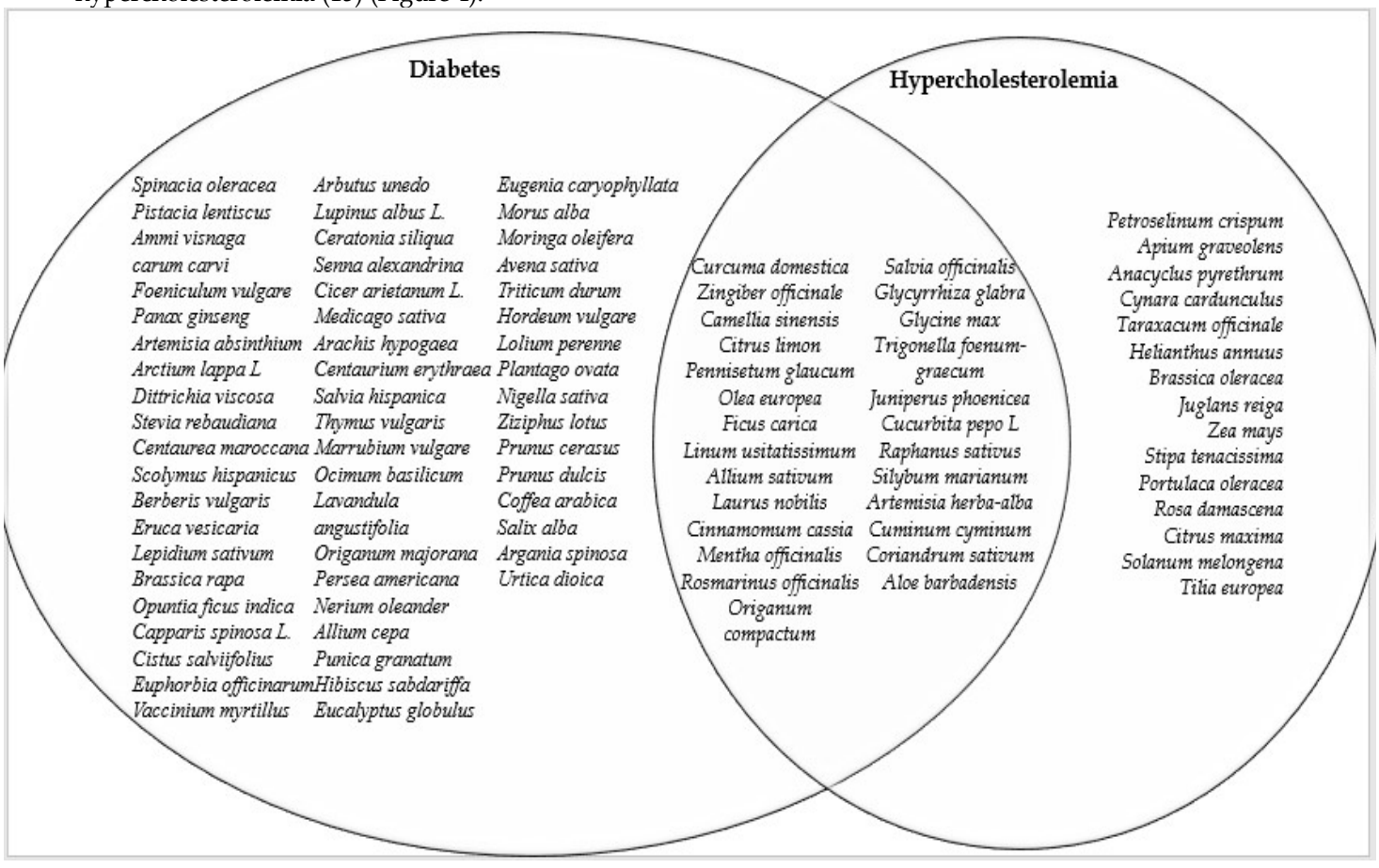

Figure 4. The plants inventoried in each category of use.

