Ethnobotanical study of Medicinal plants with hypocholesterolemic effect in the Beni Mellal Khenifra region of Morocco

Walid Errahmani and Ilham Zahir

Correspondence

Walid Errahmani[1] and Ilham Zahir[1*]

[1]Polyvalent Team in Research and Development, Polydisciplinary Faculty, Sultan Moulay Slimane University, Beni Mellal, Morocco.

*Corresponding Author: ilham.zahir@usms.ma

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Research

Abstract

Background: Hypercholesterolemia is one of the major risk factors for cardiovascular diseases. The initial treatment for this metabolic disorder involves adopting lifestyle and dietary measures. However, if this therapeutic strategy fails, medication can be considered, but most of the drugs used in such cases have side effects on human health. Faced with this situation, some patients proceed with alternative medicine approaches, such as phytotherapy. Thus, the herein study is the first of its kind, aiming to establish an inventory of Moroccan medicinal plants reported by consumers and herbalists in the region of Beni Mellal-Khenifra to treat hypercholesterolemia. Possible adverse effects of the mentioned plants are also reported.

Methods: A total of 239 questionnaire forms were filled out during direct interviews with the informants. The collected information was then analyzed, and quantitative ethnobotanical indices were calculated, such as the frequency of citation (FC), relative frequency of citation (RFC), family use values (FUV) and Plant Part Value (PPV).

Results: The findings of this study revealed the existence of indigenous ethnobotanical knowledge about medicinal plants in the studied area for the treatment of hypercholesterolemia. A total of 92 species belonging to 37 botanical families were identified with the predominance in particular of three families: Fabaceae (10 species), Lamiaceae and Asteraceae (8 species each). Furthermore, some plants were reported for the first time as remedies for treating the mentioned disease, such as *Tilia vulgaris*, *Anemone coronaria* and *Iris* sp. Additionally, the leaves were considered the most commonly used parts of the plant (PPV=0.217). On the other hand, this ethnobotanical survey also revealed a lack of knowledge about toxic plants in 78.26% of the respondents.

Conclusions: The data reported by this study could be a promising avenue to explore for further study in the field of phytochemistry to produce and identify new natural drugs with fewer side effects that could be endowed with interesting hypocholesterolemic caracteristics.

Keywords: Beni Mellal-Khenifra, Ethnobotanical Survey, hypocholesterolemic effect, Phytotherapy, Medicinal Plants

Background

Cardiovascular diseases (CVDs) are a group of disorders that affect the heart and blood vessels (Luo *et al.* 2024). These pathologies are the leading cause of mortality worldwide, according to the World Health Organization (WHO) (WHO 2020). Indeed, CVDs accounted for 17.9 million casualties globally in 2019, representing more than 44% of all deaths attributable to noncommunicable diseases (Khaltaev & Axelrod 2022, Luo *et al.* 2024).

One of the risk factors for CVDs onset is elevated blood cholesterol levels, known as hypercholesterolemia (Amerizadeh *et al.* 2023, Batista *et al.* 2009, El-Sahar *et al.* 2020, Oppedisano *et al.* 2020). In fact, one third of ischaemic heart disease cases worldwide are caused by high cholesterol levels (Abd Rahim *et al.* 2022, WHO 2008).

Changes in lifestyle and dietary habits (smoking, alcohol consumption, obesity, and sedentary behavior) appear to be the main contributors to the development of hypercholesterolemia (Batista *et al.* 2009, Silva *et al.* 2022).

This is why the first-line treatment for this condition relies on the adoption of hygienic and dietary measures which include a balanced diet, maintenance of the ideal weight, regular physical activity, and fight against cigarette smoking (Batista *et al.* 2009).
When these measures are not sufficient, a drug therapy aiming to monitor the lipid profile by reducing lipid levels in the blood, such as total cholesterol, lipoproteins (LDL, VLDL), and triglycerides (TG), may be initiated. The main drugs prescribed for this purpose are statins, fibrates, niacin, ezetimibe and bile acid sequestrants (Abd Rahim *et al.* 2022).

However, hypocholesterolemic treatments are not free of adverse effects. In particular, statins may be poorly tolerated and can cause other issues, such as resistance to treatment. These side effects and contraindications for long-term usage can lead to therapeutic failure (Abd Rahim *et al.* 2022).

As a result, some patients stop taking their medications and turn to dietary supplements and herbal medicine in an attempt to lower their blood cholesterol levels. Notably, one dietary strategy which may improve the lipid profile and offer long-term efficacy comparable with effective drug treatments involves supplementation of the diet with dietary antioxidant which is naturally present in plants (El-Sahar *et al.* 2020).

Indeed, plants have always been used to treat various diseases worldwide due to their relatively low toxicity compared to pharmaceuticals. As a result, pharmaceutical industries are increasingly interested in ethnobotanical studies of plants from various countries, including Morocco, which boasts significant floral richness, particularly in the Béni Mellal-Khénifra region.

In this regard, the present study was carried out, which aims to conduct an ethnobotanical study to highlight plants with hypocholesterolemic effects among the population of the Béni Mellal-Khénifra region. This investigation also seeks to document any possible adverse effects of the mentioned plants.

Materials and Methods

Study area

Located in the center of Morocco, the Béni Mellal-Khénifra region was established in 2015 from the division of three former regions: Meknès-Tafilalet, Chaouia-Ouardigha, and Tadla-Azilal. The region covers an area of 28,374 km², which is 3.99% of the national territory.

According to the General Population and Housing Census (GPHC) of 2014, the region has a population of 2,520,776 inhabitants, with 49.14% living in urban areas, which is lower than the national average of 60.36%. The population density is 88.8 inhabitants per km², higher than the national average of 47.6 inhabitants per km², ranking it sixth in population density after Casablanca-Settat, Rabat-Salé-Kénitra, Tanger-Tétouan-Al Hoceima, Marrakech-Safi, and Fès-Meknès. The Béni Mellal-Khénifra region is administratively divided into five provinces: Azilal, Béni Mellal, Fquih Ben Salah, Khénifra, and Khouribga, and includes 135 municipalities, comprising 16 urban municipalities and 119 rural communes (Fig. 1).

The agricultural sector is a key sector of the region and constitutes the core of its economic activity. The usable agricultural area in the Béni Mellal-Khénifra region is estimated at 948,426 hectares, accounting for 11% of the national total. The total area of irrigated land is approximately 187,483 hectares, accounting for 15% of the region's total agricultural land (General Directorate of Local Authorities 2015).

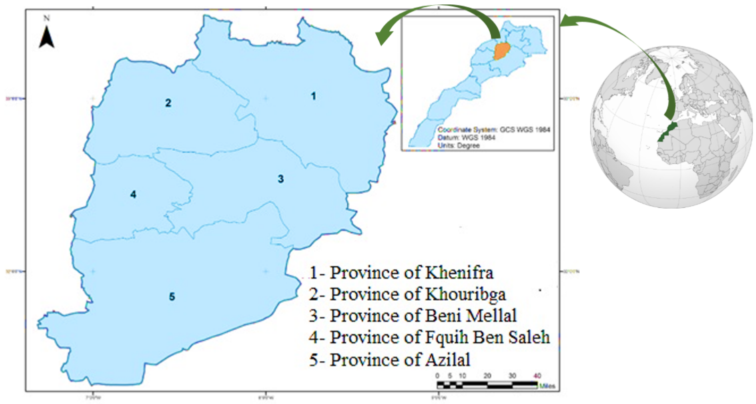

Figure 1. Presentation of the five selected stations for the study

Ethnobotanical survey

This study, conducted through a survey, took place in April and May 2023. Ethnobotanical interviews were carried out with questionnaires to gather data from the target study population. The participants included herbalists and consumers who use medicinal plants to treat hypercholesterolemia, from various rural and urban communes across the five provinces of the Béni Mellal-Khénifra region (Table 1).

Table 1. Different provenances of respondents from Beni Mellal Khenifra region (Morocco)

Province	Rural/urban commune
Azilal	- Rural commune Afourer - Rural commune Aït Blal - Rural commune Ait Bou Oulli - Rural commune Bini Ayad - Rural commune Demnate - Rural commune Foum Jemaa - Rural commune Ouaouizeght - Rural commune Ouaoula - Rural commune Tabant (village Ait Bouguemez, village Ait Saleh) - Rural commune Timoulilt, - Urban commune Azilal - Urban commune Demnate
Beni Mellal	- Rural commune Boutferda - Rural commune El Harboulia - Rural commune El Ksiba - Rural commune Foum El Anceur (village Adouz; village tamchat) - Rural commune Foum Oudi - Rural commune Mghila - Rural commune Ouled M'Barek - Rural commune Oulad Moussa - Rural commune Oulad Yaich (village Oulad Yaich ; village El Bazzaza) - Rural commune Oulad Youssef - Rural commune Sidi Jaber (village Sidi Jaber, village Aouinate) - Rural commune Taghzirt - Urban commune Beni Mellal - Urban commune Zaouiat Cheikh
Fquih Ben Salah	- Rural commune Oulad Nacer (village Lkhlalta) - Rural commune Dar Oulad Zidouh - Rural commune Oulad Zmam (village Ouled Smida) - Rural commune Sidi Aissa Ben Ali - Rural commune Souk El Had Des Bradia (village Ouled Abdellah ; village Ouled Ali) - Rural commune Souk Sebt Oulad Nemma - Urban commune Fquih Ben Salah - Urban commune Oulad Ayad
Khenifra	- Urban commune Khenifra
Khouribga	- Urban commune Bejaad - Urban commune Khouribga - Urban commune Oued Zem

To ensure proper representation of the population, a random sampling method was employed, distributing participants across five stations, each corresponding to one of the provinces of the Béni Mellal-Khénifra region: Khénifra (S1), Khouribga (S2), Béni Mellal (S3), Fquih Ben Salah (S4), and Azilal (S5) (Fig. 1).

The questionnaire was structured into three sections covering various topics: (i) the socio-demographic characteristics of participants, (ii) practices related to the use of medicinal plants for treating hypercholesterolemia (e.g., reasons for use, parts used, form, mode of preparation, mode of administration, dosage, frequency, duration, and results of phytotherapy), and (iii) potential adverse effects of the plants mentioned.

The questionnaire was based on prior ethnobotanical research conducted in various regions of Morocco (Chaachouay *et al.* 2020, El Azzouzi & Zidane, 2015, Zahir *et al.* 2020).

Inclusion criteria

The participants included herbalists and consumers who use medicinal plants to treat hypercholesterolemia, from various rural and urban communes across the five provinces of the Béni Mellal-Khénifra region.

Exclusion criteria

Individuals who did not reside in the Béni Mellal-Khénifra region were excluded from the study.

Statistical analysis

The results obtained were tabulated using spreadsheets (Microsoft Excel, 2016). Frequencies and percentages were then calculated for socio-demographic characteristics, practices related to the use of medicinal plants, and their possible side effects.

The collected data were used to calculate quantitative indices such as frequency of citation (FC), relative frequency of citation (RFC), family use values (FUV) (Houéhanou *et al.* 2016, Najem *et al.* 2019) and Plant Part Value (PPV) (Chaachouay *et al.* 2020).

Frequency of citation (FC)

This refers to the number of informants who reported using a particular plant species (Najem *et al.* 2019).

Relative Frequency of Citation (RFC)

This index highlights the local importance of each cited plant species. It was calculated using the following formula (Najem *et al.* 2019):

$$RFC = FC/N$$

Where N is the total number of informants interviewed.

Family Use Values (FUV)

This index was used to identify the importance of plant families. It was calculated using the following formula (Flouchi *et al.* 2023, Najem *et al.* 2019):

$$FUV = RFC/Ns$$

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

Plant Part Value (PPV)

This index was calculated using the following formula:

$$PPV = RU\ Plant\ part\ /\ RU$$

RU represents the total number of declared uses for all plant parts, while RU Plant part is the sum of the declared uses specific to each plant part. The part with the highest PPV index is the most used by respondents (Chaachouay *et al.* 2020).

