Sociodemographic determinants and ethnobotanical patterns of medicinal plant use in pancreatic diabetes management in rural Morocco: A mixed-methods study from Dar El Gueddari

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Research

Abstract

Background: This study aimed to investigate the sociodemographic determinants and ethnobotanical patterns associated with medicinal plant use for diabetes management in a rural population of Dar El Gueddari, northwestern Morocco.

Methods: A mixed-methods cross-sectional design was employed using structured questionnaires and semi-structured interviews. Data were analyzed using descriptive statistics and Multivariate Analysis to explore relationships between sociodemographic variables and ethnobotanical practices.

Results: Results showed that the study population was predominantly aged 20-60 years (62.5%), female (57.5%), illiterate (52.5%), married (47.5%), and low-income (<2000 DH; 73%), with all differences being statistically significant ($p < 0.05$). Ten medicinal plant species were reported for diabetes management, with *Ficus carica* and *Camellia sinensis* being the most frequently cited (14% each). Leaves (47%) and seeds (32%) were the most used plant parts, while infusion was the dominant administration method (86%). Correspondence Analysis revealed structured associations between sociodemographic profiles and phytotherapeutic practices, explaining 41.47% of total inertia.

Conclusions: The novelty of this study lies in its integrated epidemiological-ethnobotanical approach focusing on a rural Moroccan population with documented pancreatic diabetes, a condition rarely explored in traditional medicine research. These results underscore the need for targeted health education, standardized herbal usage guidelines, and integration of validated medicinal plants into community health strategies.

Keywords: Diabetes, medicinal plants, sociodemographic profiles, phytotherapeutic practices, Morocco.

Background

Pancreatic diabetes, also known as pancreatogenic or type 3c diabetes mellitus (T3cDM), is a secondary form of diabetes resulting from diseases of the exocrine pancreas such as chronic pancreatitis, pancreatic cancer, cystic fibrosis, or pancreatic resection (Hart *et al.* 2016, Andersen *et al.* 2017). It is characterized by impaired insulin secretion due to destruction of pancreatic β-cells, often accompanied by glucagon deficiency, leading to unstable glycemic control. Clinically, patients may present with symptoms similar to other diabetes types, including polyuria, polydipsia, weight loss, and recurrent hypoglycemia, but also show signs of exocrine insufficiency such as steatorrhea and malabsorption (Sjoberg & Kidd 1989, Choudhuri *et al.* 2009). Unlike type 1 diabetes, autoimmune markers are absent, and unlike type 2 diabetes, insulin resistance is less prominent, which often leads to frequent misclassification as type 2 diabetes (Hardt *et al.* 2008). Despite its clinical relevance, pancreatic diabetes remains underdiagnosed and relatively understudied compared with type 1 and type 2 diabetes, with significant gaps in epidemiological data and standardized diagnostic criteria (Unnikrishnan & Mohan 2015, Andersen *et al.* 2017).

The treatment of pancreatic diabetes (type 3c diabetes mellitus) remains challenging due to the dual impairment of endocrine and exocrine pancreatic function, often requiring insulin therapy as the mainstay of management to compensate for severe β-cell loss (Vetere *et al.* 2014, Shahjalal *et al.* 2018). In contrast, type 1 diabetes relies primarily on lifelong insulin replacement, while type 2 diabetes is commonly managed with oral hypoglycemic agents such as metformin and thiazolidinediones, which improve insulin sensitivity and glycemic control (Long *et al.* 2021). However, in pancreatic diabetes, the efficacy of these chemical agents is often limited, and insulin therapy may increase the risk of hypoglycemia due to glucagon deficiency. Additional pharmacological strategies targeting β-cell regeneration and replacement have been explored, but remain largely experimental (Jain *et al.* 2022). Adverse effects of antidiabetic chemicals include weight gain, cardiovascular risks, and fluid retention, depending on the drug class (Sarafidis *et al.* 2017). Emerging alternatives such as stem cell-derived β-cell therapy and regenerative medicine offer promise but are not yet widely available (Shahjalal *et al.* 2018). Overall, research specifically addressing pancreatic diabetes treatment remains scarce compared with other diabetes types, highlighting a significant gap in clinical and translational studies (Yang *et al.* 2025).