For diabetes, 83 plants were recorded, of which the most cited were: *O. europaea, T. foenum-graecum, C. cassia, A. herba-alba, S. officinalis, L. albus, C. sativum, E. officinarum, P. glaucum, and R. officinalis*. The bibliographic reports show that most of the floristic species have already been cited in other surveys [46,59,77,89].

Regarding hyperlipidemia, 41 floristic species were recorded in this survey with the dominance of *S. melongena, A. sativum, L. usitatissimum, T. foenum-graecum, C. cassia, A. herba-alba, S. officinalis, C. sativum, P. glaucum, and R. officinalis*. Most of these species have been recorded in other surveys [76].

2.2.2. Floristic diversity according to respondent's category

The increased use of these plants reflects from one hand a better efficacy of medicinal plants and from the other hand a remarkable food safety in diabetic and hypercholesterolemic patients, in the face of the lack of control of glucose and cholesterol levels and of information concerning the consequences from a long-term use.

Thus, the results obtained were analyzed according to the RFC and divided corresponding to the citation of herbalists (Figure 5) or local informants of the region (Figure 6).

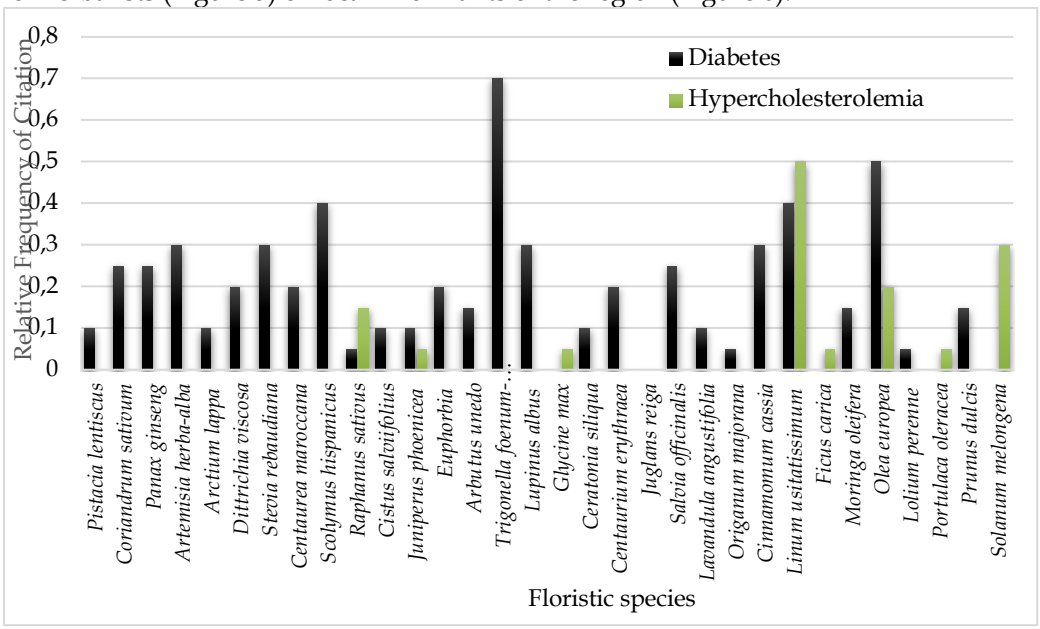

Figure 5.The relative frequency of citation of plants cited by herbalists.

Generally, the values of relative frequency of citation show a significant difference ranging from 0.004 to 0.524. However, the olive tree has the highest value, followed by fenugreek with a value of 0.374, then flaxseed with a value of 0.322 in relation to the total number of species recorded.