Additionally, quantitative statistical methods, such as one-way ANOVA (where p-values ≤ 0.05 were considered significant), and descriptive methods, including the chi-square test, were performed. These analyses were carried out using SPSS

Statistics 20 software to examine the relationship between informants' sociodemographic data and their ethnomedicinal knowledge.

Results and discussion

Study population

The survey was conducted among the population living in various rural and urban communes of the five provinces in the Béni Mellal Khénifra region. The study included 292 individuals, of whom only 239 participants responded, yielding a response rate of 81.85%.

Moreover, the study population comprised 197 consumers (82.43%) and 42 herbalists (17.57%). Notably, 191 participants use medicinal plants in the Béni Mellal Khénifra region, representing a usage rate of 79.92% (Table 2). Generally, this rate indicates that phytotherapy is practiced in the studied region. Additionally, it has been reported that the percentage of medicinal plant use varies between 55% and 95% depending on the study areas where ethnobotanical surveys were conducted. This rate changes according to the investigated area and its richness in medicinal plants (MPs), as well as the ancestral knowledge of the population regarding the use of MP (Fakchich & Elachouri 2014).

Profiling of respondents and the use of plants

Age

The average age of the study population is 42.59 ± 13.88 years, with ages ranging from 21 to 79 years. According to the results obtained, the use of medicinal plants (MPs) in the Béni Mellal-Khenifra region is widespread across all age groups, with a predominance in the 20-40 age group (47.12%) and the 40-60 age group (40.84%), with average ages of 29.93 ± 5.49 and 50.47 ± 5.36 years, respectively. However, for the age group above 60 years, with an average age of 65.39 ± 4.83 years, a lower rate of 12.04% is observed. The sample characteristics are detailed in Table 2.

Furthermore, the chi-square test result indicates a significant difference ($p = 0.003$) between age groups and the use of plants as a primary therapeutic recourse.

The results provide evidence that the use of herbal remedies varies with age, with a higher prevalence among individuals aged 20 to 40. These individuals are often active and health-conscious, seeking natural alternatives and turning to medicinal plants to address health issues and maintain overall well-being. Conversely, other international and national ethnobotanical studies have revealed that phytotherapy is predominantly used by older individuals (El Hachlafi *et al.* 2022, Özkum *et al.* 2013).

Gender

The distribution of respondents by sex showed a slight overall predominance of men (100 respondents, 52.36%) compared to women (91 respondents, 47.64% of the population studied), with a sex ratio of male/ female 1.1. However, the difference is not statistically significant ($p = 0.22$).

On the other hand, this slight predominance of males can be explained by the fact that most herbalists in the region are male. These results corroborate those of (El Alami *et al.* 2020, Benkhaira *et al.* 2021, Buwa-Komoreng *et al.* 2019), but they are incompatible with those of other studies conducted in Moroccan regions such as the Gharb region (Bouayyadi *et al.* 2015), the Al-Haouz Rehamna region (Benkhnigue *et al.* 2023) and Moyenne Moulouya, in the North-East of Morocco (Hassani *et al.* 2013).

Place of residence

Regarding the place of residence, the results show that 107 of the population studied live in the city (56.03%), while 77 people reside in the village (40.31%). In return, only 7 informers live in the mountains (3.66%), representing thus the respondents who use the least MP in our sample. However, there is no statistical link between the use of plants and the place of residence ($p = 0.764$).

Unquestionably, our results are in disagreement with those obtained by previous studies (Benkhnigue *et al.* 2023, El Hachlafi *et al.* 2022, Fakchich & Elachouri, 2014) The results of this study showed that informants living in rural areas are more interested in phytotherapy.

Education level

The use of medicinal plants varies according to the level of education. Indeed, individuals with primary and secondary education levels have usage rates of 26.18% and 22.51%, respectively, while those with university education use medicinal plants at a rate of 28.80%. In contrast, illiterate individuals account for 18.32%, and those with non-formal education are the least represented, at 4.19%.

However, statistically, the use of medicinal plants in the Béni Mellal Khenifra region is independent of the level of education (p = 0.135). Thus, these results indicate that whatever their level of education, our respondents use plants for medicinal purposes. In fact, even people with university education may turn to the use of plants due to their extensive knowledge in the field of phytotherapy and their trust in the benefits of these natural remedies.

However, several studies have revealed that illiterate individuals show a greater interest in medicinal plants compared to those with higher education levels (Benkhnigue *et al.* 2023, Bouayyadi *et al.* 2015, El Hachlafi *et al.* 2022).

On the other hand, it is essential to recognize that the use of medicinal plants can also be influenced by additional factors, including monthly income, cultural context, personal beliefs, and individual health experiences (Chaachouay *et al.* 2020, Flouchi *et al.* 2023, Najem *et al.* 2019).

Table 2. Sociodemographic details of respondents in the study area

Category	**Total population**		**Respondents using plants**			
	Number of informants	**Percentage (%)**	**Number of informants**	**Percentage (%)**	**F-Value**	***p*- Value**
Province						
Azilal	47	19.67%	43	22.51%	1.181	0.309
Beni Mellal	96	40.17%	79	41.36%		
Fkih Ben Saleh	50	20.92%	36	18.85%		
Khenifra	10	4.18%	10	5.24%		
Khouribga	36	15.06%	23	12.04%		
Total	239	100%	191	100%		
Age Group						
20 - 40 years	112	46.86%	90	47.12%	7.900	0.000
41 - 60 years	99	41.42%	78	40.84%		
> 60 years	28	11.72%	23	12.04%		
Total	239	100%	191	100%		
Gender						
Female	117	48.95%	91	47.64%	1.074	0.343
Male	122	51.05%	100	52.36%		
Total	239	100%	191	100%		
Family situation						
Single	62	25.94%	50	26.18%	3.912	0.021
Married	162	67.78%	129	67.54%		
Divorced	3	1.26%	2	1.05%		
Widowed	12	5.02%	10	5.24%		
Place of residence						
City	128	53.56%	107	56.03%	0.620	0.539
Village	104	43.51%	77	40.31%		
Mountain	7	2.93%	7	3.66%		
Total	239	100%	191	100%		
Education Level						
Illiterate	47	19.67%	35	18.32%	4.472	0.036
Non-formal Education	13	5.44%	8	4.19%		
Primary Education	59	24.69%	50	26.18%		
Secondary Education	50	20.92%	43	22.51%		
University Education	70	29.29%	55	28.80%		

Practices of using medicinal and aromatic plants

Choice between phytotherapy and modern medicine

The analysis of the results indicates a distribution of the population into 3 distinct groups (Fig. 2).

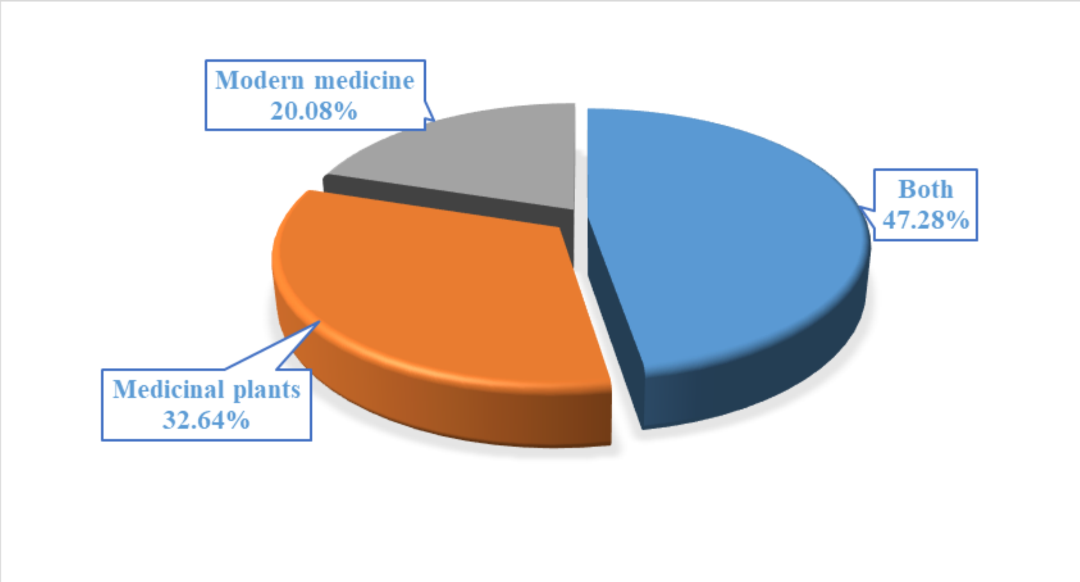

Figure 2: Choice between phytotherapy and modern medicine by the studied population

In fact, among the 239 people surveyed, we distinguish:

- 32.64% of the respondents use traditional medicine alone. This preference for natural remedies can be explained by several reasons. First, some people view phytotherapy as a gentler and less invasive method for treating their health issues. They prefer to avoid pharmaceutical medications and opt for plant-based remedies due to their natural origin and reputation for safety. Additionally, respondents may avoid modern medicine due to the side effects associated with certain drugs. Finally, accessibility and low cost of plants also play a role, as phytotherapy may be more easily accessible and less expensive than modern medical treatments (Eddouks *et al.* 2007).

- 20.08% of the respondents use modern medicine alone. These results can be explained by the trust placed in modern medicine, specific medical needs, and availability of treatments (Boussageon *et al.* 2015). Moreover, some people may consider modern medicine to be the most effective method for treating their illness, such as hypercholesterolemia.

- 47.28% of the respondents opt to utilize phytotherapy in conjunction with modern medicine. This choice can be explained by the fact that some respondents recognize that each approach has its own advantages and use both to optimize their well-being. Furthermore, the complementarity of treatments plays an important role: phytotherapy and modern medicine can complement each other. This is because some health issues require a combined approach, where the benefits of both approaches are used synergistically (WHO 2013). However, it should be noted that in this case, the use of plants must be rational and in coordination with the treating physician to avoid potential interactions between medications and plant compounds.

For more details, among the 239 people surveyed in the study, it was observed that 79.92% of respondents have opted for herbal medicine. According to our results, the main reasons motivating respondents to prefer herbal remedies are as follows: 54.46% declare that these remedies are effective, 8.91% believe they are less expensive, 14.85% appreciate their easy accessibility, while 21.78% use them to avoid side effects of medications. This finding aligns with a study conducted by Lyoussi *et al.* (2023) reporting that more than 75 percent of the people in Sefrou province rely on folk medicine as a principal means of preventing and curing illnesses.

On the other hand, there are 48 respondents (20.08%), who use modern medicine. Among them, 67.86% chose this medical approach due to its effectiveness, while 32.14% prefer it because of its precise dosages compared to phytotherapy (Fig. 3).