Medicinal plants have been widely investigated as complementary or alternative approaches for the management of diabetes mellitus, particularly in resource-limited settings. Numerous species, including *Trigonella foenum-graecum* (fenugreek), *Momordica charantia* (bitter melon), *Gymnema sylvestre*, and *Tribulus terrestris*, are commonly used in the form of aqueous, ethanolic, or methanolic extracts to enhance glycemic control through mechanisms such as improved insulin secretion, enhanced peripheral glucose uptake, and inhibition of intestinal glucose absorption (Bindu Jacob and Narendhirakannan R.T. 2018, Alburyhi & El-Shaibany 2024). Evidence from preclinical and limited clinical studies suggests moderate efficacy in reducing fasting blood glucose and HbA1c, particularly in type 2 diabetes mellitus (Yedjou *et al.* 2023, Zanzabil *et al.* 2023). However, most studies remain experimental, with significant variability in dosage, extraction methods, and phytochemical standardization (Alam *et al.* 2022). Importantly, there is a marked scarcity of research specifically addressing medicinal plant use in pancreatic diabetes, despite its distinct pathophysiology and therapeutic challenges. This gap is particularly evident in developing countries, where traditional medicine is widely used but poorly documented, underscoring the need for rigorous ethnopharmacological and clinical investigations (Omale *et al.* 2023, Yedjou *et al.* 2023).

Medicinal plants are extensively used in traditional healthcare systems for the management of diabetes mellitus, particularly type 2 diabetes, which is the most frequently reported form in ethnobotanical surveys across Morocco. Species such as *Trigonella foenum-graecum*, *Olea europaea*, *Marrubium vulgare*, and *Allium sativum* are commonly prepared as aqueous infusions, decoctions, or powders to reduce hyperglycemia, improve insulin sensitivity, and manage associated metabolic disorders (Chaachouay *et al.* 2023, Boutaj 2024). The widespread use of these remedies is driven by cultural acceptance, accessibility, low cost, and limited access to conventional pharmacotherapy in rural areas (Arraji *et al.* 2024, Mahzoune *et al.* 2026). Ethnopharmacological studies from regions such as Rif, Casablanca-Settat, Azilal, and Laâyoune highlight the strong reliance on herbal medicine for chronic disease management, particularly diabetes and hypertension (Loud *et al.* 2025, S'hih *et al.* 2025). However, despite this extensive traditional use, scientific studies specifically investigating medicinal plants for pancreatic diabetes remain virtually absent. This gap is critical given the distinct pathophysiology of type 3c diabetes and its underdiagnosis. Therefore, there is an urgent need for targeted pharmacological and clinical research, especially in rural and developing regions where medicinal plant use is predominant, and healthcare resources are limited (Chaachouay *et al.* 2023, Boutaj 2024).

The main objective of this study was to investigate ethnobotanical patterns of medicinal plant use in the management of diabetes, as well as the sociodemographic determinants influencing these practices, within a rural population of El Gharb,

northwestern Morocco. Specifically, the study aimed (i) to identify the medicinal plant species used, their parts, and preparation methods; (ii) to analyze the association between these ethnobotanical practices and key sociodemographic factors such as age, education, income, and residence; and (iii) to explore multivariate relationships between plant-related variables and diabetes management practices using Correspondence Analysis (CA). Unlike previous research that has largely focused on type 2 diabetes and descriptive inventories of antidiabetic plants, this study uniquely incorporates the context of pancreatic diabetes, a highly underexplored and often misdiagnosed form of diabetes. The integration of advanced statistical modelling enhances the analytical depth beyond traditional ethnobotanical surveys. This combined epidemiological-ethnobotanical approach provides novel insights into how social determinants shape therapeutic choices in a resource-limited rural setting. The findings may support the preservation of traditional knowledge, inform culturally appropriate phytotherapeutic strategies, and guide future pharmacological and public health investigations targeting neglected forms of diabetes in developing regions.

Materials and Methods

Study area

This investigation was carried out in El Gharb, northwestern Morocco. Dar Gueddari is in the northwest of the country, within Sidi Kacem Province in the Rabat-Sale-Kenitra region, approximately 60 km from Kenitra and 100 km from the capital city Rabat (Figure 1). The study area was selected due to its predominantly rural character, limited healthcare accessibility, reliance on traditional medicinal practices, and the scarcity of epidemiological data concerning pancreatic diabetes and nutritional behaviors in this population.