In total 36 medicinal species were inventoried by the selected herbalists of the region, of which the majority of plants (31) are anti-diabetic and 10 species were listed as anti-hypercholesterolemic. However, the values of the anti-diabetic plants inventoried by the herbalists ranged from 0.05 to 0.7. Among the 31 documented species, only 2 have a significant RFC, i.e., *T. foenum-graecum* (0.7) and *O. europaea* (0.5), followed by *S. hispanicus* and *L. usitatissimum* which occupy the same rank with a value of 0.4. For cholesterol, the first rank is occupied by *L. usitatissimum* (0.5), followed by *S. melongena* (0.3) and *O. europaea* (0.2). *Linum usitatissimum* keeps a strong interest for both diseases being cited in recipes by the totality of herbalists (Figure 5).

Otherwise, the information collected by the citizens of the region revealed 77 and 38 species dedicated to cure diabetes and cholesterol respectively. The RFC values of diabetes and hypercholesterolemia ranged from 0.008 to 0.661 and 0.014 to 0.626, respectively (Figure 6). Out of a total of 77 medicinal species used against diabetes, only 10 were widely cited in this survey such as *E. officinarum* and *L. albus* which scored an RFC of 0.120, similarly *C. sativum* and *A. herba-alba* (0.129), *L. usitatissimum* (0.161), *E. globulus* (0. 177), *C. cassia* (0.201), *S. officinalis* (0.241), *T. foenum-graecum* (0.438), and finally *O. europaea* which was cited by a large number of users and recorded an RFC of 0.661. While for hypercholesterolemia, the relative frequency of citation of the different plants ranged from 0.029 to 0.626. On the other hand, 14 plants scored an RFC > 0.1, including *L. nobilis* and *C. pepo* (0.104), *S. marianum, B. oleracea*, and *O. compactum* (0.119), *C. cardunculus*

(0.134), *P. glaucum* (0. 149), *C. domestica* (0.179), *O. europaea* (0.208), *P. oleracea* (0.223), *A. sativum* and *Z. officinale* (0.238), *L. usitatissimum* (0.447), and *S. melongena* which has the high-est RFC value (0.626).