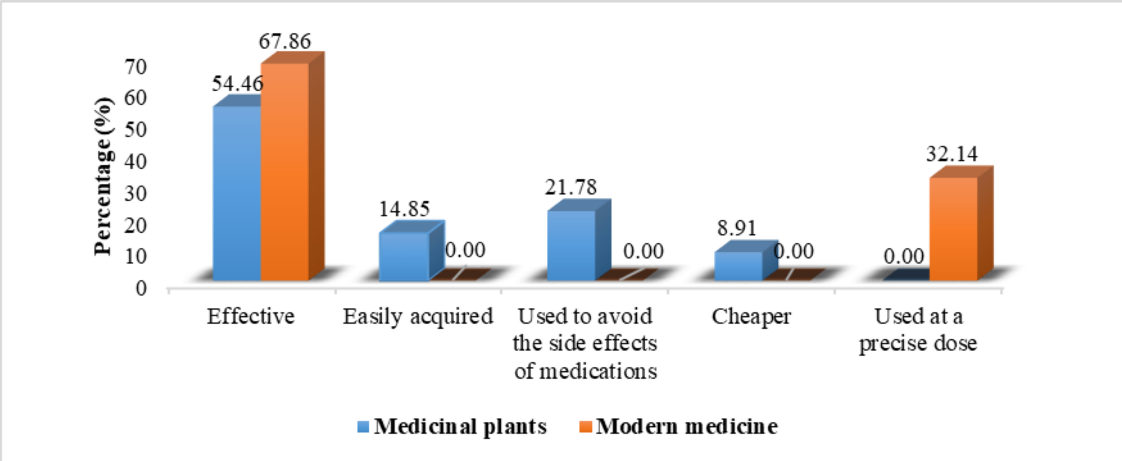

Figure 3. Percentages of various reasons for medication preferences among respondents

Plants used in the treatment of hypercholesterolemia

Specific analysis of botanical families

A total of 92 species belonging to 37 botanical families were recommended by the respondents to combat hypercholesterolemia in the Béni Mellal-Khenifra region. The scientific names of these species and their families, vernacular names, plant parts used, preparation methods, possible associations, FC, RFC, and FUV of the 92 species are detailed in Table 3.

Thus, 92 inventoried medicinal species are distributed into 83 genera and belong to 37 botanical families. The most represented family in terms of species count was Fabaceae, with ten species (10.87%), followed by Lamiaceae and Asteraceae, with eight species each (8.70%).

The Amaryllidaceae, Apiaceae, Poaceae, and Solanaceae were represented by five species each (5.43%), while the Rosaceae had four species (4.35%). The Brassicaceae, Lauraceae, Malvaceae, and Zingiberaceae had three species each (3.26%), while the Cucurbitaceae, Euphorbiaceae, Iridaceae, Ranunculaceae, and Rutaceae were represented by two species each (2.17%). The other families were represented by one species each (1.09%).

The use of plants belonging to the Fabaceae, Asteraceae, and Lamiaceae families is very widespread internationally (Mounkaila *et al.* 2017) and nationally (Benkhnigue *et al.* 2023, El-Ghazouani *et al.* 2021, El Hachlafi *et al.* 2022, Lyoussi *et al.* 2023). For this reason, the therapeutic importance of these families has been highlighted on several occasions. Furthermore, the importance of these families can be explained on the one hand to their richness within the Moroccan flora and their ability to adapt to diverse environments, and, on the other hand, to their biogeographic range (Mediterranean) (Benkhnigue *et al.* 2023).

Quantitative analysis according to the RFC and FUV indices

According to the RFC, indicating the relative frequency of use of each plant, the most frequently used species are *Allium sativum* (RFC = 0.157), *Zingiber officinale* (RFC = 0.147), *Linum usitatissimum* (RFC = 0.105), *Trigonella foenum-graecum* (RFC = 0.089), *Olea europaea* (RFC = 0.084), *Curcuma longa* (RFC = 0.079), *Coriandrum sativum* (RFC = 0.073), *Origanum vulgare* (RFC = 0.068) and *Cinnamomum verum* (RFC = 0.058) (Fig. 4).

These plants are widely recognized for their medicinal properties and play an important role in lipid metabolism regulation (Chen *et al.* 2017, Dastyar & Ahmadi, 2022, El-Desoky *et al.* 2012, Foroozandeh *et al.* 2022). In fact, earlier it was reported that plants like turmeric, ginger, garlic, fenugreek, inclusion of coriander seeds in the diet showed significant hypolipidemic effects (Chithra & Leelamma 1997). Thus, their frequent use among the studied population reflects the trust placed in these plants for their health benefits and cholesterol management.

In terms of the FUV index, the survey respondents identified four plant families most used in traditional phytotherapy for cholesterol in the Béni Mellal-Khenifra region. These are the Linaceae, which hold the first place (FUV = 0.105), followed by the Oleaceae (FUV = 0.084), Zingiberaceae (FUV = 0.077), and Theaceae (FUV = 0.031) (Fig. 5).

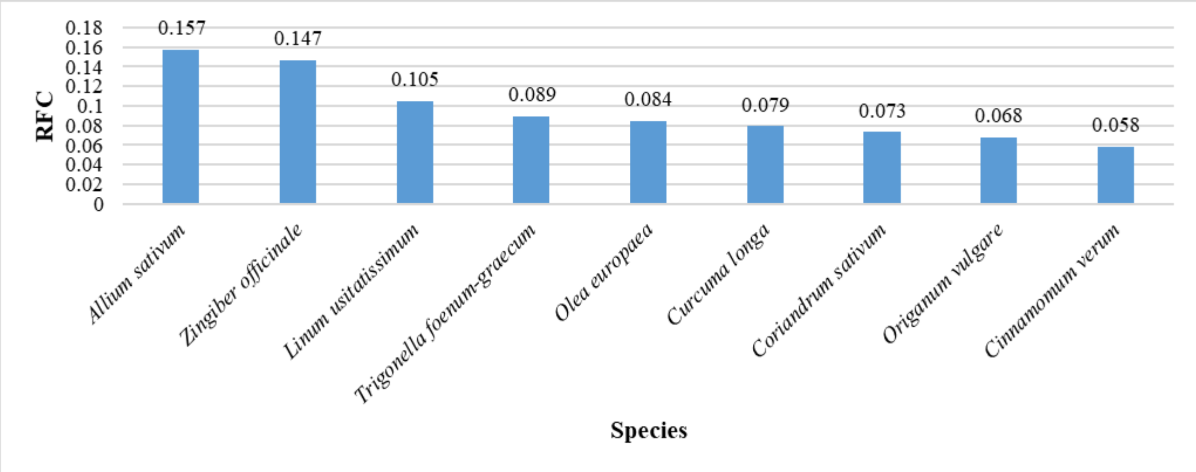

Figure 4. Distribution of the most cited plant species according to their relative frequency of citation

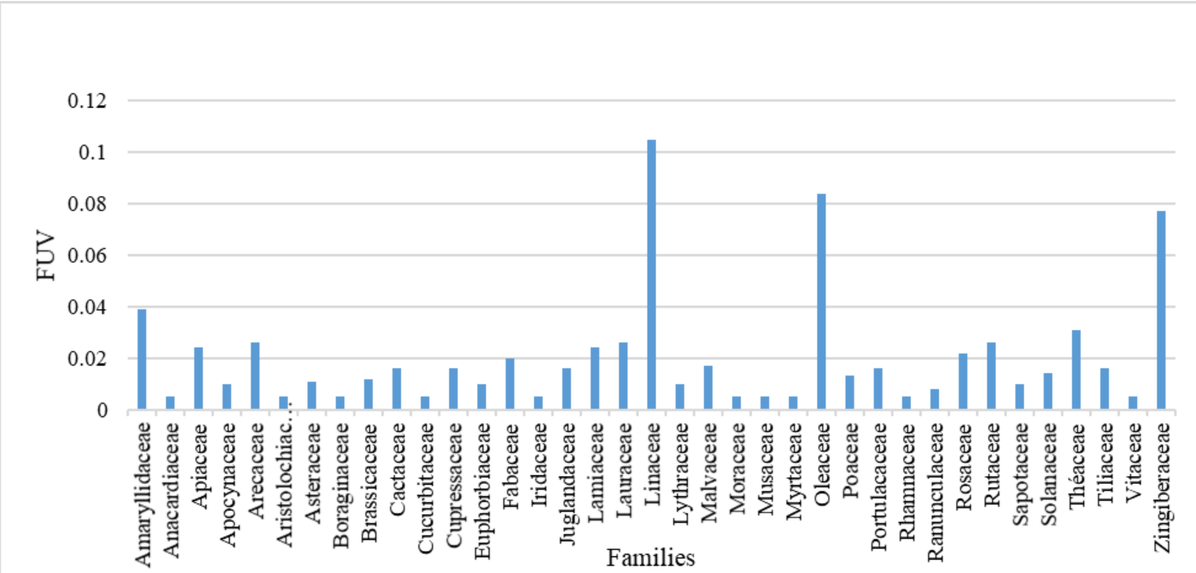

Figure 5. Distribution of the cited plant families according to their family use values

Furthermore, our results confirm those observed in a survey conducted on phytotherapy practices among the Rif population in northern Morocco by Chaachouay *et al*. (2020), where the Linaceae family was notably among the most cited families. According to the literature review, we found that among the 92 identified species, the hypocholesterolemic activity of 80 species has been previously reported by ethnobotanical studies and/or scientific investigations conducted in various regions of Morocco and around the world. These plants include: *Allium sativum*, *Zingiber officinale*, *Trigonella foenum-graecum*, *Olea europaea*, *Curcuma longa*, etc (Tables 3 and 4).

On the other hand, we also identified 12 species that have not been studied in this context, such as *Tilia vulgaris*, *Anemone coronaria*, *Arctium atlanticum*, *Aristolochia longa*, *Cynara cardunculus var. altilis*, *Euphorbia echinus*, *Euphorbia resinifera*, *Lupinus luteus*, *Trifolium sp*., *Vachellia gummifera*, *Iris* sp., and *Malva pusilla* (Table 3). In fact, these plant species should attract researchers' interest for phytochemical and pharmacological studies to identify their chemical constituents and potential active substances responsible for their hypocholesterolemic properties.

Scientific evidence and mechanisms of action of hypocholesterolemic medicinal plants: A literature review

Bibliographic research was conducted using articles published on Google, Google Scholar, PubMed, and ScienceDirect to identify scientific evidence from *in vivo* and/or *in vitro* studies regarding the hypocholesterolemic properties of plants. Table 4 lists the mechanisms of hypocholesterolemic properties of six plants traditionally used by the population studied to control cholesterol.

Table 3. List of medicinal plants used to treat hypercholesterolemia by the population of the Beni Mellal Khenifra region with local name, English name, used parts, modes of preparation, Frequency of citation, Relative Frequency of Citation and Family Use Values

Family	Scientific name	English name	Vernacular name	PU	MP	Possible Association	FC	RFC	FUV	E.E/ S.E
Amaryllidaceae									0.039	
	Allium cepa L.	Onion	البصل Basla	B (3)*	J (2) R P (1)	Lemon (1)	3	0.016		Raj *et al*. 2021
	Allium sativum L.	Garlic	ثومة Thouma	B (30)	R P (18) C P (8) I (1) J (2) M (1)	Lemon (4) Coriander (3) Artichoke (1) Tomato (1) Purslane (1) Mallow (1) Clover (1) Ginger (1) Cumin (1)	30	0.157		Al-Numair 2009
	Beta vulgaris L.	Sugar beet	شمندر Chamandar	B (1)	R P (1)		1	0.005		Al-Dosari *et al.* 2011
	Beta vulgaris subsp *vulgaris*	Red beetroot	باربا Barba	B (1)	R P / C P (1)		1	0.005		El Sheikh & Othman 2019
	Dysphania ambrosioides (L.) Mosyakin & Clemants	Mexican tea	مخينزة Mikhinza	L (2)	D (2)		2	0.010		Da Silva *et al.* 2014
Anacardiaceae									0.005	
	Searsia pentaphylla (Jacq.) F.A.Barkley ex Moffett	Five-leaved rhus	تزغا Tizrha	Fr (1)	R P (1)		1	0.005		Chaachouay *et al*. 2020
Apiaceae									0.024	
	Ammi visnaga (L.) Lam.	Toothpick weed	بشنيخا Bachnikha	O (2)	D (2)		2	0.010		Bhagavathula *et al.* 2015
	Apium graveolens L.	Celery	لكرافص Lkarafas	W P (1)	J (1)	Lemon (1)	1	0.005		Moelviani *et al*. 2019
	Cuminum cyminum L.	Cumin	الكمون Al Kamoun	Se (3)	P (2) R P (1)	Ginger (1) Garlic (1) Flaxseed (2) Coriander (2)	3	0.016		Andallu & Ramya, 2007
	Foeniculum vulgare Mill.	Fennel	البسباس Al Basbas	B (2) Se (1)	R P (1) M (1) C P (1)		3	0.016		Shahat *et al.* 2014