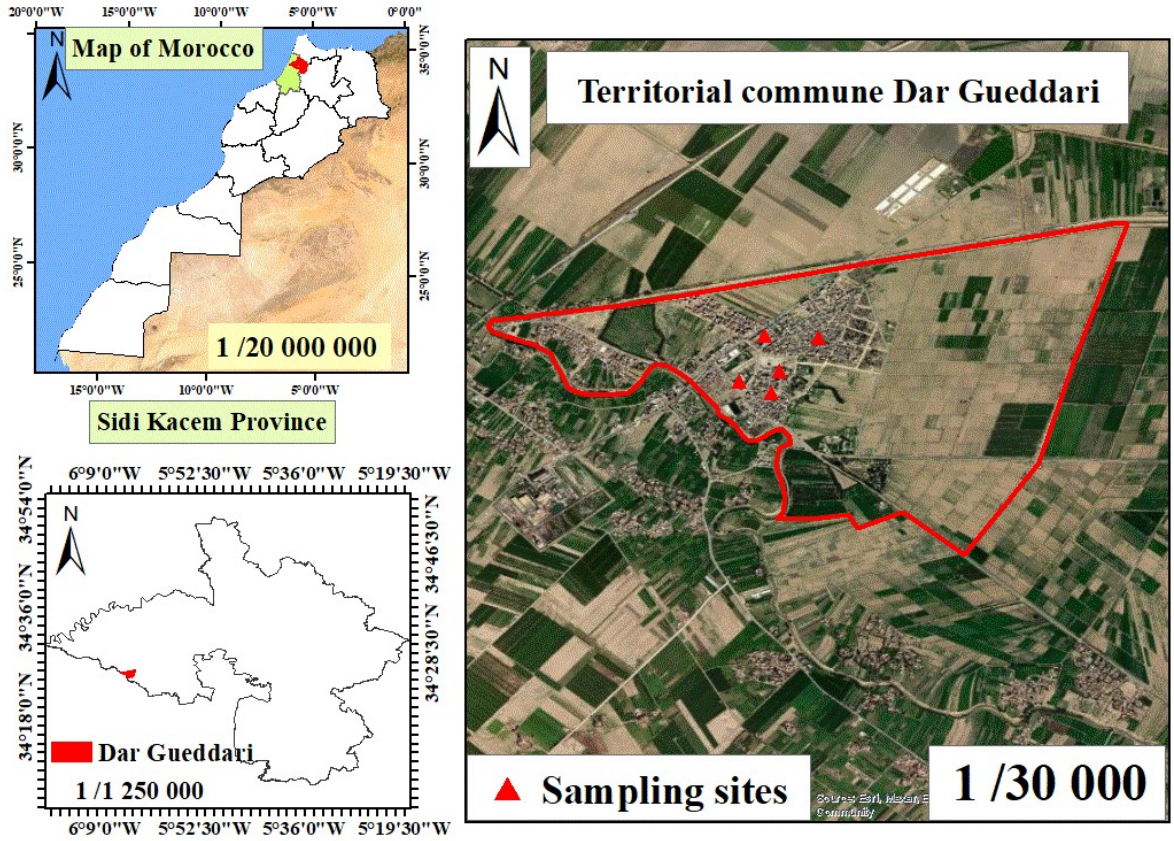

Figure 1. Geographical location of the sampled area

Dar El Gueddari was originally a small settlement named after the El Gueddari family. The surrounding area was historically inhabited by the Arab tribe of the Gueddadra, along with families of workers who managed the Gueddari estates, many of whom migrated from Tadla, Haouz, Jbala, Rahamna, and Chaouia regions. Among these groups, several family names can be cited, including Barka, Jarbia, Haimed, Reddad, Farjii, Cherradi, Hrizi, Tadlaoui, Jebli, Belhaj, Hlalia, as well as other families originating from neighboring tribes such as Zdak (Bridjat) and the Lahmine families (Kratt, relatives of the Gueddari lineage). These families historically resided on Gueddari lands, often engaging in small-scale economic activities. Some families of

external origin were allocated agricultural lands by the Moroccan state under King Mohammed V and were referred to as the “Mohammadiennes.”