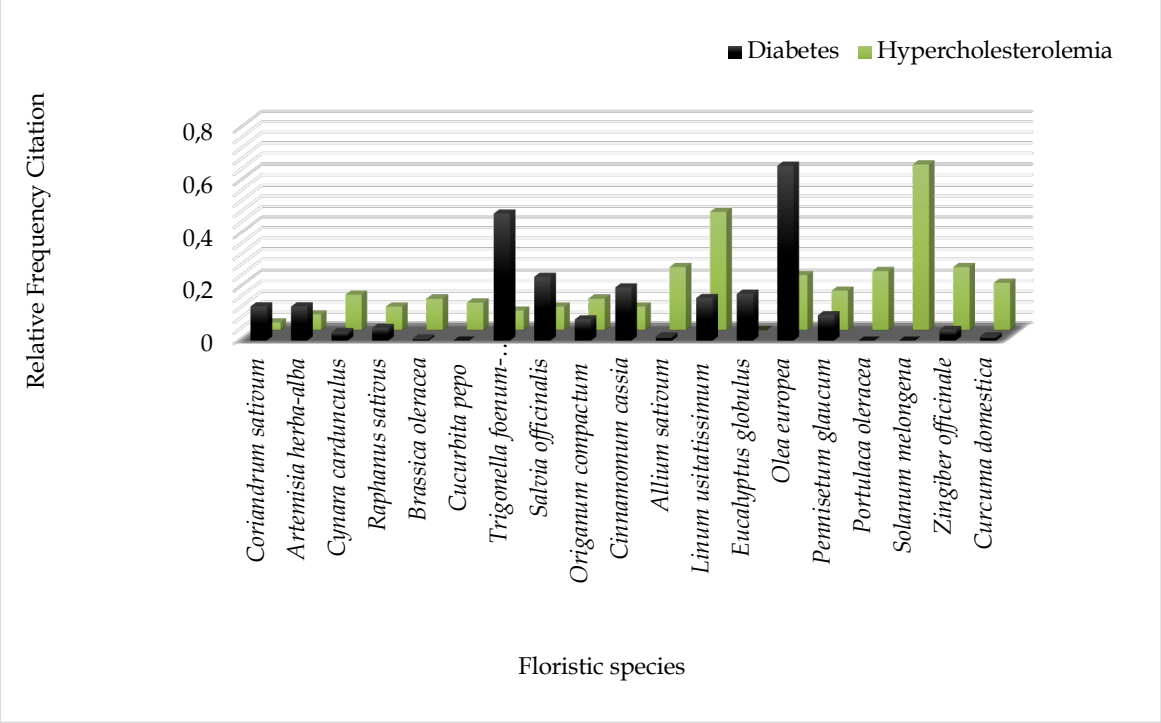

Figure 6. The relative frequency of citation of plants reported by interviewees.

Overall, the results obtained by statistical analysis show the predominance of *O. europaea* and *L. usitatissimum* as MP used in the management of metabolic diseases in the region of Rabat, and this was also demonstrated by the calculation of the family use value (FUV) (Figure 7), This study valued the two floral families Oleaceae (FUV=0.52) and Linaceae (FUV=0.32) presented by their representatives cited above.

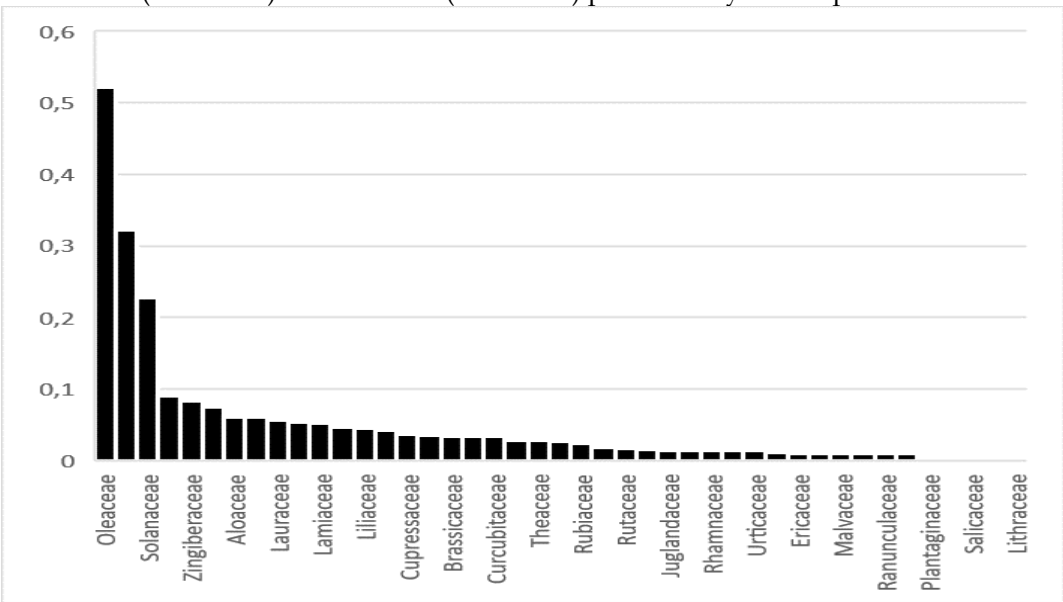

Figure 7. Diversity familial according FUV.

Olea europaea, the only representative of its floristic family and the most cited by the participants in both pathologies, is a species endemic to Morocco, and includes two cultivars: *Olea europaea* L. subsp. europaea var. europaea, the cultivated variety, and *O. europaea* subsp. europaea var. sylvestris (Mill.) Lehr., the wild or spontaneous variety [118]. In Morocco, this species is more widespread in the wild state than in the cultivated state of which it occupies an area of 1,070,000 ha in cultivated areas. The surveys established previously in Morocco have all marked the increased use of the leaves of the olive tree as an antidiabetic agent, and some have cited the leaves of this plant as anticholesterolemic unedr decoction, infusion or

powder [44,46,48,58–62,64,65,67,68,70–81,83,85–87,89,98,99,113]; similar uses are recorded outside Morocco, namely Algeria [56,57,90,91], Kenya [53], Pakistan [55] and Turkey [97,106]. The antidiabetic activity has also been experimentally proven by *in vivo* or *in vitro* studies [119–124].

