Comparative ethnobotanical survey of *Pimpinella anisum* L., *Coriandrum sativum* L., *Carum carvi* L. *in* three zones of Morocco: Therapeutic uses, sources of knowledge, and efficacy against diseases and food purposes

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Research

Abstract

Background: This study aimed to compile data on the variation of medicinal uses of three medicinal plants (*Pimpinella anisum* L.*, Coriandrum sativum* L.*,* and *Carum carvi* L.) among local populations in three Moroccan regions.

Methods: Interviews were conducted in seven sites belonging to three regions of Morocco from 2019 to 2020. To analyze recorded data, graphic, descriptive indicators, and multivariate tests were employed. We investigated the responses of participants about therapeutic uses and the factors influencing their responses.

Results: In the research zone, interviews were conducted with 600 persons ranging in age from 20 to 60 years who use *Pimpinella anisum* L.*, Coriandrum sativum* L.*,* and *Carum carvi* L. for therapeutic purposes. The selected plants were used by participants for food purposes (milk flow), cosmetic interests, and therapeutic roles counting digestive disorders, intestinal spasms, laxatives, dysmenorrhea, bloating, intestinal cramps, and antitussive effects. The majority of people only utilize the plants in their dried form, while tisane, powder, and infusion were the most popular usage forms across all analysed sites. The surveyed sites varied in terms of all studied factors, though.

Conclusions: This study could be very helpful in preserving ancestors' knowledge and advancing our understanding of the medicinal plants of Morocco, including the Middle Atlas and the Saiss plain.

Background

Traditional medicine is practiced around the world and is reliant on the local environment's natural resources as well as the knowledge and skills required to use them (Elujoba *et al.* 2005). Since ancient times, man has relied heavily on plants as a source of curative medications, particularly in impoverished homes (Olajuyigbe 2012). There are still many groups all over the world that practice herbal medicine (Kassaye *et al*. 2006). Additionally, 80% of the African population still relies only on medicinal plants for treatment, according to the World Health Organization (2001). Many nations have recently invested a

lot of time and energy into the research of medicinal plants. Chemistry, pharmacology, and botany must all be integrated in the development of new herbal medicines (Wyk 2011; Yusupova *et al*. 2023). Identification and documentation of medicinal plants can be done effectively through ethnobotanical surveys and ethnopharmacological research (Schultz & Garbe 2023).

Due to its geographic location and the effects of several climate types, Morocco boasts a diverse range of flora. Vascular plants are classified into almost 5200 species and subspecies, which are further split into 155 families and 981 genders. There are 900 indigenous species in the flora, which constitutes endemism. On the other hand, there are more than 600 species of medicinal plants in Morocco (Tahraoui *et al*. 2023). These plants are employed for a variety of industrial and medical reasons. In the north of Morocco, the vegetal biodiversity is characterized by the presence of multiple plants in the plains, mountains, and rivers. In addition to their ecological and forage importance, these plants have many uses, traditionally practiced by the local population.

In many Moroccan provinces, particularly in rural areas, the health care system has not yet reached the expected level. Several constraints hinder effective medical supervision of the rural population due to their poverty, harsh geographical location, and unbalanced spatial distribution of health facilities, which are concentrated in urban areas. Faced with this situation, and due to the poverty of the major households in the area, the rural population is depending more and more on this traditional medicine. Equally, the abundance of medicinal plants in rural areas, their low cost, and their curative efficacy promote their usage for therapeutic purposes. However, in some cases, this traditional knowledge is monopolized by a small part of the population who doesn't share it with the rest of the community, which is currently threatening the continuity and guarantee of this knowledge transmission (Salawu *et al*. 2023). Therefore, the documentation of medicinal plants via laboratory and ethnobotanical studies is crucial in order to transmit this knowledge and traditional techniques to a large spectrum of scientists and informants.

In this study, we aimed to explore the culinary and medicinal uses of three medicinal plants, including anise seed (*Pimpinella anisum* L.), caraway (*Carum carvi* L.) and coriander (*Coriandrum sativum* L.), in different regions of Morocco. In detail, we aimed to: i) identify the medicinal uses of these plants depending on the plants and the sampling sites; ii) characterize the used parts, use forms, and use mode for each plant; and iii) investigate the efficacy of plants against treated diseases and the side effects of each species (toxicity) among the interviewed participants. In this study, we targeted the populations in seven cities from three regions: Taounate and Taza from the Northern region, Meknes and Fez from the plain of Saiss (central region), and Immouzzer, Sefrou, and Ifrane from the Middle Atlas region. These medicinal plants are well known for their biological properties in the laboratory (Hajlaoui *et al.* 2021; Es-safi e*t al.* 2021; Nouioura *et al*. 2023), while no study had addressed deeply their therapeutic uses among the populations of the Morocco and North Africa. Therefore, this study is suggested to present new and comparative data on their traditional uses among the populations of sampled sites.

Material and Methods

Study areas

Fig. 1 displays the sampling sites, including Taounate and Taza from the Northern region, Meknes and Fez from the plain of Saiss (central region), and Immouzzer, Sefrou, and Ifrane from the Middle Atlas region. These regions are characterized by different climatic and topographic contexts. The Middle Atlas is a hilly region defined by a semiarid climate. The average annual rainfall is estimated at 364 mm, while the average temperature is estimated at 5.3-35 °C annually (Linares *et al*. 2013). The winters are severely cold and snowy, while the summers are moderately hot. The Saiss Plain is located in central Morocco and covers an area estimated at 40.075 km^2, which represents 5.7% of the country's area. The average annual temperature is estimated at 7-45 °C, while the average rainfall is estimated at 490 mm (500 mm in Fez and 600 mm in Meknes) (El Garouani *et al*. 2021). The winters are cold and rainy, while the summer is severely hot during July and August. The northern region is dominated by the Mediterranean climate due to its location in the south of the Mediterranean basin. This zone is characterized by rainy winters, while summers are hot and dry. The average annual temperature is estimated at 17 °C, while the average annual rainfall is estimated at 700 mm.

The recorded climatic conditions and topographical characteristics in the studied zones support an important vegetal diversity. Further, there are many important medicinal plants, including *Pistacia Atlantica Desf.*, *Thymus algeriensis*, and *Thymus zygis* from the Middle Atlas (Hachi *et al*. 2016), *Origanum vulgare L.* and *Teucrium fruticans L.* from Saiss Plain, and *Carum carvi* L., *Coriandrum sativum L.*, and *Pistacia lentiscus* L. from the North of Morocco (El-Hilaly *et al*. 2003).

Data were collected from seven cities, including Taza and Taounate in the north of Morocco, Azrou, Ifrane, Immouzar, and Sefrou in the Middle Atlas, Fez and Meknes on the Saiss plain, and we selected this number of cities, characterized by

different climatic conditions and geographical locations, to provide accurate and representative data on the use of medicinal plants in the entire country of Morocco.