	Coriandrum sativum L.	Coriander	قزبر Kozbar	Se (10) W P (4)	P (7) I (2) M (1) J (1) C P (3)	Flaxseed (2) Nigella (1) Christ's Thorn (1) Purslane (1) Garlic (2) Tomato (1) Lemon (2) Clover (1) Carrot (1) Ginger (1) Cumin (1) Fenugreek (1) Barley (1)	14	0.073		Chithra & Leelamma. 1997
Apocynaceae									0.010	
	Caralluma europaea (Guss.) N.E.Br.	European caralluma	دغموس Darhmous	St (2)	P/J (1) J (1)		2	0.010		Ouassou *et al.* 2021
Arecaceae									0.026	
	Chamaerops humilis L.	Mediterranean fan palm	الدوم Doum	Fr (5)	R P (3) P (1) I/P (1)		5	0.026		Gaamoussi *et al.* 2010
Aristolochiaceae									0.005	
	Aristolochia longa L.	Long aristolochia	برزطم Barzatam	Fr (1)	R P (1)		1	0.005		
Asteraceae									0.011	
	Arctium atlanticum (Pomel) H.Lindb.	Burdock	بردان/ارقطيون Bardan	B (1)	R P (1)		1	0.005		
	Artemisia vulgaris L.	Wormwood	الشيح Chih	L (3) WP (1)	D (2) I (2)	Oregano (1)	4	0.021		Kim *et al.* 2012
	Matricaria chamomilla L.	Chamomile	بابونج Babounj	Fl (1)	D (1)		1	0.005		Nargesi *et al.* 2018
	Silybum marianum (L.) Gaertn.	Milk thistle	شوكة حمار Chouka Hmar	St (1)	R P (1)		1	0.005		Tajmohammadi *et al.* 2018
	Carthamus tinctorius L.	Safflower	العصفر Al ôsfor	Se (1)	R P (1)		1	0.005		Changsri *et al.* 2010
	Cichorium intybus L.	Bitter chicory	الهندبا Al Handaba	L (1)	R P (1)	Lemon (1)	1	0.005		Ahmed *et al.* 2011

	Cynara cardunculus var. *sylvestris* (Lam.) Fiori	Wild cardoon	الخرشوف Al Khorchouf	St (5) Se (1) L (1)	R P (4) C P (1) J (1) D (1)	Chamomile (1)	7	0.037		Oppedisano *et al.* 2020
	Cynara cardunculus var. *altilis* DC.	Domesticated cardoon	إقرني Alkarni	L (1)	R P (1)		1	0.005		
Boraginaceae									0.005	
	Echium vulgare Bourg. ex Reut.	Viper's bugloss	كصة حية Gasa Haya	St Fl (1)	I (1)		1	0.005		Alsanie *et al.* 2018
Brassicaceae									0.012	
	Brassica oleracea var *capitata f. alba*	White cabbage	كرنب Kornob	L (2)	C P (2)		2	0.010		Ray *et al.* 2021
	Lepidium sativum L.	Watercress	حب رشاد Hab Rachad	Se (3)	R P (2) P (1)	Fenugreek (1)	3	0.016		Althnaian, 2014
	Raphanus sativus L.	Radish	الفجل Al Fajal	B (2)	R P (2)	Olive (1)	2	0.010		Sadeek 2011
Cactaceae									0.016	
	Opuntia ficus-indica (L.) Mill.	Cactus pear	الصبار Sabar	C (3)	R P (1) J (2)	Lemon (1) Okra (1)	3	0.016		El-Said *et al.* 2011
Cucurbitaceae									0.005	
	Cucurbita pepo subsp. pepo	Courgette / zucchini	كرعة خضرة Garâa Khadra	Fr (1)	R P (1)		1	0.005		El-Sahar *et al.* 2020
	Cucumis sativus L.	Cucumber	الخيار Al Khayar	Fr (1)	J (1)	Carrot (1) Coriander (1)	1	0.005		Karthiyayini *et al.* 2015
Cupressaceae									0.016	
	Tetraclinis articulate (Vahl) Mast.	Thuja	عرعار Arâar	L (2)	R P (1) I (1) D (1)	Oregano (1)	3	0.016		Bouadid *et al.* 2022
Euphorbiaceae									0.010	
	Euphorbia echinus Hook.f. & Coss.	Spiky spurge	درغموس Darrhmous	W P (1) St (1) Rh (1)	P (2) R P (1)		3	0.016		

	Euphorbia resinifera O.Berg	Resin spurge	زكوم Zakoum	W P (1)	D (1)		1	0.005	
Fabaceae								0.020	
	Ceratonia siliqua L.	Carob	الخروب Kharoub	Fr (2) Se (1)	P (3)		3	0.016	Jaffari *et al.* 2020
	Glycine max (L.) Merr.	Soybean	فول الصويا Foul Soya	Se (4)	P (1) J (1) R P (1) D (1)		4	0.021	Han *et al.* 2006
	Glycyrrhiza glabra L.	Liquorice	العرقسوس Arak Sous	St (4)	D (1) P (1) R P (2)		4	0.021	Markina *et al.* 2022
	Lens culinaris Medik.	Lentils	العدس Al âdas	Se (1)	C P (1)	Bean (1) Oats (1)	1	0.005	Ahmad, 2014
	Lupinus luteus L.	Yellow lupin	الترمس Termis	Se (1)	P (1)		1	0.005	
	Medicago sativa L.	Alfalfa	الفصة Al Fasa	W P (3)	C P (3)		3	0.016	Dixit & Jain, 1990
	Trifolium sp	Clover	البرسيم Al Barssim	W P (1)	C P (1)	Garlic (1) Coriander (1) Lemon (1)	1	0.005	
	Trigonella foenum-graecum L.	Fenugreek	الحلبة Al Halba	Se (16) L (1)	C P (6) P (5) D (4) M (1) J (1)	Coriander (1) Barley (1) Watercress (1)	17	0.089	Chen *et al.* 2017
	Vachellia gummifera (Willd.) Kyal. & Boatwr	Morocco gum	الطلح Talh	Fr (1)	R P (1)		1	0.005	
	Vicia faba L.	Bean	الفول Al Foul	Fr (2) Se (1)	C P (3)	Lentils (1) Oats (1)	3	0.016	Khatun *et al.* 2019
Iridaceae								0.005	
	Crocus sativus L.	Saffron crocus	زعفران Zaâfaran	S (1)	I (1)		1	0.005	Abd Rahim *et al.* 2022
	Iris sp	Iris	السوسن Sawasan	L (1)	D (1)		1	0.005	
Juglandaceae								0.016	

	Juglans regia L.	Nut	الكركاع Gargaâ	Fr (3)	R P (2) J (1)	Avocado (1)	3	0.016	Ashraf *et al.* 2020
Lamiaceae								0.024	
	Melissa officinalis L.	Lemon balm	مرسيطا Marasita	L (1)	I (1)		1	0.005	Karimi *et al.* 2010
	Mentha spicata L.	Mint	نعناع Naânaâ	L (4) W P (2) St/L (2)	I (1) D (6) R P (1)	Tea (3) Turmeric (2) Lemon (1)	8	0.042	Bayani *et al.* 2017
	Ocimum basilicum L.	Sweet basil	الريحان Rayahan	L (3)	I (2) R P /M (1)		3	0.016	Touiss *et al.* 2019
	Origanum vulgare L.	Oregano	زعتر Zaâtar	L (12) W P(1)	D (9) I (3) C P (1)	Thuja (1) Tea (1) Ginger (2) Cinnamon (1) Wormwood (1)	13	0.068	Foroozandeh *et al.* 2022
	Salvia hispanica L.	Chia	الشيا Chia	Se (1)	R P (1)		1	0.005	Sierra *et al.* 2015
	Salvia officinalis L.	Common sage	السالمية Salmia	W P (1) L (2)	D (1) I (1) M(1)		3	0.016	Kianbakht & Dabaghian, 2013
	Salvia rosmarinus Spenn.	Rosemary	الأزير Azir	L (5)	I (3) D (2)	Olive (1)	5	0.026	Afonso *et al.* 2013
	Thymus vulgaris L.	Common thyme	زعيترا Ziâitra	L (3)	I (3)		3	0.016	Klimiuk *et al.* 2023
Lauraceae								0.026	
	Cinnamomum verum J.Presl	Cinnamon	القرفة Al Karfa	Ba (11)	P (5) D (3) I (1) M (1) C P (1)	Oregano (1) Galangal (1) Oats (1)	11	0.058	El-Desoky *et al.* 2012
	Laurus nobilis L.	Bay laurel	ورقة سيدنا موسى Wakat Sidna Moussa	L (2)	D (2)		2	0.010	Chbili *et al.* 2020
	Persea americana Mill.	Avocado	أفوكا Avoca	Fr (2)	R P (1) J (1)	Nut (1)	2	0.010	Brai *et al.* 2020
Linaceae								0.105	

	Linum usitatissimum L.	Flaxseed	زريعة الكتان Zariât Al Katan	Se (20)	P (14) R P (4) M (1) C P (1)	Tea (1) Coriander (4) Cumin (2) Nigella (1) Christ's Thorn (1)	20	0.105		Naik *et al.* 2018
Lythraceae									0.010	
	Punica granatum L.	Pomegrenate	الرمان Roman	Fr (1) Ba (1)	R P (1) I (1)		2	0.010		Kurniati *et al.* 2021
Malvaceae									0.017	
	Abelmoschus esculentus Moench	Okra	ملوخية Maloukhiya	L (1) Fr (2)	J (2) R P (1)	Cactus (1)	3	0.016		Djamil *et al.* 2020
	Hibiscus sabdariffa L.	Roselle	كركدية Karkadi	Fl (5)	I (4) D (1)		5	0.026		Olatunji *et al.* 2005
	Malva pusilla Sm.	Mallow	الخبيزة Al Khoubiza	W P (2)	C P (2)	Lemon (1) Garlic (1)	2	0.010		
Moraceae									0.005	
	Ficus carica L.	Common fig	الكرم Al Karama	L (1)	I (1)		1	0.005		Mahmoud *et al.* 2013
Musaceae									0.005	
	Musa acuminate Colla	Bananas	موز Mawz	Fr (1)	R P (1)		1	0.005		Berawi & Bimandama, 2018
Myrtaceae									0.005	
	Syzygium aromaticum (L.) Merr. & L.M.Perry	Clove	قرنفل Koronfol	F B (1)	P (1)		1	0.005		Chang Hwa *et al.* 2012
Oleaceae									0.084	
	Olea europaea L.	Olive	الزيتون Zaytoun	L (11) Fr (5)	D (3) Di (1) I (7) R P (5)	Rosemary (1) Radish (1) Barley (1) Lemon (1)	16	0.084		Cheurfa *et al.* 2019
Poaceae									0.013	
	Avena sativa L.	Oats	الشوفان/ الخرطال Choufan / Khartal	Se (4)	C P (3) P (1)	Bean (1) Lentils (1)	4	0.021		Amerizadeh *et al.* 2023