The town of Dar Gueddari, located in western Morocco, is characterized by a rich cultural and artistic heritage reflecting its historical depth and the traditions of its inhabitants. This heritage encompasses diverse forms of expression, including traditional crafts, music, and culinary practices, which collectively contribute to the cultural identity of the region.

Data collection

Sociodemographic parameters

The sociodemographic variables included age group (<20 years, 20-60 years, and >60 years), residential setting (urban or rural), gender (men and women), education level (illiterate, primary education, and secondary education), marital status (single, married, divorced, and widowed), and monthly income categories (<2000 DH, 2000-10000 DH, and >10000 DH). These parameters were selected because they represent key structural and behavioral determinants that are known to influence health-related decision-making, access to biomedical care, and reliance on traditional medicine. Age may affect therapeutic preferences and cumulative exposure to traditional knowledge, while a residential setting is closely associated with healthcare accessibility and the persistence of ethnomedical practices, particularly in rural areas. Gender and marital status can shape caregiving roles and health-seeking behavior, potentially influencing the likelihood of using medicinal plants. Education level is a critical predictor of health literacy and acceptance of biomedical versus traditional therapies, whereas income reflects economic capacity and may determine dependence on low-cost herbal remedies. Collectively, these variables allow for a comprehensive assessment of how socioeconomic context shapes the adoption and persistence of medicinal plant use in diabetes management.

Table 1. Summary of the study sociodemographic variables

Domain	Variable	Categories / Measurement
Sociodemographic characteristics	Age group	<20 years; 20-60 years; >60 years
	Residential setting	Urban; Rural
	Gender	Men; Women
	Education level	Illiterate; Primary education; Secondary education
	Marital status	Single; Married; Divorced; Widowed
	Monthly income	<2000 DH; 2000-10000 DH; >10000 DH

Plants-related data

The ethnobotanical parameters recorded in this study included medicinal plant species, vernacular names, plant parts used (e.g., leaves, roots, seeds, and bark), and modes of preparation (e.g., infusion, decoction, maceration, and powder). These variables were selected because they constitute the fundamental components for understanding traditional therapeutic practices and evaluating the cultural and pharmacological relevance of medicinal plants used in diabetes management. Identification of plant species and vernacular names provides insight into local ethnomedical knowledge, facilitates taxonomic verification, and supports the preservation of indigenous medicinal heritage. Documentation of plant parts used is essential because the distribution and concentration of bioactive compounds may vary considerably among different plant organs. Similarly, preparation modes were investigated due to their direct impact on phytochemical extraction, bioavailability, dosage, and biological activity of medicinal remedies.

Research design

A mixed-methods ethnobotanical approach was adopted, integrating structured questionnaires with semi-structured qualitative interviews to comprehensively document medicinal plant use in diabetes management within the study population. The questionnaire was developed following an extensive review of previously validated ethnobotanical and diabetes-related survey instruments and subsequently adapted to the sociocultural characteristics of the study area. The final version was organized into several thematic sections addressing: (i) sociodemographic characteristics (age, gender, education level, marital status, residence, and income); (ii) ethnobotanical parameters, including medicinal plant species, vernacular names, plant parts used, preparation methods, and perceived therapeutic applications. The questionnaire was reviewed by a panel of laboratory researchers and specialists in ethnobotany and public health to ensure scientific relevance, linguistic clarity, and cultural appropriateness.

Before the main field survey, a pilot pre-test was conducted on a small group of participants (n=10) from the study region to evaluate question comprehensibility, sequence coherence, and response consistency. The pilot phase revealed several methodological issues, including ambiguity in local plant nomenclature, variability in respondents' interpretation of preparation methods, and difficulties in distinguishing diabetes types. To address these limitations, the wording of several questions was simplified, additional explanatory examples were incorporated, and standardized terminology for preparation modes and plant parts were introduced.

The refined questionnaire was subsequently used during field investigations conducted between September 2021 and February 2022. Participants were recruited through purposive and snowball sampling strategies to identify knowledgeable informants and traditional medicine users. Semi-structured interviews were audio-recorded to preserve the accuracy of traditional knowledge and facilitate qualitative interpretation. GPS coordinates of plant collection sites were recorded to support ecological contextualization and spatial validation, while photographic documentation was systematically performed to assist species verification. Voucher specimens were collected according to standard botanical procedures, then pressed, air-dried, preserved, and authenticated by a qualified botanist before deposition in a recognized herbarium to ensure reproducibility and long-term conservation of ethnobotanical resources.