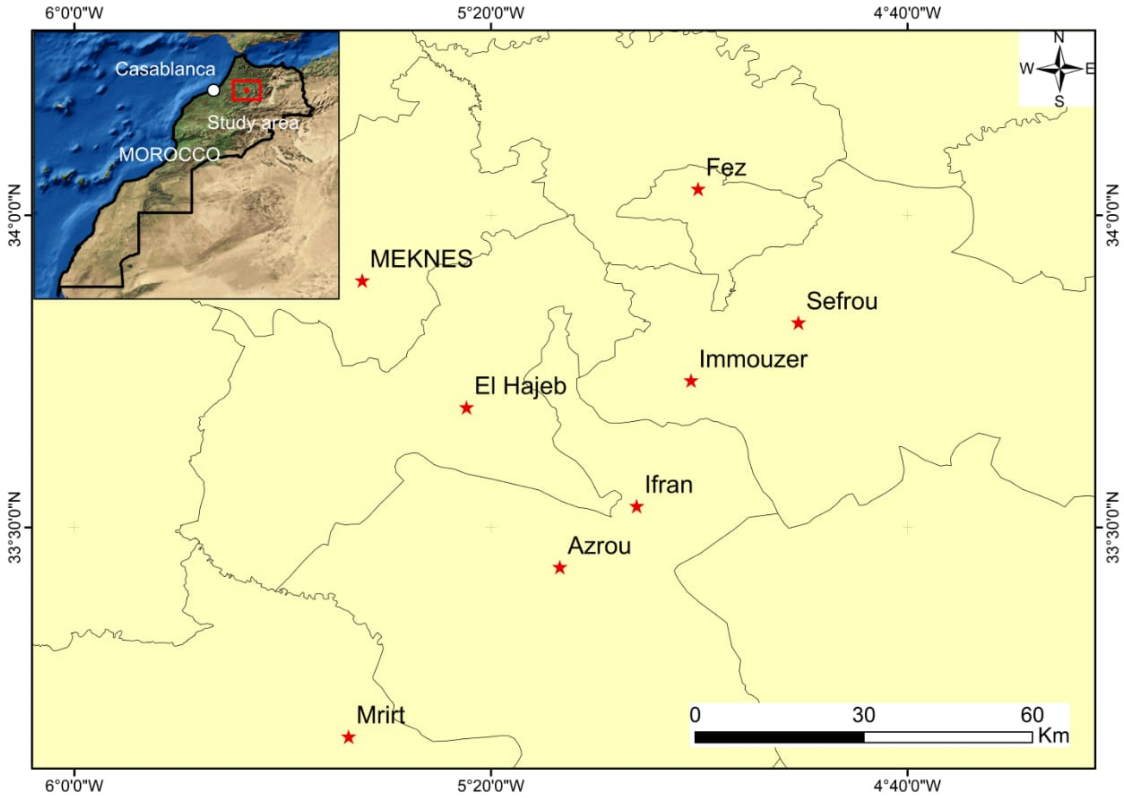

Figure 1. Samples sites from North, Plain of Saiss, and Middle Atlas (Morocco)

Data collection and interviews

The ethnomedical investigation was conducted for one year, from 2019 to 2020. This period was selected to cover the entire sampling zone. In order to carry out the goals of this survey, a questionnaire was created and disseminated around the sampled sites. We aimed to collect the maximum amount of data on the uses selected for each planned site. Therefore, the questionnaire was divided into six principal sections: i) biographical details of targeted populations (surname, first name, sex, age, education, family, etc.), ii) information about the study plants (knowledge and source of information); iii) therapeutic uses of each medicinal plant, and iv) usage forms, modes, and parts for each species; v) effects of the used plants on the health of participants (cure, toxicity, and side effects), and vi) storage conditions for each species. According to Daget and Godron (1982), the ethnomedical surveys were carried out using a random and stratified sampling approach, allowing for the use of a representative sample.. The most thorough inventory can be obtained using this technique (Lahsissene *et al*. 2009). Then, the questionnaire was distributed among the populations of the sampling sites. Using the Plant List website, all species' scientific names were reviewed and revised (Rivera *et al*. 2014). Additionally, the WHO's taxonomy of world illnesses was applied (Staub *et al*. 2015).

Statistic tests

Recorded data for each parameter was organized in Microsoft Excel before analysis. In addition, we calculated the percentages for each parameter. We calculated the percentage for five age categories (number of participants for each age category ⁄ total number of participants), educational levels (primary, college, high school, university, and illiterate), family situations (married, single, and divorced), and health disorders among participants. Similarly, we calculated the percentages for therapeutic uses, used parts, usage modes, and therapeutic effects for each medicinal plant. Then, we tested for the normality of the data via the Shapiro-Wilk test before starting the statistical analysis. A paired T-test was used to compare parameters with two groups of data, including knowledge of the plants, use form (dried or fresh), and use dose (precise or inaccurate). Parameters with three or four groups (source of information, preparation modes, and use form) were compared with an ANOVA one way test. Parameters with up to five groups were compared with the multiple range test.

To investigate the effect of sampling site (n= 7) on the age of participants (n= 5), sources of information (n= 4), therapeutic uses (n=12), used parts (n= 5), preparation modes (n= 3), and forms of use (n= 4) we used the Correspondence Analysis Test

(multivariate statistics). The sampling sites were considered as factors, while the other parameters were considered dependent variables. In Correspondence Analysis plots we considered axes with eight values greater than 1 and a superior percentage of inertia. All statistics were done in IBM SPSS 25 software.

Results and Discussion

Demographic features of Participants

In total, 600 informants in the research area were questioned; the results are displayed in Fig. 2. The ages of the questioned participants ranged from 20 to 60 years old, though the percentage of each age category was variable. The category of age between 51 and 60 years old was the most recorded among participants, with 26%. Further, 22.67% and 22.33% of participants have the age categories 31-40 and 41-50 years old, respectively. The ages between 20 and 30 and up to 60 years were the least recorded among the interviewed participants, with 13% and 16%, respectively. Further, the age of the investigated populations among the sampled sites. Ifrane, 51-60 years old was the most dominant category, while age of >60 years old was dominant in Sefrou and Meknes. In Immouzer, the age category 20-30 was the most recorded among the explored participants. The participants in Fez were dominated by those aged between 31 and 40 years old. In Taza and Taounate, the age category of 41-50 years old was the most prevalent among the interviewed participants (Fig. 3).

In terms of gender, men dominated the participants with 57.33%, while women represented only 42.67% of the participants. Additionally, only 10.83% of participants were divorced, compared to 32.25% of participants who were single. In contrast, the majority of participants (67.67%) were married. On the other hand, the percentages of education levels were different among participants. Additionally, 35.33% of participants were illiterate, with 29.33% having college-level literacy. Primary level was present in 23.5% of participants, followed by 12.33% with high school diplomas. Similarly, the education levels of populations were variable among the sampled sites. Participants with secondary levels and illiterates were the most observed in Ifrane, Sefrou, Taounate, and Immouzer. The university level corresponds to Taza and Taounate (Fig. 4).