Linum usitatissimum is an herbaceous plant belonging to the Linaceae family, known in Morocco as "Zariat-kettan". Due to its nutritional and phytochemical value (high fiber content, protein, phytoestrogen, flavonoids, linolenic acid), this plant is endowed with therapeutic effects [125,126]. Flaxseed has been widely used in traditional medicine to reduce inflammation and fever [88], to treat lung diseases, severe colds and coughs, as a muscle relaxant, to cure abdominal pain, as an antidiabetic and anticholesterolemic [127]. The results of our study were in agreement with those previously carried out in Morocco [44,46,59,60,63,65,67,76,78,79,96,98,99,102]. The *in vitro* activity of the polyphenolic fraction of *L. usitatissimum* showed a potent anti-diabetic activity when compared with acarbose. Its enzymatic inhibition of α-amylase is higher than that of α-glucosidase[126].

2.3. Ethnopharmacological profile

2.3.1. Preparation and administration method

In the totality of the answers, the oral administration of the medicinal plants proved to be more effective for the treatment of diabetes and hypercholesterolemia. Data analysis shows that the majority of the recipes are developed by simple grinding of medicinal plants for both pathologies, followed by decoction with a per-centage of 25 and 20%, respectively (Figure. 8). A new preparation method added to the list is the use of cooked plants for the treatment of hypercholesterolemia. Otherwise, the participants use mainly the infusion, the mixture of plants with honey, milk or vegetable oil (very often olive oil), and herbal tea in the recipes prescribed for hypercholesterolemia. However, these results prove the increased use of the different modes of preparations cited in this survey, but the majority of the questionnaires conducted in Morocco report that the decoction is the most used method.

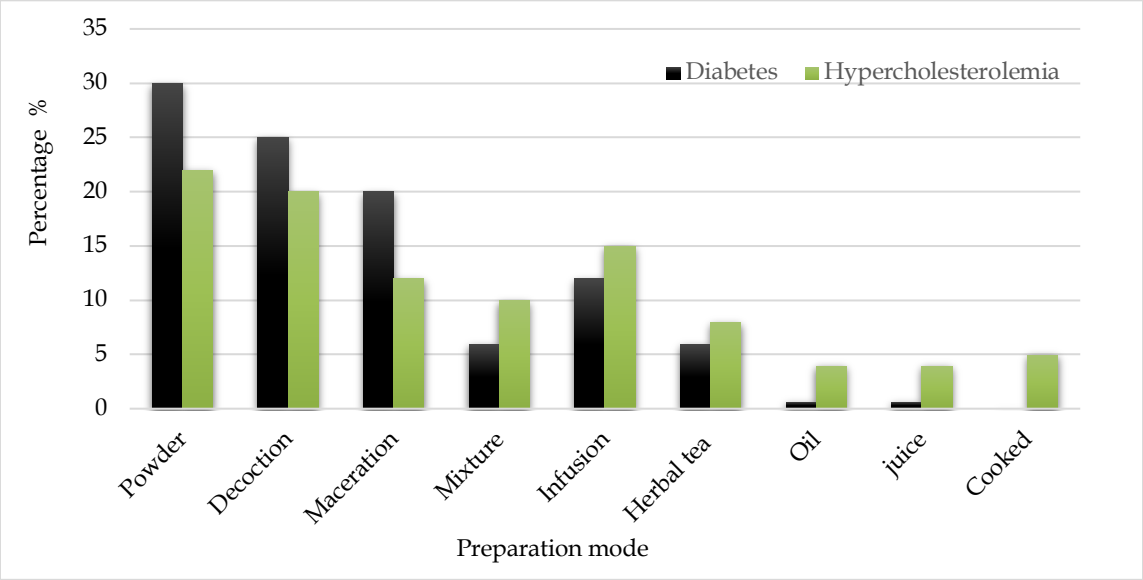

Figure 8. Preparation mode of herbal recipes.