Clinical measurements

This study was conducted within the selected study area in collaboration with local healthcare facilities and in accordance with ethical guidelines approved by the Moroccan health authorities and the university ethics committee. The research team did not perform any clinical examinations or biochemical measurements directly. Instead, all medical evaluations and diabetes diagnoses had previously been established by healthcare professionals and specialized physicians as part of routine clinical care within local medical centers and hospitals, following standardized clinical protocols.

Only participants (200 participants) with a confirmed diagnosis of pancreatic diabetes were included in the study. Diagnostic confirmation was based on patient medical records and physician assessments supported, when available, by relevant clinical, biochemical, and imaging findings routinely used in local healthcare practice. Participant recruitment was initially conducted through random distribution of the survey within the study population; however, eligibility for final inclusion was restricted exclusively to individuals whose pancreatic diabetes status had been medically confirmed by their attending physicians. This approach ensured diagnostic reliability, improved the homogeneity of the study sample, and minimized potential classification bias throughout the investigation.

Data analysis

The Excel datasets were organized and structured according to predefined analytical variables and study objectives. Data distribution normality was assessed using the Kolmogorov-Smirnov test. Categorical variables were summarized as frequencies and percentages, whereas continuous variables were expressed as mean ± standard deviation. Sociodemographic characteristics (age, gender, residential zone, education level, marital status, and monthly income) were analyzed using one-way ANOVA followed by Tukey's post hoc test.

Multivariate relationships were explored using Correspondence Analysis (CA) to examine associations between dependent variables (medicinal plants) and independent variables (plant parts used, and preparation methods) for diabetes management. Results were presented in a 2D plot, and axes were selected based on eigenvalues and % of variance (>50%). On the other hand, CA analysis was conducted to test relationships between sociodemographic features and plants' parameters (species, used parts, and preparation modes). Results were presented in a 3D plot, and the axes were selected based on higher eigenvalues and % of variance.

All statistical analyses were performed using SPSS Statistics (version 25.0), and graphical outputs were generated using GraphPad Prism. A significance threshold of $p < 0.05$ was applied throughout the study.

Results and Discussion

Sociodemographic features of participants

In this study, we investigated the sociodemographic features of the Dar El Gueddari population, and the results are presented in Table 2. These parameters include age, gender, habitation zone, education level, marital status, and monthly income.

Table 2. Sociodemographic features of the studied population

Variable	Category	Percentage (%)	Statistical significance
Age group	<20 years	7.5	$p < 0.05$
	20-60 years	62.5	
	>60 years	30	
Gender	Men	42.5	$p < 0.05$
	Women	57.5	
Education level	Illiterate	52.5	$p < 0.05$
	Primary education	45	
	Secondary education	2.5	
Marital status	Single	7.5	$p < 0.05$
	Divorced	5	
	Married	47.5	
	Widowed	40	
Monthly income (DH)	<2000 DH	73	$p < 0.05$
	2000-10000 DH	26	
	>10000 DH	1	

Age

The age distribution of participants from Dar El Gueddari is presented in Table 2. The results indicated that participants were distributed across three age categories (<20, 20-60, and >60 years), with varying proportions. The predominant age group was 20-60 years (62.5%), followed by participants aged >60 years (30%), whereas individuals aged <20 years represented a marginal proportion (7.5%). A statistically significant difference was observed between age categories ($p < 0.05$).

In the present study, adults aged 20-60 years represented the predominant age category among participants with pancreatic diabetes (62.5%), followed by individuals aged >60 years (30%), whereas participants aged <20 years were minimally represented (7.5%), indicating a significant predominance of middle-aged and older adults ($p < 0.05$). These findings are consistent with previous Moroccan studies reporting a higher prevalence of diabetes among adults over 40 years of age. For example, (Chadli *et al.* 2016) reported mean ages of 34.8 ± 14.3 years for type 1 diabetes and 58.0 ± 10.0 years for type 2 diabetes, while (Gharbi *et al.* 2016) identified the 41-55-year age group as the most affected category. Similarly, (Farhane *et al.* 2021) documented a mean age of 57.31 ± 0.91 years among Moroccan patients with type 2 diabetes. However, unlike previous investigations primarily centered on type 2 diabetes, the present study specifically targeted pancreatic diabetes, a less explored and frequently underdiagnosed condition. The predominance of adult and elderly participants highlights the potential influence of age-related pancreatic dysfunction on disease occurrence and emphasizes the importance of age-adapted screening, management strategies, and epidemiological investigations for pancreatic diabetes in rural Moroccan populations.