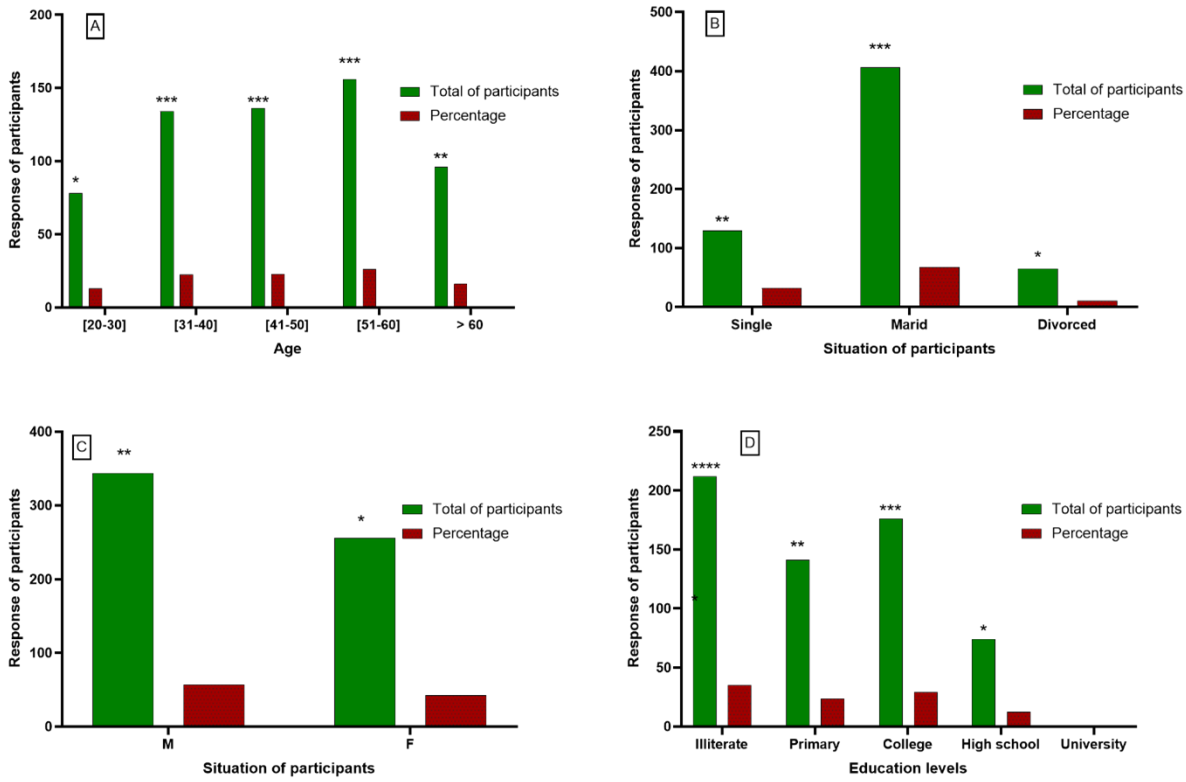

Figure 2. Demographic features (A: Age; B: Family situation; C: Gender (M: mens and F: women); D: Education level) of interviewed populations (* denote statically different; *<**<***)

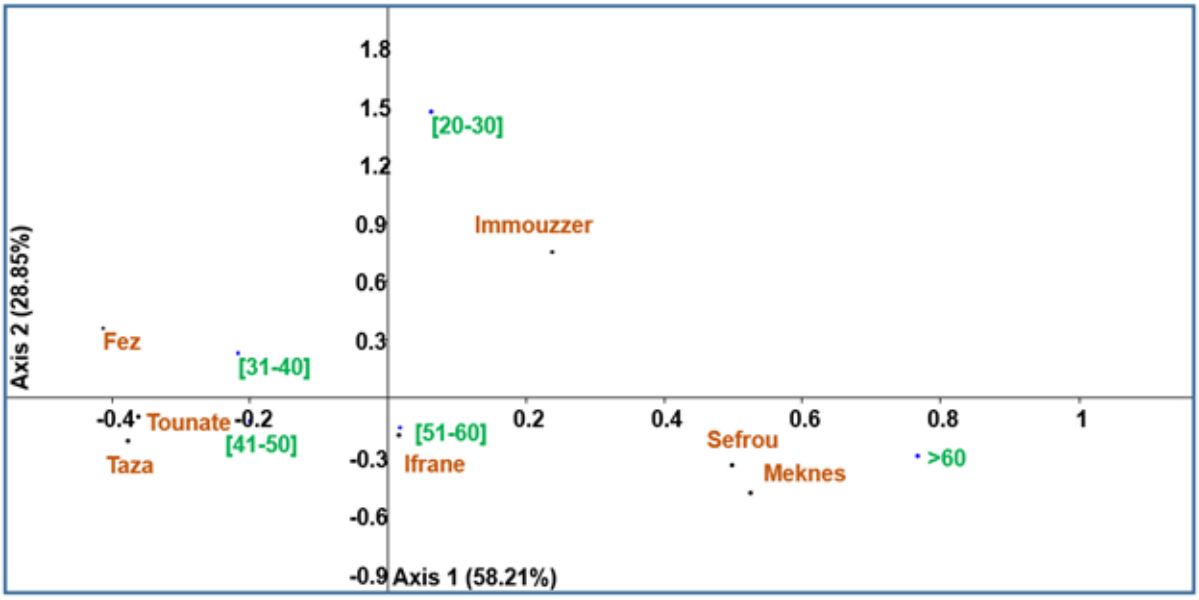

Figure 3. Variation of age categories among interviewed populations depending on sampling sites