2.3.2. Formulation of recipes

The information collected during this survey shows that all the prescribed recipes are administered orally, as well as the informants are found having an important background concerning the treatment of diabetes with medicinal plants, even if they are not affected by the disease, and this is perhaps due to the importance that this disease occupies in the Moroccan population (Table.4). Furthermore, diabetes has been estimated to affect more than 15,000 children in Morocco, with more than 2 million people in the 18-25 age group suffering from this disease without any knowledge of its mitigation.

Table 4. Traditional recipes of both diseases.

N°	Prescribed recipes
1	A mixture of barks of *Centaurea maroccana*, seeds of *Trigonella foenum-graecum* and *Ziziphus lotus*, flower bud of *Glycyrrhiza glabra* with equal portions and flavored by the leaves of *Origanum compactum* are ground into a fine powder and administered orally one teaspoon during each morning.
2	*Solanum melongena* fruits cut into slices and macerate overnight in warm water. Drinking the solution every morning is beneficial for lowering bad cholesterol.
3	Infusing half a teaspoon of *Curcuma longa* in a cup of boiling water and drinking one cup every day is beneficial for diabetes.
4	A mixture of *Juniperus phoenicea* leaves with yogurt is beneficial for diabetes
5	Powder of *Coffea arabica* flavored with the leaves of *Thymus vulgaris* administered one teaspoon before each meal.
6	A mixture of fine powder of the seeds of *Trigonella foenum-graecum*, *Coriandrum sativum*, *Carum carvi*, and *Foeniculum vulgare* with equal proportions is administered in powder form every morning.
7	A mixture of *Trigonella foenum-graecum* seed, *Cinnamomum cassia* Blume bark, *Zingiber officinale* rhizome, in powder form is macerated for one night. The macerate to which is added a few drops of *Citrus limon* is administered orally before meals.
8	A mixture of *Cinnamomum cassia* Blume bark and *Pennisetum glaucum* seeds was ground and allowed to macerate in a cup of lukewarm water for one night. The mixture was administered daily before meals and one time per day.
9	A mixture of the leaves of *Salvia officinalis*, *Olea europaea, Origanum compactum* was macerated and administered orally one time daily, before meals.

Trigonella foenum-graecum is an annual plant belonging to the Fabaceae family, known as "Halba". The seeds are widely used in Moroccan cuisine as a spice or food additive and even in traditional medicine for its carminative, expectorant, laxative effects and for treatment of digestive and mucosal ailments [128]. Various ethnobotanical and ethnopharmacological studies have identified this plant as an antidiabetic agent in [42,45,46,48,58–63,65,67,68,70–81,83–86,88,94,98,99], as well as outside Morocco [51,55,56,90,92,95,104,105]. Indeed, Inbaraj and Muniappan [129] were able to determine the correlation between *in vitro* and *in vivo* antidiabetic activity of fenugreek, the *in vitro* α-glucosidase enzyme inhibition activity showed a percentage inhibition of 68% at a concentration of 100 µg/mL near that of acarbose (94%). This result was also demonstrated *in vivo* in albino rats by the oral glucose tolerance test, which marked a significant reduction in blood glucose level after 15 min of administration.