Gender

In this study, we examined the gender distribution of the interviewed population, with results presented in Table 2. Participants were categorized as male or female, showing differential proportions between groups. The findings indicated a higher proportion of women (57.5%) compared with men (42.5%), with the observed difference being statistically significant ($p < 0.05$).

In the present study, women represented the predominant proportion of participants with pancreatic diabetes, indicating a significant female predominance within the investigated rural population. These findings partially contrast with previous reports suggesting that pancreatic diabetes and several diabetes-related complications are more frequently observed in men. For example, (Cherchi *et al.* 2020) reported a significantly higher prevalence of diabetic retinopathy among men with type 2 diabetes compared with women (22.0% vs. 19.3%, $p < 0.0001$). Previous studies have also highlighted sex-related differences in diabetes progression, cardiovascular risk, and therapeutic responses, emphasizing the influence of biological and hormonal factors on disease outcomes (Lin *et al.* 2016, Seghieri *et al.* 2017). However, unlike earlier investigations mainly focused on type 2 diabetes in urban or multicenter clinical settings, the present study specifically examined pancreatic

diabetes within a rural Moroccan context, where sociocultural factors, healthcare accessibility, and traditional therapeutic practices may influence gender-related disease patterns. The predominance of women observed in this study may reflect differences in healthcare-seeking behavior, demographic composition, or greater reliance on traditional medicine among rural women. These findings highlight the importance of integrating gender-sensitive approaches into pancreatic diabetes screening, management, and public health interventions in underserved rural communities.

Education

The education level of the samples studied was variable (Table 2). Illiteracy was the most dominant among participants, with 52.5%, followed by participants with a primary level, with 45% of participants. In contrast, the secondary education level was recorded among only 2.5% of participants.

In the present study, illiterate participants represented the predominant educational category among individuals with pancreatic diabetes, highlighting the low educational attainment characterizing the investigated rural population. Education level is a major determinant of diabetes awareness, treatment adherence, nutritional practices, and long-term disease management. Limited educational background may negatively affect understanding of pancreatic diabetes symptoms, treatment strategies, and prevention of complications, thereby influencing self-management capacities. These findings are consistent with previous Moroccan studies conducted on other forms of diabetes. For instance, study (Elhanafi *et al.* 2025) reported that unschooled participants constituted 48.5% of diabetic patients in the Souss Massa region, while (Adarmouch *et al.* 2019) demonstrated that culturally adapted educational interventions significantly improved diabetes knowledge and foot-care practices among patients with type 2 diabetes.

However, dissimilar to previous investigations primarily focused on type 2 diabetes in urban or mixed populations, the present study specifically addressed pancreatic diabetes in a rural context where healthcare access and educational opportunities remain limited. The predominance of low educational levels emphasizes the need for targeted awareness campaigns, simplified educational materials, and culturally adapted prevention programs to improve pancreatic diabetes management and reduce disease-related complications in underserved rural communities.

Marital status

The marital situation of participants is presented in Table 2. Most participants were married, with 47.5% of participants, followed by widowed, with 40% of participants. In contrast, only 7.5% and 5% of the participants were single and divorced. Statistical analysis showed that these values were significantly different.

Several studies (Escolar-Pujolar *et al.* 2018, Ramezankhani *et al.* 2019, Rastkar & Jalalifar 2023, Karimi *et al.* 2025) have investigated the relationship between marital status and diabetes, reporting variable findings according to population characteristics and study design. Previous evidence suggests that unmarried individuals, including single, divorced, or widowed persons, may present a higher risk of diabetes and related complications compared with married individuals, potentially due to differences in social support, lifestyle, and psychological stability (Ramezankhani *et al.* 2019, Rastkar & Jalalifar 2023, Karimi *et al.* 2025). Marital status may also influence dietary habits, treatment adherence, and long-term disease management, particularly in chronic conditions such as pancreatic diabetes.