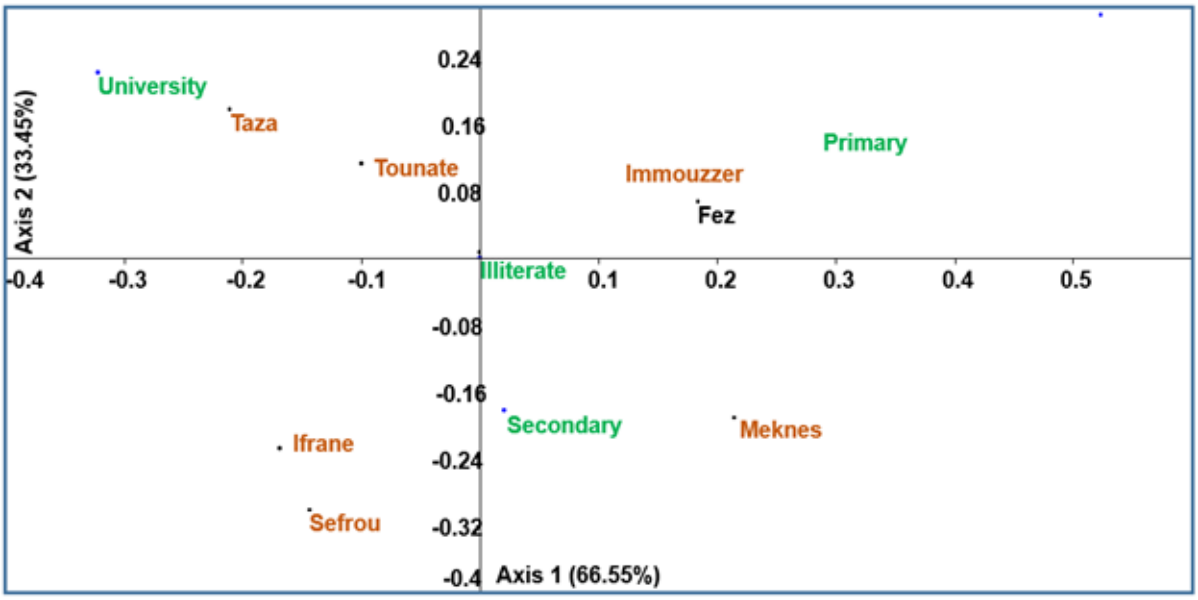

Figure 4. Variation of education levels among interviewed populations depending on sampling sites

A lot of ethnomedical research has been done in the same areas on different aspects of medicinal plants, such as Middle Atlas antidiabetic herbs (Hachi *et al*. 2016), the economic value of medicinal plants in Taounate province (El-Hilaly *et al*. 2003), and the use of medicinal plants to treat serious digestive problems in the Fez-Meknes region (Es-Safi *et al*. 2020). These studies have addressed the demography and status of these populations. Es-Safi *et al*. (2020) mentioned that the age of populations in Fez-Meknes is variable between 20 and up to 60 years old, with the dominance of the 20-40 and 40-60 categories at 44.75% and 37.35%, respectively. In terms of education levels, illiterates and primary school students were dominant with 36.11% and 25.62%, while gender was dominated by women with 54.63% compared to 45.37% for men. In another study, the therapeutic plants utilized by diabetes patients in the Fez-Meknes region were researched by Mechchate *et al*. (2020), who also noted the range in patient ages from 25 to >65 years old with the dominance of 50-65 years at 53.10%. The majority of patients were married (88.10%), while the education level was dominated by illiterate elementary students (65.70% and 25.80%, respectively). Najem *et al*. (2020) investigated the ethnobotanical treatments of oral disorders among 58 herbalists in the Central Middle Atlas, dominated by men (87.40%) and recorded the variation of ages from <30 to >60 years old, with the dominance of 50-60 and over 60 years with 30.37% and 24.36%, respectively. In terms of education level, participants with secondary education were dominant (42%), followed by primary education (28%. In the northern zone of Morocco, Bencheikh *et al*. (2021) investigated medicinal plants used conventionally to treat kidney diseases among 12 health

herbalists and 476 non-specialists. The results revealed the variation of age from less than 25 years to more than 65 years, with a dominance of 46-65 (53%) and 25-45 years (27%), while gender was dominated by women (58%) compared to men (42%). The illiterate (59%) and those with only a secondary education (17%) dominated the education level. The analysis of all these previous studies showed that the demographic characteristics of participants varied depending on the sampling sites and studied topics, which agrees with our results. However, our study investigated the variation of demographic features on a large scale (600 participants) in seven sites belonging to three regions of Morocco, which is more representative compared to small-scale investigations in the bibliography.

Well-being of participants

Fig. 5 shows the health and illnesses of the people that were interviewed at the studied sites. Only 29.66% of the 600 participants were healthy, while 69.44% were suffering from at least one disease. There were various percentages of four diseases among the unhealthy participants. Further, high blood pressure dominated all diseases with 21.83% of cases, followed by diabetes in 20.17% of participants. Digestive problems were recorded in 19.5% of participants, while cardiovascular issues were recorded in a small number of participants, estimated at 8.83%. On the other hand, the recorded diseases had a different distribution at each site that had been sampled (Fig. 6). In Taza, stomach issues were most frequently reported, but in Immouzer, participants' high blood pressure levels were most frequently noted. In Taounate, Ifrane, and Meknes, diabetes and cardiovascular disorders were most frequently reported. The healthy individuals, on the other hand, were not associated with any particular site because they dominated all places.

Numerous investigations have looked into disorders that affect people who utilize medicinal plants in different zones of Morocco (Chaachouay *et al*. 2019, 2020; Bencheikh *et al*. 2021; Mohamed *et al*. 2022; Benkhnigue *et al*. 2023). These studies reported the presence of various diseases among participants, including anemia, cancer, dermatological diseases, liver diseases, insomnia, asthenia, and oral and gum infections. However, these diseases were distributed in different regions of Morocco. For example, among 600 participants (users of medicinal herbs) in the Tarfaya Province, Idm'hand *et al*. (2020) found that the prevalence of gastrointestinal ailments (31.96%) and genito-urinary problems (12.19%) was different from our findings. In this study, we showed that among participants, diabetes was the most often reported illness, while the other diseases were distributed differently depending on the sampled site. In the same sense, El-Hilaly *et al*. (2003) revealed stomach issues as the most dominant illness in the Taounate region (North Morocco), which are also treated with medicinal herbs. The most frequently reported illnesses in El Jadida (Northwest Morocco) were digestive problems, which participants primarily treated with traditional medicine (Briguiche and Zidane 2016). In the Middle Atlas, Chaachouay *et al*. (2022) reported the use of medicinal plants to treat various diseases such as diarrhea, anthelminthic infections, and indigestion. Ajjoun *et al.* (2022) reported the use of medicinal plants to treat skin diseases among the populations of entire Morocco. These confirm the variation of illness from one site to the next, as we recorded in our study (Missoum et al. 2019; Touiti et al. 2020; Idm'hand et al. 2020). This spatial variation could be governed by the health infrastructure or alimentary practices in each area (Wilson et al. 2017; Przybyłowicz and Danielewicz 2022). For example, Vitale *et al*. (2020) demonstrated that pasta consumption and related dietary habits influence cardiovascular risk factors in people with type 2 diabetes. Equally, the age of populations could interfere with the type of disease (Forni *et al*. 2019; Hou *et al*. 2019).

Source of information on medicinal benefits of plants

Fig. 7 displays the knowledge of studied medicinal plants among investigated populations. The majority of participants are aware of the studied medicinal plants. Further, 100% of the participants knew *Pimpinella anisum L.* and *Coriandrum sativum L.* compared to 85% of *Carum carvi L.* In contrast, only 14.44% of participants know *Carum carvi L*. The sources of information about the studied plants are presented in Fig. 7. The participants mentioned different sources of information about each medicinal plant. In *Pimpinella anisum L.*, the most important sources of information were herbalists (55.5%), other sources (30.5%), and the media (14.5%). Similarly, herbalists were the principal source of *Carum carvi L.*(52.5%), followed by other sources (21.16%) and the media (12.16%). The herbalists were the principal source of information about *Coriandrum sativum L.* with 60.84%, followed by others with 27% and the media with 12.16%. However, these sources vary depending on the sampling site.