In addition, Marmouzi et al. [130] tested the *in vitro* antidiabetic activity of the aqueous extracts of the leaves and fruits of *Z. lotus* which marked an inhibitory activity against α-amylase and α-glucosidase higher than that of conventional drugs. This shrub of the Rhamnaceae family growing in arid and semi-arid, sub-Saharan and sub-humid regions of Morocco [131], is highly cited by the Moroccan population and herbalists as a medicinal plant used in the treatment of metabolic diseases such as diabetes, hypercholesterolemia and cardiovascular diseases [58–60,65,67,68,73–75,77–81,83,86,98], and in ethnobotanical studies carried out outside Morocco [55–57]. Bencheikh et al. [115], studied the effect of an aqueous fruit extract from *Z. lotus* on plasma triglyceride, total cholesterol and HDL levels in mice exposed to a high-fat diet. Indeed, the cholesterol-lowering activity of the aqueous extract was associated with an increase in plasma HDL levels, leading to the elimination of cholesterol in the form of bile acid. Similarly, Pasha et al [132] studied the effect of an ethanolic extract of coriander on lipid parameters in diabetic rats. This study showed that oral administration of extract reduces the level of total cholesterol, triglycerides, LDL, and VLDL, which decreases the risk of cardiovascular diseases [133]. This condiment plant is endowed with several pharmacological activities namely anticancer, anti-inflammatory, neuroprotective, anxiolytic, anticonvulsant, and analgesic as a result of its richness in gallic acid, linalool [124,134–138]. Aqueous coriander extract showed higher inhibition against α-amylase and a-glucosidase compared with the standard acarbose [139].

The hexanic and methanolic extracts and essential oil of *J. phoenicea* showed a significant inhibitory activity towards α-amylase that was comparable to that of acarbose [140]. This plant of the Cupressaceae family growing in the coastal areas of the Mediterranean [141] is well known for its therapeutic effects against diarrhea, rheumatism, bronchitis, diabetes and has been recently identified as a plant used for the

prevention of Covid-19 [142] and for diabetes [45,46,48,59,63,65,67,71,72,77,78,81,83,86,88,101,102]. These surveys also cited *O. compactum* as a medicinal species treating diabetes. This endemic plant having a great history in herbal medicine as an agent treating digestive disorders, antidiabetic, antifungal, anti-inflammatory, antimutagenic and anticancer[143–145].

It is important to underline that most of the recipes prescribed by herbalists are based on a single plant, while those given by local informants are based on a formulation of more than 3 plants, which can give possible toxicity following negative interactions between these plants. Also, Mechchate et al. [146] studied the *in vivo* antidiabetic activity of a mixture of *L. usitatissimum*, *C. sativum* seeds, and the leaves of *O. europaea* var. *sylvestris* which has the effect of reducing the blood glucose level after oral administration of the combination of these three floral species in the same quantity.

3. CONCLUSION

This ethnopharmacological survey brings the first step in the branch of phytotherapy and highlights all medicinal plants used for the treatment of diabetes and hypercholesterolemia by the regional population of Rabat. The three planes (socio-demographic, floristic and pharmacological) are interconnected: the use value of each species depends on the informant profile and the category of use. Among 98 species, 57 were listed as anti-diabetic and 15 as anticholesterolemic, with 26 species presenting indications for both pathologies. The relative frequency of use emphasizes *T. foenum-graecum* and *O. europaea* in the diabetic use category, and S. melongena and L. usitatissimum in the cholesterolemic use category. The leaves represent the most used part along with the dominance of the oral consumption in the form of powder. The patients are well adapted to the use of a mixture of plants. In conclusion, this survey paves the way for phytochemical and pharmaco-logical studies which are necessary to confirm the activity of the highlighted species and toxicological stud-ies regarding their long-term use effects, and possible interaction with other drugs.

4. MATERIALS AND METHODS

4.1.Studied region

Rabat - Sale - Kenitra region covers an area of 17,570 km2, which represents 2.5% of the total area of the Morocco (RGPH, 2014). It participates in 15.2% of the national wealth. The region of Rabat-Salé-Kénitra extends over two large watersheds, namely the hydraulic basin of Bouregreg and Chaouia and the hydraulic basin of Sebou; they are in turn formed by several sub-watersheds with inputs of rainfall origin. Thus, the region is characterized by a semi-arid Mediterranean weather with a marine or continental oceanic effect (Figure 9).