	Hordeum vulgare L.	Barley	الشعير Chaâir	Se (4)	D (1) P (2) C P (1)	Fenugreek (1) Coriander (1) Olive (1)	4	0.021	Abulnaja & El Rabey 2015
	Panicum miliaceum Walter	Common millet	إلان Ilan	Se (1)	P (1)		1	0.005	Bora *et al.* 2018
	Saccharum officinarum L.	Sugar cane	قصب السكر Kasab Soukar	St (2)	J (2)	Lemon (1)	2	0.010	Rosales 2021
	Zea mays L.	Maize	لكبال Lkbal	Br (1)	I (1)		1	0.005	Okokon & Nyong, 2018
Portulacaceae								0.016	
	Portulaca oleracera L.	Purslane	ترجلة Tarajla	W P (3)	C P (3)	Garlic (1) Tomato (1) Coriander (1)	3	0.016	El-Newary 2016
Rhamnaceae								0.005	
	Ziziphus jujuba Mill.	Common jujube	سدرة Sadra	Fr (1)	P (1)	Coriander (1) Nigella (1) Flaxseed (1)	1	0.005	Hemmati *et al.* 2015
Ranunculaceae								0.008	
	Anemone coronaria L.	Poppy anemone	بلعمان Balâman	Fl (1)	I (1)		1	0.005	
	Nigella sativa L.	Nigella	الحبة السوداء Al Haba Souda	Se (2)	P (1) Di (1)	Coriander (1) Flaxseed (1) Christ's Thorn (1)	2	0.010	Ibrahim *et al.* 2014
Rosaceae								0.022	
	Crataegus monogyna Jacq.	Hawthorn	زعرور Zaârour	L (6)	C P (4) I (1) M (1)		6	0.031	Kausar *et al.* 2011
	Malus domestica (Suckow) Borkh.	Apple	تفاح Toufah	Fr (8)	R P (8)		8	0.042	Salgado *et al.* 2008
	Mespilus germanica L.	Common medlar	مزاح Mzah	L (1)	I (1)		1	0.005	Karami *et al.* 2014
	Prunus dulcis (Mill.) Rchb.	Almond	لوز Louz	Fr (2)	R P (1) P (1)		2	0.010	Harnafi *et al.* 2020
Rutaceae								0.026	

	Citrus limon (L.) Osbeck	Lemon	الحامض Al Hamad	Fr (9)	J (5) R P (2) C P (2)	Onion (1) Garlic (3) Mallow (1) Clover (1) Coriander (1) Mint (1) Olive (1) Bitter Chicory (1) Celery (1)	9	0.047	Kelechi *et al.* 2017
	Citrus maxima (Burm.) Merr.	Pomelo	بومبلوموس Poumploum ous	Fr (1)	J (1)		1	0.005	Mohammed *et al.* 2021
Sapotaceae								0.010	
	Argania spinosa Skeels	Argan tree	أركان Argan	Fr (2)	R P (1) C P (1)		2	0.010	Berrougui *et al.* 2003
Solanaceae								0.014	
	Capsicum annuum L.	Sweet pepper	لفلفل Al Falafala	Fr (1)	R P (1)		1	0.005	Al-Jumayi *et al.* 2020
	Capsicum frutescens L.	Hot pepper	لفلفل الحار Al Falafala Al Hara	Fr (1)	P (1)		1	0.005	Adigun *et al.* 2020
	Lycium europaeum L.	European tea tree	الغردق/عنب الذيب Al Rhardak / âinab Al Dib	L (1)	R P (1)		1	0.005	Tej *et al.* 2019
	Solanum lycopersicum L.	Tomato	ماطيشة Maticha	Fr (2)	R P (1) C P (1)	Purslane (1) Garlic (1) Coriander (1) Cucumber (1)	2	0.010	Mohajeri 2013
	Solanum melongena L.	Aubergine/ Eggplant	دنجال Danjal	Fr (8)	J (3) R P (4) C P (1)	Tomato (1)	8	0.042	Guimarães *et al.* 2000
Theaceae								0.031	
	Camellia sinensis (L.) Kuntze	Tea	أتاي Atay	L (6)	D (3) C P (1) I (2)	Ginger (1) Mint (1) Turmeric (1)	6	0.031	Batista *et al.* 2009
Tiliaceae								0.016	
	Tilia vulgaris B.Heyne	Common linden	الزيزفون Al Zayzafoun	L (2) Fl (1)	I (3)		3	0.016	
Vitaceae								0.005	

	Vitis vinifera L.	Common grape	شجرة العنب Chajarat Al âinab	L (1)	I (1)		1	0.005		Gris *et al.* 2011
Zingiberaceae									0.077	
	Alpinia officinarum Hance	Galangal	خدنجال Khodanjal	Rh (1)	D (1)	Cinnamon (1)	1	0.005		Lin *et al.* 2015
	Curcuma longa L.	Turmeric	الخرقوم Al Khorkoum	Rh (15)	J (2) I (3) R P (1) P (7) D (2)	Mint (2) Tea (1) Lemon (1) Sugar cane (1) Cinnamon (1) Carrot (1)	15	0.079		Budiman *et al.* 2015
	Zingiber officinale Roscoe	Ginger	زنجبيل Zanjabir	Rh (28)	J (8) I (7) R P (3) P (5) D (4) M (1)	Cucumber (1) Lemon (5) Celery (1) Apple (1) Oregano (2) Tea (1) Cumin (1) Garlic (1)	28	0.147		Herve *et al.* 2019

Legend:

Part used (PU): B: Bulb, F B: Flower Buds, C: Cladodes, S: Stamina, Br: Bristles, Ba: Bark, L: Leaves, Fl: Flowers, Fr: Fruit, Se: Seeds, O: Ombelle, W P: Whole Plant, Rh: Rhizome, St: Stems. ()*Number of times mentioned.

Method of preparation (MP): D: Decoction, Di: Distillation, I: Infusion, J: Juice, M: Maceration, R P: Raw plant, C P: Cooked plant, P: Powder.

Quantitative indices: FC: Frequency of citation**,** RFC: Relative Frequency of Citation, FUV: Family Use Values.

Ethnobotanical/Scientific Evidence (E.E/ S.E)

Table 4. Hypocholesterolemic properties of medicinal plants cited in the study area

Plant	**Part Used**	**Form of Use**	**Hypocholesterolemic Activity (*in vitro*/*in vivo*)**	**Bibliographic references**
Allium sativum L. (Garlic)	Bulbs	Hydroalcoholic extract	*In vivo*, the oral administration of 0.2 or 0.4 g/kg of garlic extract to rats fed a high-cholesterol diet led to a significant reduction in plasma levels of total cholesterol (TC), triglycerides (TG), and LDL-cholesterol, as well as a significant increase in plasma HDL-cholesterol.	Al-Numair 2009
Zingiber officinale Roscoe (Ginger)	Rhizomes	Essential oil	*In vivo*, the levels of TC in serum and egg yolk, LDL-cholesterol, and TG decreased with the oral administration of ginger rhizome essential oil, along with an increase in HDL-cholesterol levels.	Herve *et al.* 2019.
Linum usitatissimum L. (Flaxseed)	Seeds	Powder	Flax seeds significantly reduced (p<0.05) TC, TG, LDL-C, and VLDL-cholesterol (VLDL-C), and non-significantly increased HDL-C.	Naik *et al,* 2018
Trigonella foenum-graecum L. (Fenugreek)	Seeds	Hydroalcoholic extract (30:70)	*In vivo*, the extract reduced TG levels (0.49 ± 0.09 g/L) and LDL levels (0.53 ± 0.15 g/L), and increased HDL levels (0.14 ± 0.04 g/L).	Singh *et al.* 2022
Olea europaea L. (Olive)	Leaves	Aqueous and ethanolic extract	*In vivo*, both aqueous and ethanolic extracts showed a significant reduction in TC and LDL-cholesterol levels. Mice treated with the aqueous extract exhibited significantly reduced TG and VLDL-cholesterol levels. A significant increase in HDL-cholesterol levels was observed in mice treated with the aqueous extract.	Cheurfa *et al.* 2019
Curcuma longa L. (Turmeric)	Rhizomes	Turmeric extract	*In vitro*, the *C. longa* L. extract shows higher activity in inhibiting triglyceride and cholesterol synthesis, with inhibition activities of 70.43%.	Budiman *et al.* 2015
Coriandrum sativum L. (Coriander)	Seeds	Powder	The levels of TC and TG decreased significantly in the tissues of the rats fed a high fat diet with added cholesterol the animals of the experimental group which received coriander seeds. Significant increases in β-hydroxy, β-methyl glutaryl CoA reductase and plasma lecithin cholesterol acyl transferase activity were noted. The level of LDL, VLDL cholesterol decreased while that of HDL cholesterol. The increased activity of plasma LCAT, enhanced hepatic bile acid synthesis and the increased degradation of cholesterol to fecal bile acids and neutral sterols appeared to account for the hypocholesterolemic effect of the spice.	Chithra & Leelamma 1997
Cinnamomum verum J.Presl (Cinnamon)	Bark	Aqueous extract	Cinnamon extract significantly lowered the serum levels of TC, LDL and TG in n diabetic rats.	El-Desoky *et al*. 2012
Origanum vulgare L. (Oregano)	Whole plant	Hydro alcoholic extract	*In vivo, Origanum vulgare* extract reduced the levels of cholesterol, TG, LDL and increases the level HDL in three groups of male Wistar rats received the extract at 50, 75 and 100 mg/kg.	Foroozandeh *et al.* 2022

Possible associations

Based on the data collected, it was observed that plants were used either alone (73.58%) or in combination with other plant species (26.42%) (Fig. 6). This result may be explained by the fact that some Individuals prefer to use a single plant if its therapeutic properties are well known, rather than combining multiple plants whose interactions and effects may be less clear. These results are consistent with a survey conducted by El Rhaffari & Zaid (2002) in southeastern Morocco (Tafilalet), where plants were either prepared alone (85.3%) or combined with other ingredients (14.7%).

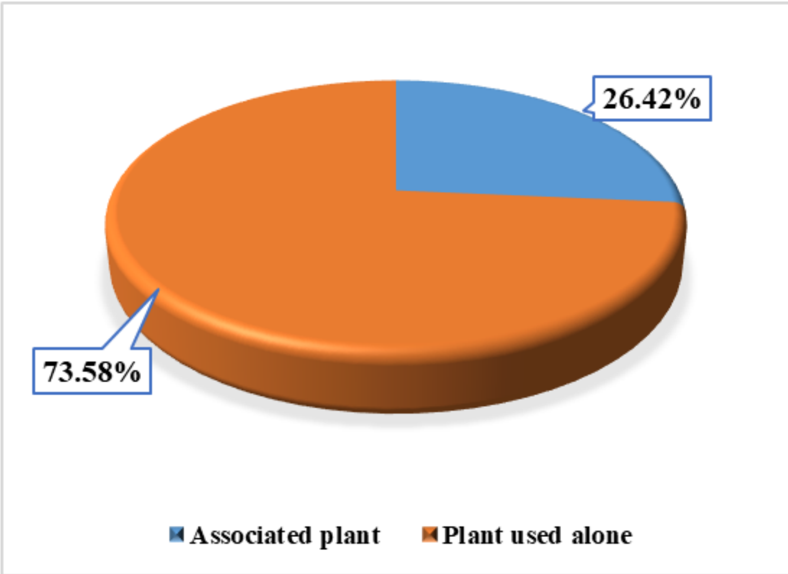

Figure 6. Distribution of respondents using plants alone or in combination

Plant type

Regarding plant type, cultivated plants are widely used in phytotherapy, representing 74.73% of the total species identified. Wild plants come in second, which represent 19.09%. A percentage of 6.18% pertains to plants with an unknown type (Fig. 7). The preference for cultivated plants can be explained by several factors: their accessibility, the knowledge of their medicinal properties, and the ease of controlling their quality, which ensures their purity and the absence of contaminants (pesticides, insecticides, etc.) in these plant species. These results are inconsistent with previous studies conducted in different regions of Morocco (Benkhnigue *et al.* 2023, Katiri *et al.* 2017, Lyoussi *et al.* 2023, Slimani *et al.* 2016).