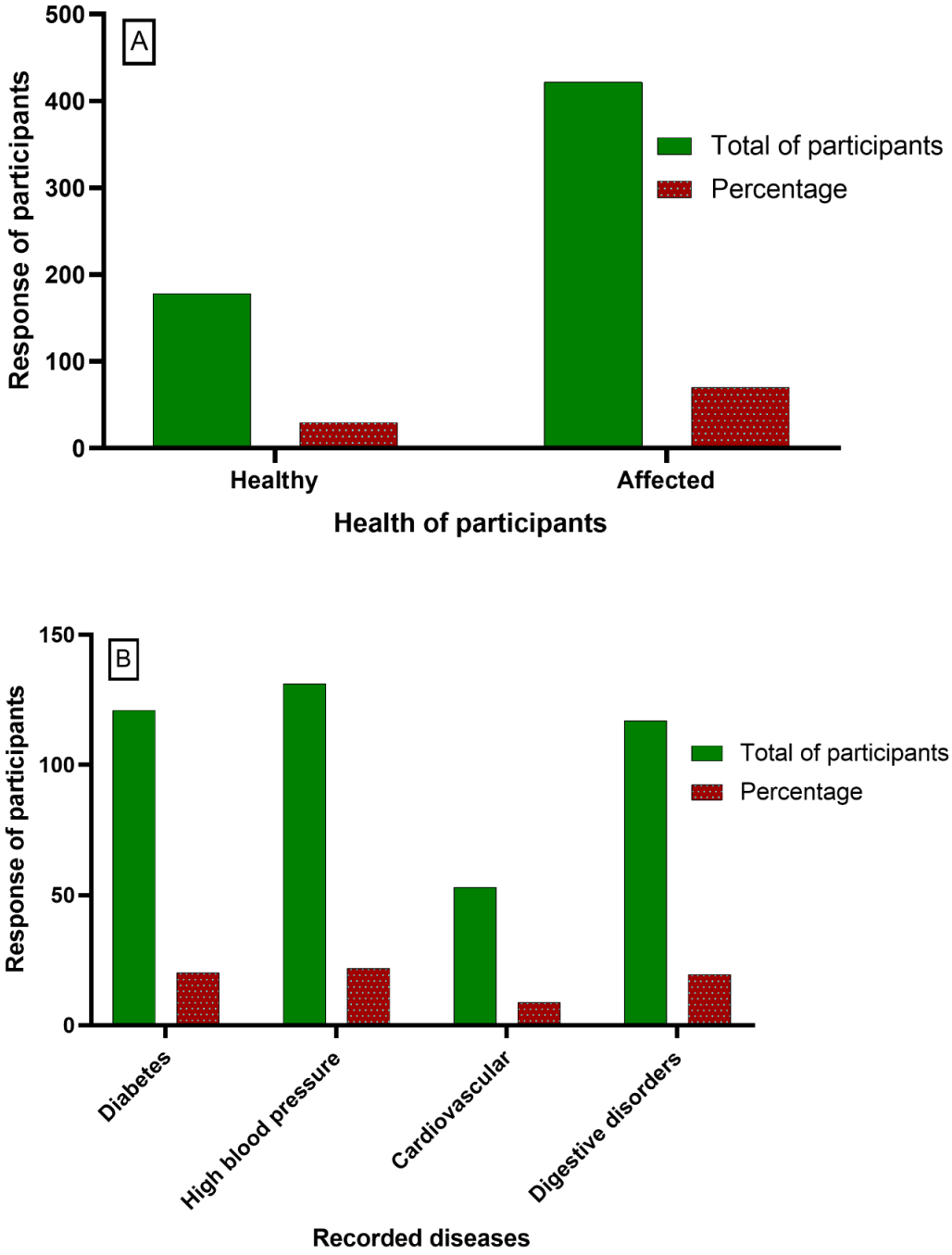

Figure 5. Health status (A) and recorded diseases (B) among interviewed participants

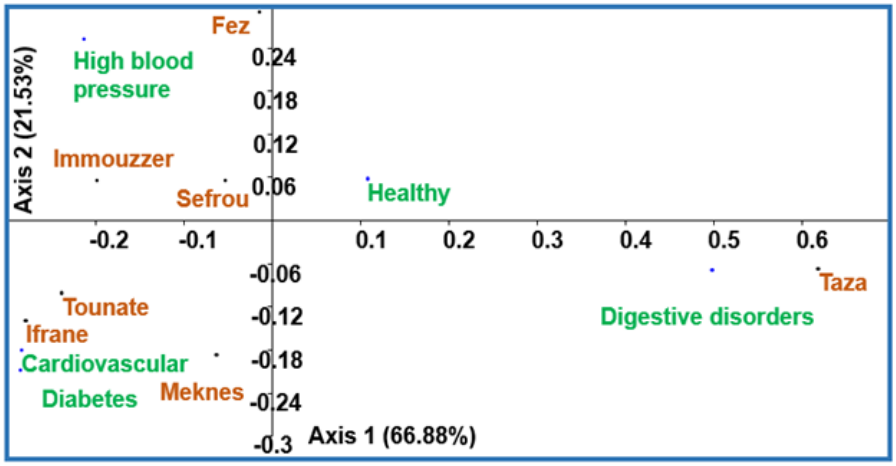

Figure 6. Geographical distribution of recorded diseases among populations of sampled sites analyzed with CA