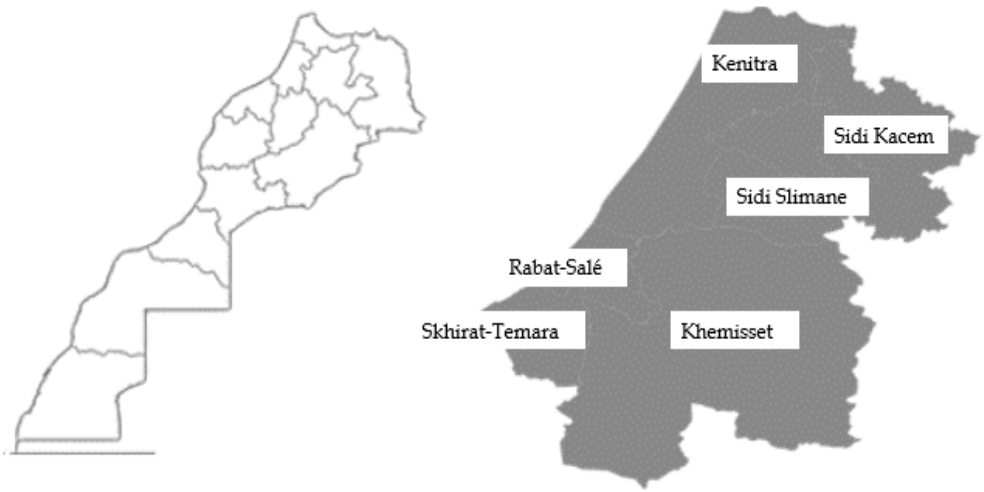

Figure 9. Study area location: Rabat-Salé-Kenitra.

4.2. Data extraction

The ethnopharmacological survey was carried out from December 2021 to May 2022. During this phase, various locations in the cities of the region were visited. The survey was conducted by using two methods: one online using the platform "Google Forms" and social networks "Facebook" and "WhatsApp",

and the other in the field by conducting interviews with different traditional healers with experience in the management of metabolic diseases types diabetes and hyperlipidemia.

Data extraction was conducted based on informants following the written and online interview form. During the interview, 241 informants participated in the diabetes survey, 214 in the cholesterol survey. As well as, 20 traditional herbalists were randomly selected in the region of Rabat and were invited to answer questionnaire fixed on different axes allowing to collect the maximum of information. This included a socio-demographic section, a floristic section which summarizes the used floristic species, part of the plant, and a pharmacological section detailing the method of plant extraction, the mode of administration, the duration of the treatment and the related illness.

4.3.Statistical analysis

The results obtained from the interview form were interpreted using a quantifiable approach combining the use value of each species (UV), the relative frequency of citation (RFC), and the familial use value (FUV). The two parameters UV and RFC were determined according to the method described by [147] and calculation of these parameters was done using the following formulas (equations (1) and (2)).

$$UV = \sum \frac{U}{N} \qquad (1)$$

Where U is the number of referees who mentioned the use of the species, and N is the number of referees (Totality).

$$RFC = \frac{Fc}{N} \qquad (2)$$

Where Fc is the citation frequency of the species, and N is the number of referees (Totality).

In addition, FUV was defined according to [41] and calculated according to equation (3):

$$FUV = \frac{UVf}{Nf} \qquad (3)$$

Where UVf is the use value of the families, and Nf represent the number of species in each family.

Author contributions: Concept – A.B., H.H.; Design – A.B., H.H., C.E.K.; Supervision – A.B., H.H., M.T.; Resources – C.E.K.; Materials – H.H., M.T.; Data Collection and/or Processing – C.E.K.; Analysis and/or Interpretation – C.E.K., O.B.; Literature Search – C.E.K.; Writing – C.E.K.; Critical Reviews – H.H., V.K., I.U.R., L.C.M., P.L.L., A.B.

Conflict of interest statement: The authors declared no conflict of interest.

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