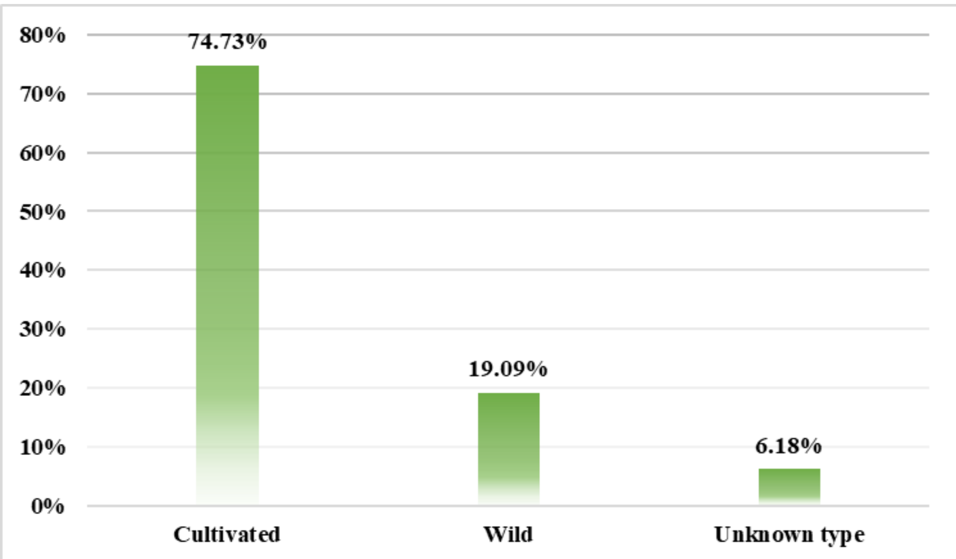

Figure 7. Use of plants based on their type

State of use

The different states of plant used in remedy preparation are illustrated in Fig. 8a. According to the results, the use of dried plants is the most common, representing 53.60% of cases, while the use of fresh plants accounts for 46.40% of cases.

Dried plants offer advantages such as ease of long-term storage, reduced moisture, and the possibility of use at any time. The study conducted by Jaadan et *al*. (2020) in northeastern Morocco indicates that most medicinal plants (91%) are used in their dried state, with 9% used fresh.

After harvest, plants are generally preserved by drying, either in the sun or in the shade. According to the data, 59.39% of plants are used in a dry state after being sun-dried, while 17.77% are dried in the shade. The drying method for the remaining 22.84% is not specified (Fig. 8b). Thus, the results show that most plants are sun-dried. This drying method is common because it is simple and often used to remove moisture from plants. These data align with the study by Belhaj & Zidane (2021). However, it is not the most effective method as it may degrade the plant's constituents due to ultraviolet rays.

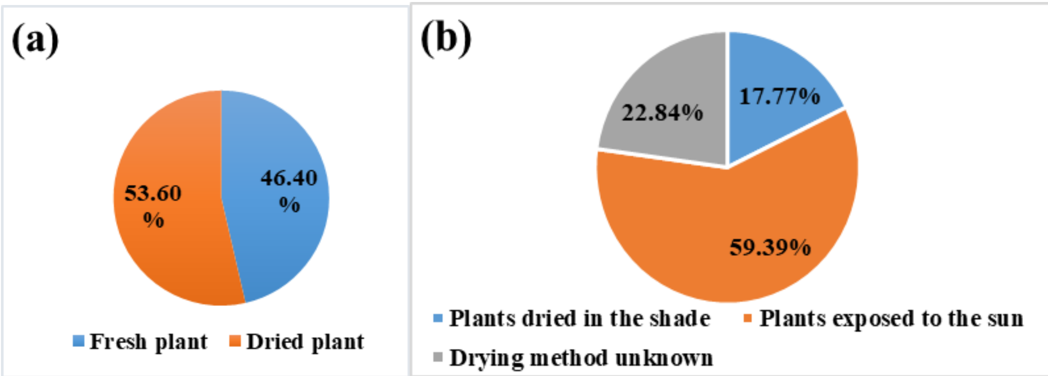

Figure 8. Use of plants based on their state of use (a) and drying method (b)

Conservation method

The analysis of the results presented in Fig. 9a reveals that plant preservation is mainly done away from light, representing 85.02%. About 14.98% of the plants can be preserved while being exposed to light. This can be explained by the sensitivity of plants to light, making it preferable to keep them away from light to ensure their preservation. Additionally, storing plants away from light is preferred for several reasons, including protection against the degradation of chemical compounds present in plants and reduction of oxidation. Indeed, some chemical compounds in plants can undergo oxidation in the presence of light. These results are consistent with the study conducted by Ndjouondo *et al.* (2015), which also found that 90.91% of MP are preserved away from light.

On the other hand, among the cited preservation methods, the conservation in bottles (plastic, glass) represents 50.91%, followed by the conservation in plastic bags with a rate of 39.39%. Paper bags represent 9.70% of the total (Fig. 9b).

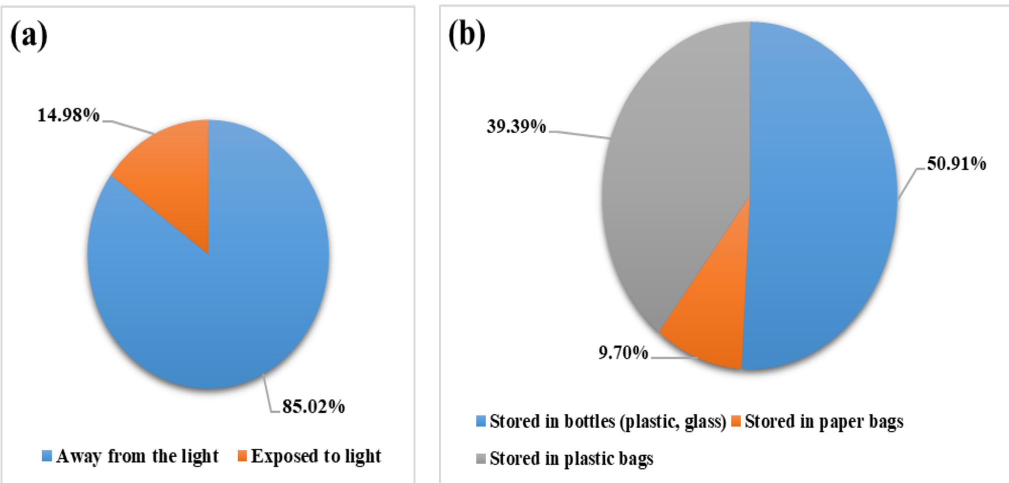

Figure 9. Plant conservation methods according to respondents

Part used

According to the PPV index, the leaves were the most used part in phytotherapy for treating hypercholesterolemia in the studied region, with a PPV of 0.217. They were followed by seeds (PPV = 0.209), fruits (PPV = 0.169), rhizomes (PPV = 0.121), bulbs (PPV = 0.107), whole plants (PPV = 0.056), stems (PPV = 0.046), bark (PPV = 0.032), and other parts such as cladodes, umbels, silk, flower buds, and stamens, which have a total PPV of 0.021 (Fig. 10).

The high frequency of leaf usage can be explained partly by their ease of harvest and partly by their high concentration of active compounds. Indeed, leaves are the site of photosynthesis (Zahir *et al.* 2020) and thus represent the main source of alkaloids, glycosides, and essential oils. Most of these metabolites have biological activities that are often explored in the treatment of many diseases. These results are consistent with those reported nationally (Benkhnigue *et al.* 2023), which indicate that the leaf is the most widely used plant part for medical purposes.

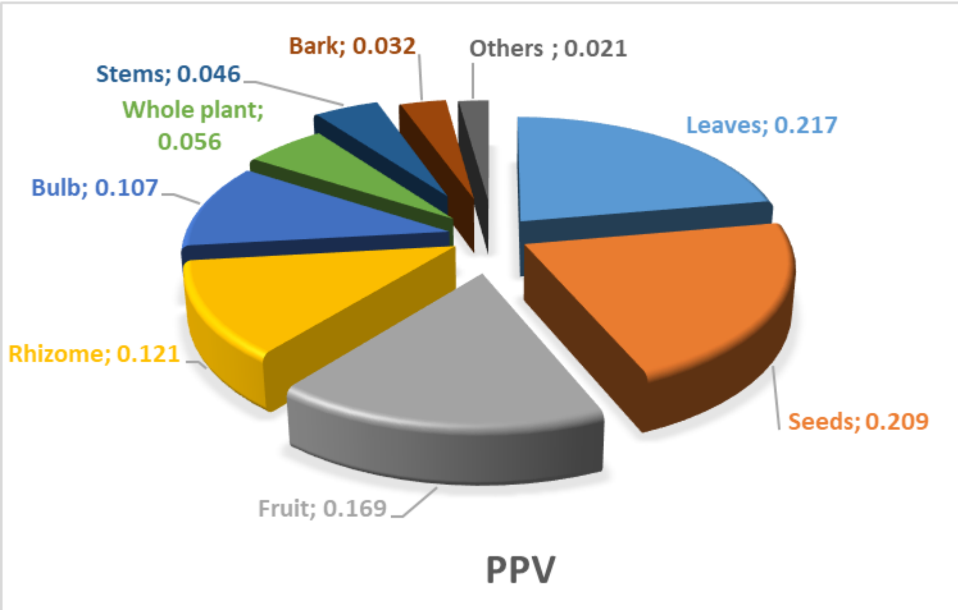

Figure 10. Different plant parts used in the study area and their PPV

Form of use

The survey results show that the most used form is the unchanged form (raw), with a percentage of 31.32%, followed by powder with 25.26% and herbal tea with 22.89%.

These results can be explained by several reasons: the raw form of medicinal plants is often more easily accessible. This situation is similar to what was reported in the study conducted by Lyoussi *et al.* (2023).

Modes of preparation methods and administration

The medicinal plant recipes used vary depending on how they are prepared and administered. To facilitate the administration of the active compounds, various therapeutic practices are employed, such as decoction, infusion, cataplasm, cooking, or maceration. Our observations show that infusion, decoction and cooked plant are the most used methods of preparation, accounting for 15.32%, 14.78% and 13.17% of cases, respectively. Other preparation methods, such as juice, maceration, and distillation, account for a total of 13.98%. These results are in contrast to those obtained by a study carried out by Barkaoui *et al.* (2017), which demonstrated that the population investigated in the regions of Chtouka Ait Baha and Tiznit (Morocco) predominantly uses the decoction method. This same finding was also reported by Benkhnigue *et al.* (2023).

Exclusively, the oral mode remains the primary method of administering herbal remedies according to the respondents. This finding is consistent with the reports by Belhaj & Zidane (2021) and Benkhnigue *et al.* (2023). This means that the oral administration allows for effective absorption of the bioactive substances contained in plants, which may help reduce cholesterol levels in the blood.

Dose used

In the studied region, the surveyed population indicated that medicinal plant remedies are mainly used without a specific dose (78.24%). Notably, approximately 38.99% of plants are used by the spoonful, 34.48% by the handful and 4.77% by the pinch. In contrast, only 21.75% of plant extracts are used with precise doses (Fig. 11).