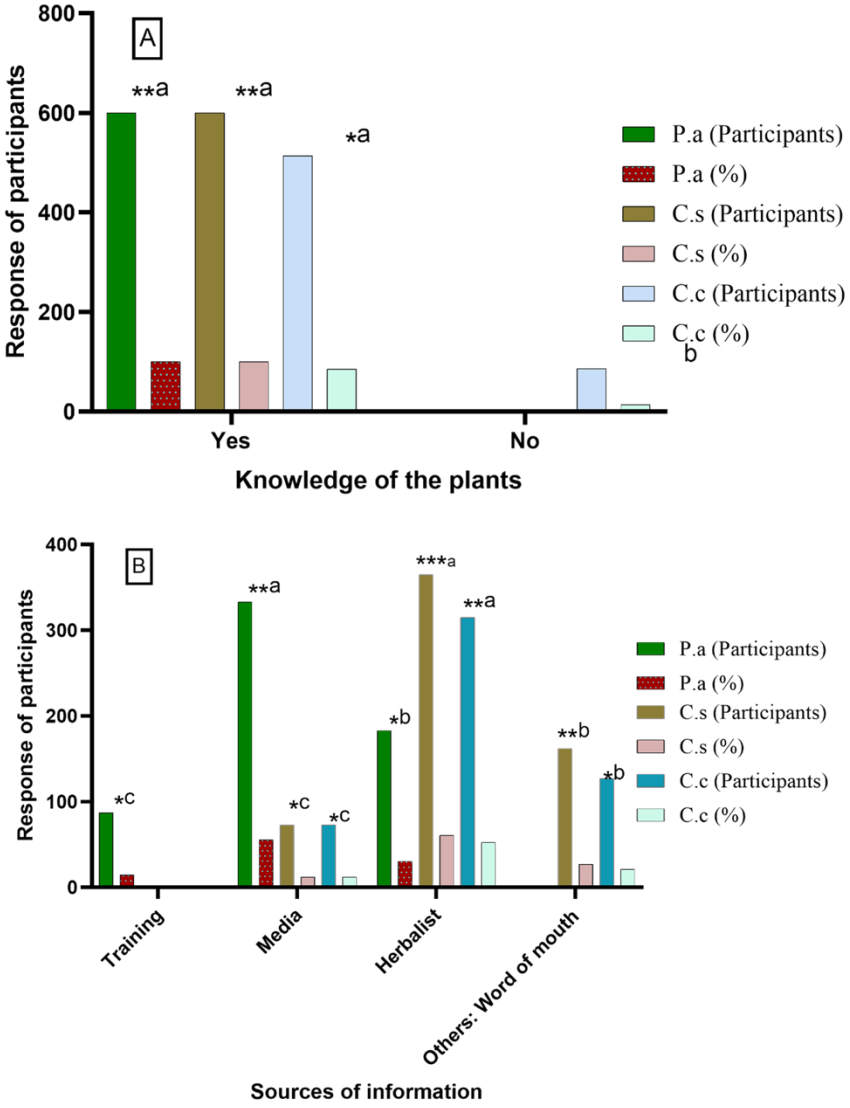

Figure 7. Knowledge of the plants (A) and Sources of information (B) (* denote statically different; *<**<*** (comparison of participants among species for the same source of information), a<b<c<d (comparison of participants from source to another for the same species))

The source of information is the channel through which the therapeutic practices of traditional medicine are transmitted from one generation to another among populations (Bencheikh *et al*. 2021; Eshete and Molla 2021). In Morocco, many studies have addressed the transmission of traditional knowledge about medicinal plants (Chaachouay *et al.* 2020; Achour et *al.* 2022; Lemhadri *et al.* 2023). For example, Es-Safi *et al*. (2020) and Finou *et al.* (2023) investigated the source of information on medicinal plants used to treat acute digestive system problems in the Fez-Meknes region. In the results, many sources were mentioned with various percentages; the most important were other people's experiences at 48.5%, followed by traditional health practitioners at 45.5%, then virtues explored by themselves at 3%, the internet at 2.4%, and finally books (0.6%). In another study, Mechchate *et al*. (2020) reported various sources of information, counting other experiences (84.8%), herbalists (6.2%), the internet (5.3%), exploring by themselves (2.0%), and books (1.7%). Similar results were reported by Benkhnigue *et al*. (2014) in the Al Haouz-Rhamna region on plants used to treat diabetes.

Concerning the studied plants, Soussi *et al*. (2023) investigated the source of information about the therapeutic uses of *Pimpinella anisum L.* in different areas of Morocco. The recorded results showed that the principal sources of information were media, counting TV, radio, and social networks with 68.24%, followed by educational training with 15.29%, while families and between friends' discussions, books, represented only 16.47%. Further, *Carum carvi L.* was reported as one of the plants used by Afghan refugees in the Northwest of Pakistan, and the know-how was related to the dietary habits of the participants (Shah *et al*. 2023). However, the *Carum carviL.*is widely known in traditional medicine in Asia, counting India, Iran, Pakistan, and Afghanistan (Amiri and Joharchi 2016; Singh *et al*. 2016), Europe, such as Ukraine and Italy (Leporatti and Ghedira 2009; Pieroni and Sõukand 2017), and Africa counting Morocco (Najem *et al*. 2019) and Tunisia (Leporatti and Ghedira 2009). Concerning coriander (*Coriandrum sativum L.*), information on the therapeutic roles of this annual has been available since ancient times (Khan *et al*. 2014; Sobhani *et al*. 2022). It is used by a wide range of populations to treat different diseases, including intestinal disorders as mentioned in Colombia (Paniagua-Zambrana *et al*. 2020), diseases of the gastrointestinal system as reported in India (Sivasankari *et al*. 2014), and diabetes in Morocco (Skalli *et al*. 2019).

Curative uses of medicinal plants

Therapeutic uses of studied medicinal plants are presented in Table 1. In total, the investigated plants were used in the treatment of eight health troubles, two for food purposes, and one for cosmetic role. However, these roles were variable depending on the plant and sampling area. *Pimpinella anisum L.* is used to treat three diseases with different percentages. Further, 34.85% of participants used it to treat dysmenorrhea, followed by anti-constipation uses for 33.02% of participants, 21.31% used it in antitussive roles, and only 10.82% used it as a promoter of milk flow (food purpose). *Carum carvi L.* was used by 44.51% of participants to treat bloating and cramps in the intestine, 43.97% to treat digestive troubles, and 11.51% to favor lactation and regulate menstruation. In contrast, *Coriandrum sativum L.* was used by 42.5% of participants both digestive troubles and spasms in the intestine, followed by antidiarrhea roles for 38.25% of participants, while alimentary roles were limited to 19.25% of participants.

Table 1. Principal therapeutic uses of studied medicinal plants

In terms of sampling sites, *Pimpinella anisum L.* is used principally to treat dysmenorrhea in Meknes, as a promoter of milk flow in Taza, as an anti-constipation agent in Ifrane and Immouzer, and as an antitussive in Taounate and Sefrou. In Ifrane, *Carum carvi L.*is mostly used to treat bloating and intertinal cramps; in Meknes and Taza, it is used to treat digestive disorders, in Fez and Immouzzer, it is used in cosmetic and other roles, and in Taounate, *Carum carvi L.*is used to promote lactation and regulate menstruation. *Coriandrum sativum L.* is used to treat digestive disorders and intestinal spasms in three sites (Meknes, Ifrane, Immouzzer, and Sefrou); in Taounate, it is used as an antidiarrheal agent; and in Taza and Fez, it is used for cosmetic, food, and other purposes (Fig. 8).