Moroccan studies have similarly reported heterogeneous distributions of marital status among diabetic patients. For example, (Kenfaoui *et al.* 2024) identified married participants as the predominant group among patients with type 2 diabetes in northeastern Morocco, while (Elhanafi *et al.* 2025) reported that 68.3% of diabetic participants from the Souss Massa region were married, followed by widowed and single individuals. These findings are consistent with the present study, where married participants were also predominant. However, unlike previous investigations focused mainly on type 2 diabetes, the current study specifically addressed pancreatic diabetes in a rural setting, emphasizing the importance of family and social support in disease management and therapeutic practices.

Income of participants

The monthly incomes of participants are presented in Table 2. Most participants (73%) declared <2000 dh as the monthly income, followed by participants with incomes between 2000-10000 dh (26%). Only 1% of the participants declared >10000 dh as their monthly income. The comparison of incomes showed a significant difference among participants at $p<0.05$.

In the present study, most participants with pancreatic diabetes belonged to low- and moderate-income categories, reflecting the vulnerable socioeconomic conditions of the investigated rural population. Income level is closely associated

with food security, dietary quality, healthcare accessibility, and disease management. Individuals with limited financial resources often experience restricted access to nutritious foods and medical care, which may negatively affect glycemic control and increase the risk of diabetes-related complications (Silverman *et al.* 2015, Butt *et al.* 2022). Previous studies have also demonstrated associations between low socioeconomic status and diabetes burden. In Morocco, a study conducted by (Elhanafi *et al.* 2025) reported that 37.3% of diabetic patients attending primary healthcare centers were classified within low-income categories, highlighting the socioeconomic vulnerability of diabetic populations. Furthermore, reduced socioeconomic status has been associated with higher risks of pancreatic disorders and pancreatic cancer, conditions strongly linked to pancreatic diabetes (Jacobson *et al.* 2021, Klein 2021, Akhondi *et al.* 2025).

However, unlike previous investigations primarily focused on type 2 diabetes, the present study specifically addressed pancreatic diabetes in a rural Moroccan setting where economic limitations may promote dependence on low-cost traditional remedies and nutritionally inadequate diets. These findings emphasize the importance of socioeconomic support programs, nutritional education, and community-based awareness strategies to improve pancreatic diabetes management in underserved rural populations.

Treatment of diabetes with medicinal plants

Used medicinal plants

A total of 10 medicinal plant species were reported by the interviewed population for diabetes management, with notable variations in their frequency of use (Figure 2A). *Ficus carica* and *Camellia sinensis* were the most frequently cited species, each accounting for 14% of reported uses. These were followed by Foeniculum vulgare with 12%, while *Olea europaea*, *Artemisia vulgaris*, and *Trigonella foenum-graecum* each represented 10% of responses. In contrast, *Opuntia ficus-indica* and *Raphanus sativus* were the least frequently reported medicinal plants, each accounting for 6% of use. Statistical comparison of the reported percentages was performed using one-way ANOVA followed by Tukey's post hoc test, revealing significant differences among the frequencies of plant use ($p < 0.05$).

In the present study, medicinal plants were extensively used by participants with pancreatic diabetes, reflecting the strong reliance on traditional phytotherapy in rural Moroccan communities. Frequently reported species included *Trigonella foenum-graecum*, *Nigella sativa*, *Olea europaea*, *Ficus carica*, and *Opuntia ficus-indica*, which are recognized for their rich phytochemical composition and antidiabetic properties. These plants contain bioactive compounds such as flavonoids, polyphenols, alkaloids, catechins, oleuropein, and dietary fibers that may contribute to hypoglycemic, antioxidant, and lipid-regulating effects. Previous studies demonstrated that fenugreek improves fasting glucose and HbA1c, *Nigella sativa* modulates oxidative stress and glycemic control, while olive leaf extracts enhance insulin sensitivity (Hamza *et al.* 2012, Brimson *et al.* 2023, Hinad *et al.* 2025). Similarly, *Ficus carica*, fennel, celery, purslane, and prickly pear have shown glucose-lowering and α-glucosidase inhibitory activities in experimental and clinical investigations (El-Mostafa *et al.* 2014, Banihani 2017, El Ghouizi *et al.* 2023, Noureddini *et al.* 2025).