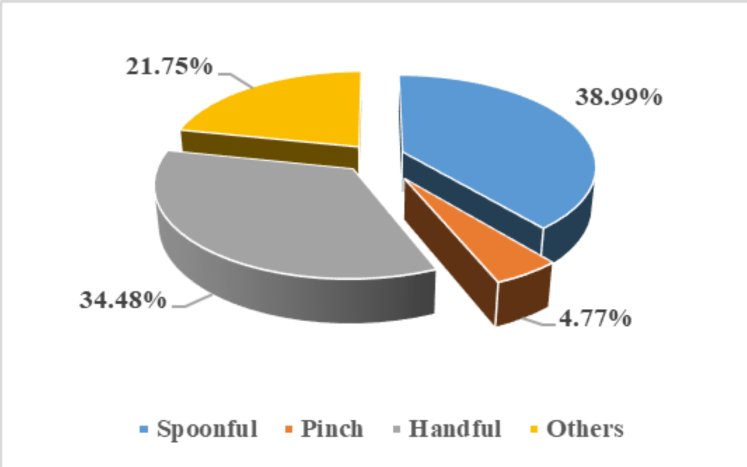

Figure 11. Use of plants based on used dose

These results support a study conducted by Benkhnigue *et al*. (2010) in the Mechraâ Bel Ksiri region. However, it is essential to use plants with a precise dose to avoid potential side effects from overdose, as there is often dose-dependent toxicity (Zahir *et al.* 2020).

Frequency of taking per day

According to the results of our survey, 67.03% opt for a single dose per day, followed by 24.05% who take two doses per day, and 8.92% take three doses per day (Fig. 12). These results are interesting as they provide insight into the dosing habits of the surveyed population. In fact, for some, a single dose per day may be sufficient to achieve the desired effects, while others may require a higher dosage divided into multiple doses. This finding is in perfect agreement with an ethnobotanical study conducted in Rabat, Morocco (Skalli *et al.* 2019).

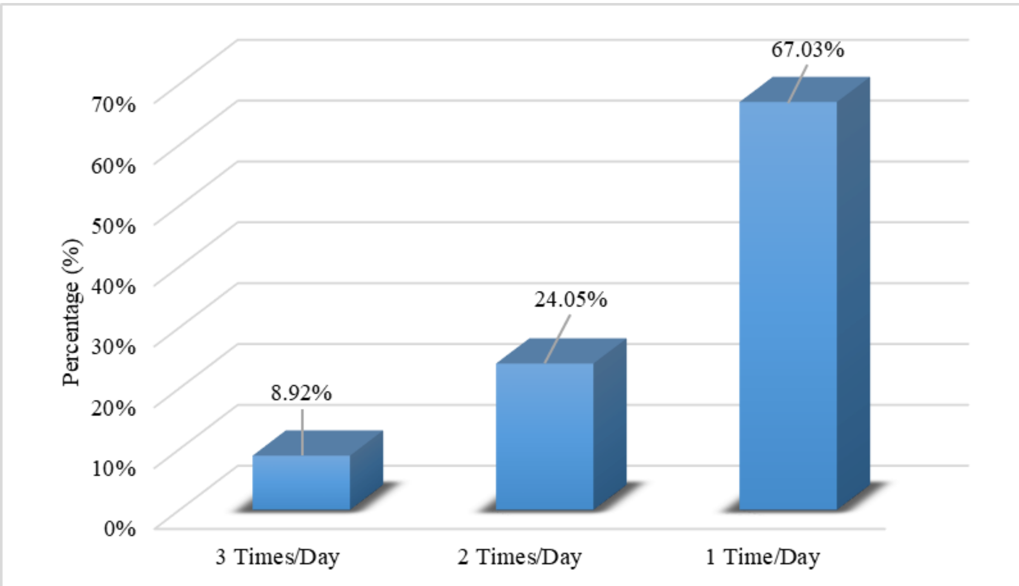

Figure 12. Number of plant intakes per day according to respondents

Timing of intake

The analysis of the different times of intake per day reveals the following percentages: 44.61% of the respondents choose to take their treatment before breakfast, while 9.73% prefer to take it after breakfast. Additionally, 13.11% opt for an intake before lunch, whereas 9.29% choose to take it after lunch. Furthermore, 5.50% prefer to take their treatment before dinner, while 17.76% opt for an intake after dinner (Fig. 13).

Thus, it is observed that nearly half of the respondents choose to take their treatment before breakfast. This may be explained by the fact that it is often recommended to take certain herbal remedies on an empty stomach to optimize their absorption. However, others prefer to take their treatment after breakfast, which may indicate that they need to eat something first, possibly to reduce side effects or gastrointestinal irritation.

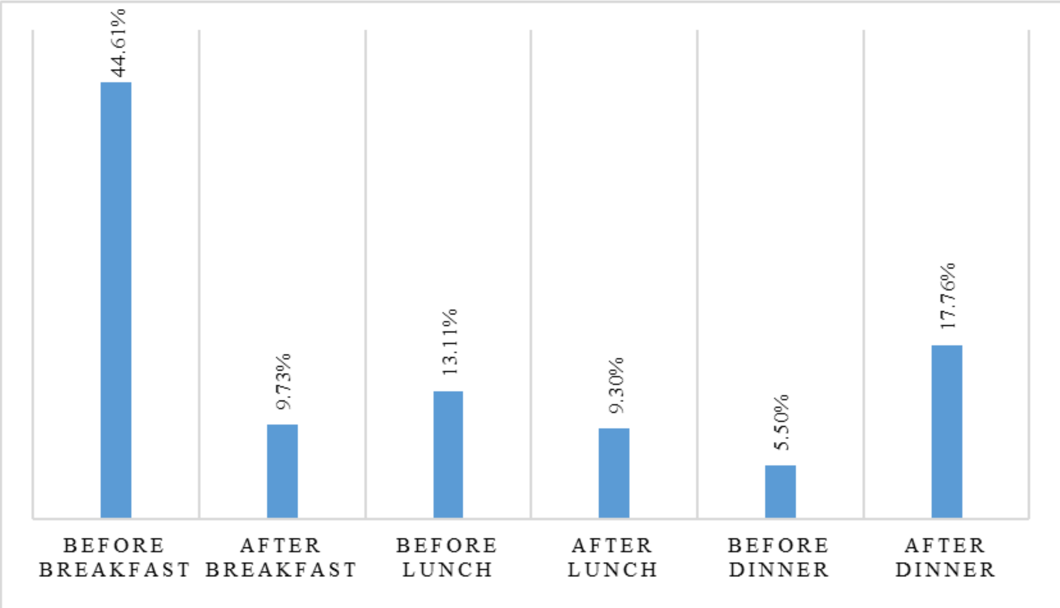

Figure 13. Percentages of different times of intake of herbal remedies for treating hypercholesterolemia

Duration of therapy

The duration of the treatment varies considerably. Thus, the analysis in Fig. 14 indicates that the most common duration is the herbal remedies used by the study population until healing with a rate of 39.19%. Then, the duration of treatment of one month is observed with a rate of 21.08%, followed by the duration of one week which represents 14.05%. The other durations (one day, two days, three days and others) cumulatively account for 25.68%.

These results show that for some herbal remedies, the treatment must continue until the symptoms completely disappear. This data is consistent with the findings mentioned in the study by Chaachouay et *al*. (2020) conducted in the Rif region of northern Morocco. However, it is important to note the use of MP should be limited to avoid potential chronic toxicity caused by the long-term consumption of these plant essences.

Satisfaction after using plants

Regarding the state of satisfaction, 86.52% of respondents believe that MP -based remedies improve their health status, while 7.28% think that these preparations lead to recovery. However, 6.2% of the studied population report that these remedies are ineffective and can cause side effects (Fig. 15).

Thus, it appears that the expectations of interviewees regarding to the results of MP -based remedies differ. Indeed, some may expect a complete recovery, while others consider an improvement in their condition to be a satisfactory result (Laadim *et al.* 2017). This could explain why some believe that the remedies lead to recovery, while others think they are not effective. Furthermore, our results are consistent with those found in other ethnobotanical investigations, where it has been observed that respondents are satisfied with the results obtained after using plants (Chraibi *et al.* 2018, Zahir *et al.* 2020).

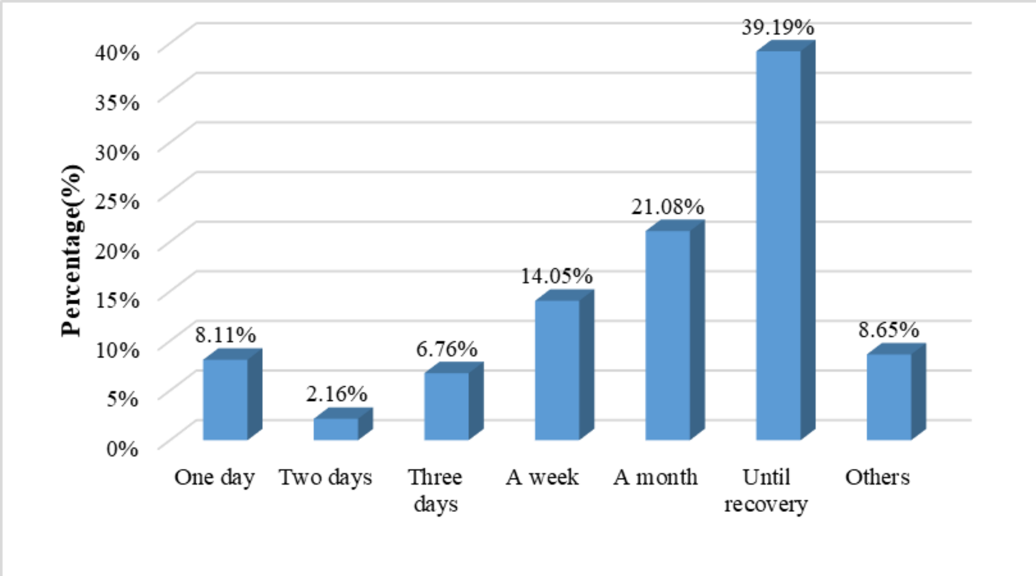

Figure 14. Percentages of different durations of use of herbal remedies

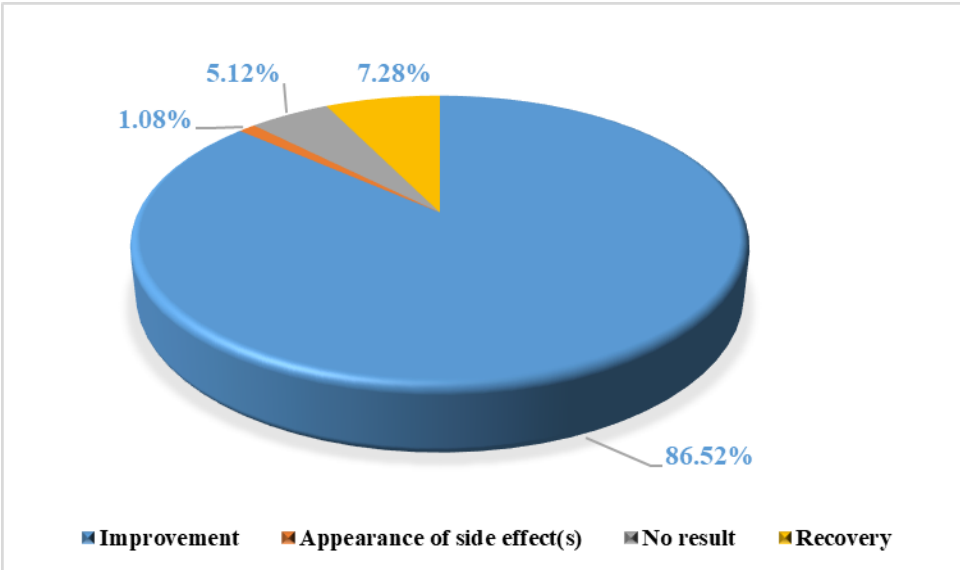

Figure 15. Evaluation of results obtained after using plants

Plant intoxication

The data analysis revealed that most of the surveyed population have limited knowledge about plant intoxication. Indeed, about 78.26% of informants report that the plants they mentioned are not toxic, while 21.74% think otherwise (Fig. 16).