Table 1. Principal therapeutic uses of studied medicinal plants

Therapeutic uses	Anti-constipation	Dysmenorrhea	Promotes milk flow	Antitussive	Others	Digestive disorders	Lactation and menstrual regulation	Bloating and intestinal cramps	Cosmetic	antidiarrheal	Digestive disorders and intestinal spasms	Food
Pimpinella anisum	33.02%***	34.85%***	10.82%*	21.31%**	0	0	0	0	0	0	0	0
Carum carvi	0	0	0	0	0	43.97%**	11.51%*	44.51%**	0	0	0	0
Coriandrum sativum	0	0	0	0	0	0	0	0	0	38.25%**	42.5%****	19.25%*

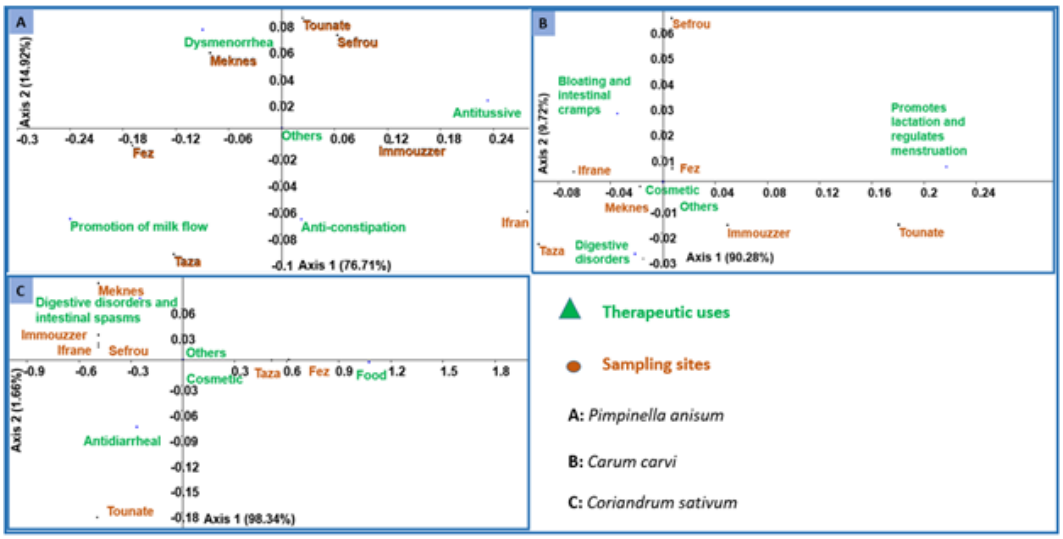

Figure 8. Therapeutic uses of medicinal plants depending on sampling sites

Carum carvi, *Coriandrum sativum L.*, and *Pimpinella anisum L.* are among the most popular species used worldwide for many purposes (Khalili *et al.* 2022; Santibáñez *et al.* 2023). Their therapeutic uses vary depending on the geographical area, availability, health status, and knowledge of the population. In Rabat (Northwest Morocco), *Coriandrum sativum L.* is traditionally used to treat diabetes (Skalli *et al*. 2019), while in Agadir (southwest Morocco), it is reported that the plant is used in food receipts (Ouhaddou *et al*. 2014). Kothalawala *et al*. (2020) reported the use of *Coriandrum sativum* L. in traditional Sri Lankan concoctions to improve immunomodulatory activity. Chew *et al*. (2022) mentioned the benefits of *Coriandrum sativum* L. in food ingredients and its capacity to manage atopic dermatitis A. *Carum carvi* L. or caraway, is a common household plant grown around the world (Miraj and Kiani 2016). Caraway fruits are used as flavoring agents in foods and beverages and have various traditional uses in ethnomedicine. *Carum carvi L.*is reported to be useful for digestive problems including heartburn, bloating, gas, loss of appetite, and mild spasms of the stomach and intestines (Saghir *et al*. 2012; Lim 2013). The oil of *Carum carviL.*is also used to help people cough up phlegm, improve control of urination, kill bacteria in the body, and relieve constipation. Women use the oil of caraway to start menstruation and relieve menstrual cramps; nursing mothers use it to increase the flow of breast milk (Munshi *et al*. 1990; Sofi *et al*. 2009). Caraway is used in mouthwashes and skin rubs to improve local blood flow (Miraj and Kiani 2016). Caraway was also used to improve lactation in nursing mothers (Sachan *et al*. 2016). The essential oil is used as a constituent in mouthwashes and bath additives, in perfumery, for scenting soap, and as a parasiticide (Hill 1952; Chiej 1984). It was commonly used as a flavoring in ice-cream, candy, meat, cheese, condiments, soft drinks, and alcoholic beverages (Morton and Zallinger 1976). Therapeutic uses of *Pimpinella anisum L.* are reported in different scientific reports from all continents. In Asia, counting Iran, India, and China. *Pimpinella anisum L.* is used as an analgesic in migraine and also as a carminative, aromatic, disinfectant, and diuretic in traditional medicine (Shojaii and Abdollahi Fard 2012; Kadan *et al*. 2013; Sun *et al*. 2019). In Europe (i.e., Italy, Turkey, and Greece), *Pimpinella anisum L.* is used as a digestive, stomachic, carminative, antitussive, expectorant, anti-spasmodic, galactogogue, diuretic, and diaphoretic agent (Arslan *et al*. 2004; Iannarelli *et al*. 2017; Anastasopoulou *et al*. 2020; Boztaş and Bayram 2020). Similarly, the species and its derivatives are used in African traditional medicine, such as in Morocco, Algeria, and Tunisia, to treat various diseases, counting the prevention purposes during the COVID-19 pandemic, galactagogue activity, and antidepressant-like effects (Elyebdri *et al*. 2017; Alami *et al*. 2020; Soussi *et al*. 2023).

All the cited bibliographies and our results confirm the utility of these plants against a wide range of diseases. These biological properties are due to the richness of these plants with chemical compounds (Wei *et al*. 2019; Aly *et al*. 2023; AlBalawi *et al*. 2023). For example, Matasyoh *et al*. (2009) identified 24 components in the essential oils from the leaves of *Coriandrum sativum L.*, and the oil was dominated by aldehydes and alcohols (56.1% and 46.3%, respectively). Sixteen compounds were identified in *C. carvi* L. essential oils, out of which cuminaldehyde was the principal component with 22.08%, followed by γ-terpinene with 17.86%), γ-terpinene-7-al with 15.41%, and *p*-cymene with 7.99% (Razzaghi-Abyaneh *et al*. 2009). Similar results were recorded in the seeds, fruits, and leaves of *Pimpinella anisum L.* (Figueredo *et al*. 2020; Anastasopoulou *et al*. 2020; Boumahdi *et al*. 2021). These compounds are responsible for the management of treated diseases.

Used fragments of medicinal plants

The used parts of the studied medicinal plants are presented in Table 2. Different parts and usage forms were recorded for each species. Seeds are the only part used for anise and *Carum carviL.*at 100%. In contrast, the used parts of *Coriandrum sativum L.* were divided equally between the whole plant (50%) and the seeds (50%). On the other hand, all plants were used in dried forms compared to fresh materials. Participants in all sampling sites used all of the investigated medicinal plants to prepare infusions. *Pimpinella anisum L.* is used principally in the form of tisane by 77.83% of participants, followed by powder by 22.17% of participants. In *Carum carvi*, all participants used only the tisane form (100%). Further, 36.5% of participants used *Coriandrum sativum L.* in the tea form, compared to 63.5% of participants in the powder form. Distilled materials and essential oils were absent among the interviewed participants for all plants.

Table 2. Used fragments of studied medicinal plants among interviewed participants

Parts	Species	Whole plant	Seed	Fruit	Root	Stem
	Pimpinella anisum	0	100*	0	0	0
	Carum carvi	0	100*	0	0	0
	Coriandrum sativum	50%*	50%*	0	0	0
Form		Fresh	Dried			
	Pimpinella anisum	0	100*	0	0	0
	Carum carvi	0	100*	0	0	0
	Coriandrum sativum	0	100*	0	0	0
Preparation		Infusion	Decoction	Others		
	Pimpinella anisum	100*	0	0	0	0
	Carum carvi	100*	0	0	0	0
	Coriandrum sativum	100*	0	0	0	0
Mode		Tisane	Powder	Distilled	essential oil	
	Pimpinella anisum	77.83**	22.17*	0	0	0
	Carum carvi	100*	0	0	0	0
	Coriandrum sativum	36.5*	63.5**	0	0	0

Many studies reported the use of studied species in traditional medicine; however, these investigations reported the use of different parts depending on the targeted disease. (Soussi *et al*. 2023) reported the use of seeds (dried powder and tisane) from *Pimpinella anisum L.* in traditional medicine from various regions of Morocco. In other studies, Jouad *et al*. (2001) reported the use of the fruits of *Pimpinella anisum L.* to treat diabetes in the Fez-Boulemane region (central Morocco). (Jouad *et al*. 2001; El-Hilaly *et al*. 2003) reported the use of leaves and seeds of *Coriandrum sativum L.* to treat intestinal pains, kidney stones, and insomnia in the north of Morocco and fruits to treat diabetes in central Morocco. In Iran, local populations use the leaves of *Coriandrum sativum L.* (decoction) to manage gasteralgia and sore throats (Ghorbani 2005). Fruits of *C. carvi* L. were reported among the medicinal plants used in the treatment of diabetes in the Central Zone of Morocco (Jouad *et al*. 2001).

Used dose and effects

The results of the doses used and their effects on each medicinal plant are presented in Table 3. The majority of participants use imprecise doses of medicinal preparations from all plants. In *Pimpinella anisum L.*, 89.67% of participants used imprecise spoonfuls to treat health disorders, compared to 10.33% who used accurate quantities. Further, 83.17% of participants use imprecise spoonfuls to treat health disorders and for food purposes with *Coriandrum sativum L.* compared to 16.83% of participants who use it in inaccurate mode. Further, 79.55% of participants used inaccurate doses of *Carum carvi L.* preparations, compared to accurate doses for 19.45% of participants.

The majority of participants (100%) only used all medicinal plants when they were necessary (following the occurrence of diseases). All participants (100%) mentioned the amelioration of their health status (cure of the treated disease) after the use of the studied medicinal plants. All participants mentioned the absence of side effects after the use of these medicinal plants in the treatment of health disorders. Similarly, no toxicity was recorded after the use of the plants at all sampling sites. To avoid the toxicity and side effects of used plants, all participants (100%) store the plants' materials at ambient

temperature and away from light. Equally, the participants avoid mixing the investigated medicinal plants with other supplementary materials.

Table 3. Posology, effects (cure, side, and toxicity), and storage conditions of studied medicinal plants

	Pimpinella anisum	*Carum carvi*	*Coriandrum sativum*
Storage conditions	Protected in ambient temperature and far from light	Protected in ambient temperature and far from the light	Protected in ambient temperature and far from the light
Posology	Only when needed	Only when needed	Only when needed
Precautions for use	No mixing with other plants or products	No mixing with other plants or products	No mixing with other plants or products
Cases of toxicity	No case	No case	No case
Side effects	No case	No case	No case
Results	Cure of treated disease with 100%	Cure of treated disease with 100%	Cure of treated disease with 100%

This is the first study to evaluate the cure, side effects, toxicity, and precautions for the use of medicinal plants in Morocco. All participants mentioned the efficacy of all plants in the treatment of the mentioned diseases and the absence of side effects or toxicity. Soussi *et al*. (2023) conducted deep ethnobotany research on the therapeutic uses of *Pimpinella anisum L.* among local populations in Morocco. Similarly, laboratory studies have tested the toxicity of *P. anisum* (Sihoglu Tepe and Tepe 2015). de Mello *et al*. (2007) have investigated the potential toxic effect of P. anisum formulation on female Wistar rats during pregnancy and lactation (44 days), on male Wistar rats, and on New Zealand rabbits (males and females) for 30 days. According to the results, *P. anisum* showed no toxic effect when administered to rats and rabbits at a dose equivalent to 10 times the human dose. Despite the absence of toxicity among the participants who use *Carum carvi*, (Agrahari 2014) demonstrated that the seed of *Carum carvi L.* contains >90% fumigant toxicity against adult male and female *Blatella germanica*. In another study, Kumar and Singh (2006) investigated the toxicity of three plants, counting *Carum carvi* L*., Syzygium aromaticum* L., and *Ferula asafetida*, as well as their active components against the snail *Lymnaea acuminate*. In the results, the toxicity of *S. aromaticum* L. flower-bud powder (96 h LC50: 51.98 mg/l) was more pronounced than that of root latex powder of *F. asafoetida* (96 h LC50: 82.71 mg/l) and seed powder of *C. carvi* (96 h LC50: 140.58 mg/l). Further, ethanol extract was more toxic than other organic extracts. That of *S. aromaticum* L. (24 h LC50: 83.53 mg/l), *F. asafoetida* (24 h LC50: 132.31 mg/l), and *C. carvi* (24 h LC50: 130.61 mg/l) killed the test species better than the other two.

Conclusion

This survey presents new ethnobotanical data on the therapeutic uses of three medicinal plants, *Pimpinella anisum L.*, *Carum carvi L.*, and *Coriandrum sativum L.,* in traditional medicine from three geographical zones from Morocco and the south of the Mediterranean. We investigated their use in folk medicine, food, and cosmetics, as well as the effect of demographic features, geographical location, and health status of the populations. The interviewed populations were aged from 20 to 60 years and used the plants to treat digestive disorders, dysmenorrhea, lactation, and regulation of menstruation. Equally, these plants are used for food and cosmetic purposes. The use of each plant varied depending on the sampling site. The principal sources of information about the therapeutic benefits of the plants were the media. Populations used the seeds or whole plants alone in dried form (tisane and powder) and were prepared in the mode of infusion. To avoid toxicity or side effects, plants were stored and used only when needed. The treatment with the plants was 100% effective. The findings demonstrated the significance of *Pimpinella anisum* L*., Carum carvi* L*.,* and *Coriandrum sativum* L. in Moroccan traditional medicine. However, it is crucial to expand this kind of research to many regions of the nation, which is suggested to increase the economic value of natural resources and, as a result, rural and poor communities' incomes.

Declarations

Ethics approval and consent to participate: Before conducting interviews, prior informed consent was obtained from all participants. No further ethics approval was required.

Consent for publication: Not applicable

Conflicts of interest: The authors declare that there is no conflict of interests regarding the publication of this paper.

Data Availability Statement: The data used to support the findings of this study are included within the article.

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