This figure indicates that a significant portion of the respondents is not aware of the risks of intoxication associated with the use of certain plants. This may reflect a lack of information or awareness about toxic plants and the necessary safety precautions. These results are consistent with the study conducted by Salhi et *al*. (2010).

Side Effects of plants

Despite the hypocholesterolemic effects of plants reported by respondents (Table 5), it is important to emphasize that some plants may cause side effects. These effects can vary based on the specific plant, the dosage used, and the health condition of each individual. According to informants, 20 plants can cause side effects such as diarrhea, miscarriage, anorexia, fatigue, weight loss, liver damage, dizziness, etc. (Table 5).

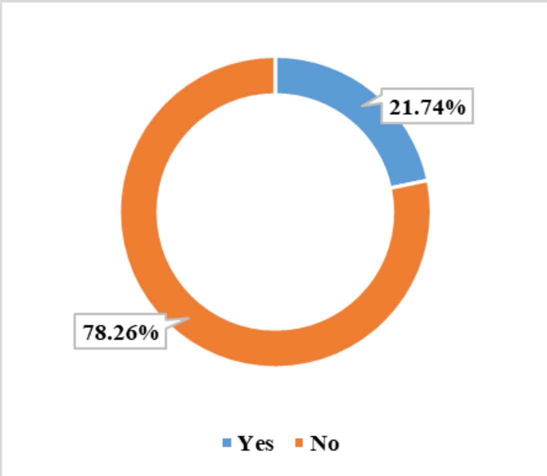

Figure 16. Respondents' statements regarding the potential toxicity of plants used in the treatment of hypercholesterolemia

Table 5. Side effects of plants reported by respondents.

Species	Reported side effect(s)
Allium sativum L.	Hypotension
Camellia sinensis (L.) Kuntze / *Coriandrum sativum* L./ *Panicum miliaceum* Walter / *Solanum melongena* L. / *Zea mays* L.	Weight loss
Ceratonia siliqua L.	Fatigue
Cinnamomum verum J.Presl	Fatigue/weight loss/menstrual disorders
Brassica oleracea var *capitata f. alba* / *Euphorbia echinus* Hook.f. & Coss.	Diarrhea
Curcuma longa L. / *Linum usitatissimum* L.	Diarrhea/weight loss
Malus domestica (Suckow) Borkh.	Gastric ulcer
Olea europaea L.	Liver damage
Cynara cardunculus var. *Sylvestris* (Lam.) Fiori / *Hibiscus sabdariffa* L./ *Ocimum basilicum* L. / *Origanum vulgare* L./ *Tilia vulgaris* B.Heyne	Dizziness
Zingiber officinale Roscoe	Anorexia/weight loss

Indeed, adverse effects have been reported by studies exploring the toxicity of these plants. We are going to focus on examples of the most cited plants in the herein investigations. For instance, garlic has been shown in studies to cause pulmonary, hepatic, and splenic damage, as well as anorexia, gastric irritation, flatulence and anemia, when consumed in high doses (Gatsing *et al.* 2005, Okoroa *et al.* 2023).

Another example to present is that of *Cinnamomum verum*. When consumed in excess, cinnamon can cause respiratory distress, increase pulse rate and increase the sweating process, followed by depressive and drowsy states. This may aggravate the symptoms of rosacea and may increase the risk of developing oral cancer. Coumarin, naturally found in cinnamon, can have a negative influence on the liver, so people with liver disorders should avoid excessive consumption (Sharifi-Rad *et al.* 2021).

Also, it was reported that olive leaves extract should be used with care, especially, when being used at higher doses for longer periods of times as it may have undesirable effects on liver and kidneys (Omer *et al.* 2012).

Furthermore, a few mild side effects such as diarrhea, acid reflux, stomach irritation and IgE-mediated allergies have been associated with the use of ginger in healthy individuals participating in a clinical trial (Hanjabam *et al.* 2023).

Additionally, excessive turmeric consumption may trigger uterine contractions during pregnancy, and may hinder iron absorption. Turmeric has been reported to reduce testosterone levels and sperm motility in men when administered orally and delay blood clotting (Fuloria *et al.* 2022).

Moreover, it has been reported that the seeds of *Coriandrum sativum* can be slightly toxic, causing convulsion, salivation, diarrhea, lethargy in mice (Patel *et al.* 2012).

Increased levels of aspartate transaminase (AST), alkaline phosphatase (ALP) and total bilirubin along with marked hepatocellular degeneration and distortion around the central vein, inflammatory cell infiltration, and cytoplasmic vacuolization of hepatic cells, were observed in mice at higher dose of *Origanum vulgare* (Liaqat *et al.* 2023).

Whereas a few rare cases of poisoning have been reported in animals fed with *Linum usitatissimum* seeds. These animals presented the following symptoms: mydriasis, colic, numbness, acute nephritis, pulmonary edema, accelerated respiration and cerebral hemorrhages (Bellakhdar 1997).

Meanwhile, 72 plants were reported by informants as non-toxic. Nevertheless, the toxic effects of 37 of them have been demonstrated by several investigations. Among these plants, *Trigonella foenum-graecum* (fenugreek) can be cited. Effectively, many teratogenic effects of fenugreek, ranging from congenital malformations to death, have been reported in humans, rodents, rabbits, and chicks. Even more, results obtained in rats, mice and rabbits show a testicular toxicity and anti-fertility, anti-implantation and abortifacient activity in females related to saponin compound of fenugreek with suggest that the underlined plant is not recommended for use during pregnancy (Ouzir *et al.* 2016). Moreover, some cases of diarrhea, flatulence, mild hepatitis, some minor allergic symptoms, and dizziness were associated with fenugreek (Singh *et al.* 2022).

Other than that, other plant species traditionally used as hypocholesterolemiant in the region were reported also as toxic including: *Medicago sativa* , *Nigella sativa* , *Glycyrrhiza glabra* , *Silybum marianum* , *Trifolium sp* , *Vicia faba* (Bellakhdar 1997), *Lepidium sativum* , *Foeniculum vulgare* (Bellakhdar 1997 , Najem *et al.* 2020) , *Tetraclinis articulata* (Zahir & Rahmani 2020), *Portulaca oleracea*, *Dysphania ambrosioides* , *Ammi visnaga* , *Aristolochia longa* , *Matricaria chamomilla* , *Euphorbia resinifera* , *Salvia officinalis* , *Salvia rosmarinus* , *Laurus nobilis* , *Crataegus monogyna* (Najem *et al.* 2020) , *Prunus dulcis* , *Glycine max* , *Capsicum frutescens* , *Mentha spicata* (Kharchoufa *et al.* 2018), *Capsicum frutescens* (Kharchoufa *et al.* 2018) , *Juglans regia* (Panth *et al.* 2016) , *Crocus sativus* (Hammiche *et al.* 2013) , *Lupinus luteus* (Thambiraj *et al.* 2018) , *Caralluma europaea* (Issiki *et al.* 2017) , *Apium graveolens* (Al-Asmari *et al.* 2017) , *Artemisia vulgaris* (Siwan *et al.* 2022) , *Carthamus tinctorius* (Mirhoseini *et al.* 2012) , *Echium vulgare* (Moyano *et al.* 2006) , *Iris* sp. (Khatib *et al.* 2022) , *Thymus vulgaris* (Rojas-Armas *et al.* 2019) , *Abelmoschus esculentus* (Umoh *et al.* 2016) , *Syzygium aromaticum* (Dehghani *et al.* 2012) and *Anemone coronaria* (Laura & Allavena 2007).

Therefore, although these plants have therapeutic virtues, their toxic potential requires vigilance in their use (Najem *et al.* 2019). Certainly, many plants can be dangerous because they contain both beneficial and toxic substances (Azzi *et al.* 2012). Thus, self-medication with these plants may be harmful (Benkhnigue *et al.* 2023). This is why the ethnomedicinal knowledge revealed by this study must be supported by toxicological and pharmacological studies of plants in order to ensure the safety of plant essences while emphasizing the importance of considering the physiological states of the animal organism such as the presence of an allergy terrain, pregnancy and infancy (Zahir & Rahmani, 2020 , Zahir *et al.* 2020).

Consulting a doctor after the onset of side effects

Among those who experienced side effects from herbal remedies, 35% consulted a doctor, while 65% did not (Fig. 17). These results indicate that just over one-third of those affected deemed it necessary to seek medical help after presenting side effects. The decision to consult a doctor may depend on factors such as the severity of the symptoms, confidence in herbal remedies, economic conditions and access to healthcare services.

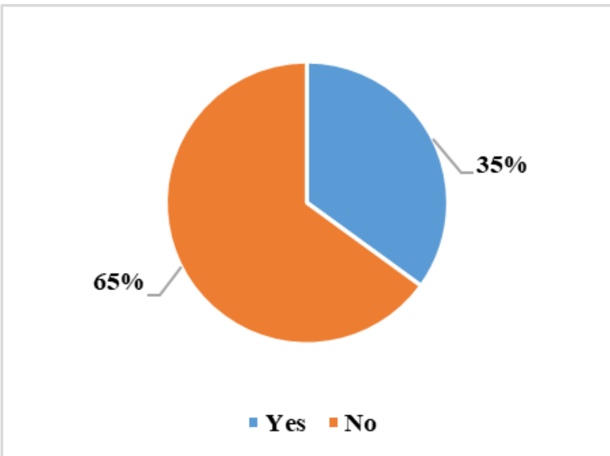

Figure 17. Percentages of respondents who consulted a doctor after the onset of side effects

Conclusion

This study is part of the valorization of Moroccan medicinal plants used in the treatment of hypercholesterolemia. To this end, we conducted an ethnobotanical survey in the Beni Mellal Khenifra region regarding the use of plants with hypocholesterolemic effects through a distributed questionnaire.

The results of this study reveal that the population studied in this region has acquired and possesses significant expertise in phytotherapy. As result, they frequently turn to traditional medicine to treat hypercholesterolemia, with a rate of 79.92%. A total of 92 MPs were identified, belonging to 37 botanical families. The two most frequently cited plant species are *Allium sativum* and *Zingiber officinale*, with RFC of 0.157 and 0.147, respectively. The most mentioned families, according to the FUV, are the Linaceae, which occupy the first place (VUF = 0.105), followed by the Oleaceae (FUV = 0.084), the Zingiberaceae (FUV = 0.077), and the Theaceae (FUV = 0.031).

It is also important to note that 12 species have been inventoried for the treatment of hypercholesterolemia for the first time, including *Tilia vulgaris*, *Anemone coronaria*, and *Iris* sp. Unfortunately, the majority of these plants are used without precise dosage, with 20 species have been reported to cause intoxication. Furthermore, leaves are the most commonly used plant parts (PPV = 0.217).

As a perspective, it would be interesting to extend this study to other regions of Morocco to establish complete monographs and establish a database of plants with hypocholesterolemic effects, especially those that have never been previously investigated. This should be done through appropriate analyses and *in vivo* experimental studies to scientifically validate their use. Additionally, further research is needed to identify the main phytochemical constituents of these plants, followed by the evaluation of their efficacy and pharmacological activities to identify the active compound(s) that may offer curative and preventive properties against cholesterol.

Moreover, data on the toxicity of medicinal plants are essential to ensure the safety of their use, as well as to standardize precise dosages and determine their therapeutic doses.

Declarations

Ethical Approval: All participants provided oral prior informed consent.
Consent to Participate: Not applicable.
Consent for publication: Not applicable
Availability of data and materials: Not applicable
Competing interests: We certify no conflict of interest.
Funding: This study received no particular support from governmental, private, or not-for-profit funding organizations.
Author contributions: WE: data collection, a compilation of literature sources, data analysis, assessment, interpretation, realization of manuscript , IZ: superviser the investigation, design for searching, methodology, contributed significantly to data analysis, review, editing and preparation of the final draft. The final paper was read and approved by all the authors.

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