However, unlike most previous Moroccan studies focused primarily on type 2 diabetes, the present investigation specifically addressed pancreatic diabetes within a rural setting characterized by limited healthcare access and strong dependence on traditional medicine. These findings highlight the cultural and therapeutic importance of medicinal plants but also emphasize the absence of standardized dosages and clinical validation for pancreatic diabetes. Consequently, educational and awareness programs are needed to promote safe phytotherapeutic practices, while future pharmacological and clinical studies should evaluate efficacy, toxicity, and interactions between medicinal plants and conventional antidiabetic treatments.

Used parts

Figure 2B presents the different plant parts used by the investigated population for diabetes management. Overall, four categories of plant materials were identified with varying frequencies of use. Leaves constituted the most frequently utilized plant part, representing 47% of reported uses, followed by seeds with 32%. In contrast, fruits and whole plants were the least commonly reported materials, accounting for 12% and 9%, respectively. Statistical comparison of the reported percentages was conducted using one-way ANOVA followed by Tukey's post hoc test, and the observed differences were found to be statistically significant ($p < 0.05$).

The correspondence analysis demonstrates the parts of medicinal plants used are presented in Figure 3. The data are presented in two axes with 33.33% each. *P. oleracea* is mostly used as an entire plant to treat diabetes in the study area. In *O. ficus-indica* and *R. sativus*, the fruits were the most used parts. In *T. focunum-g, C. sativum,* and *F. vulgare,* seeds were

the most used parts. In *O. europaea, A. graveolens, F. carica,* and *C. sinensis,* leaves were the most used material to manage diabetes by the local population.

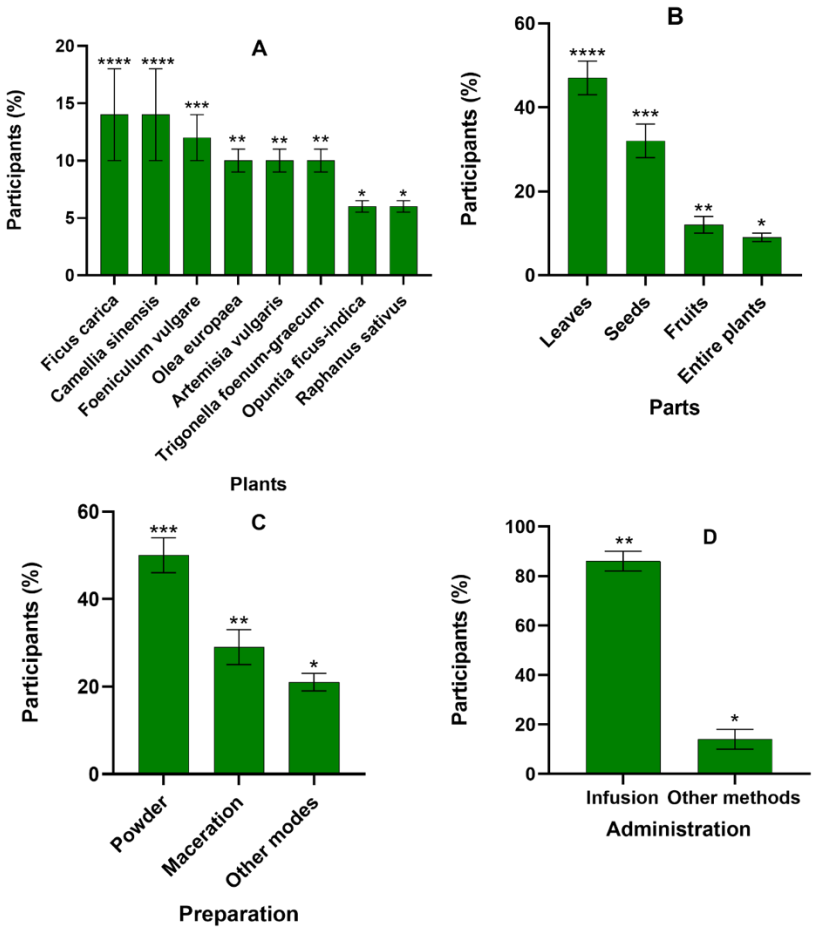

Figure 2. Used medicinal plants (A), used parts (B), preparation modes (C), and administration methods (D) among biabetec participants in Dar Gueddari (* denotes statistically different at p<0.05; ****>***>**>*)

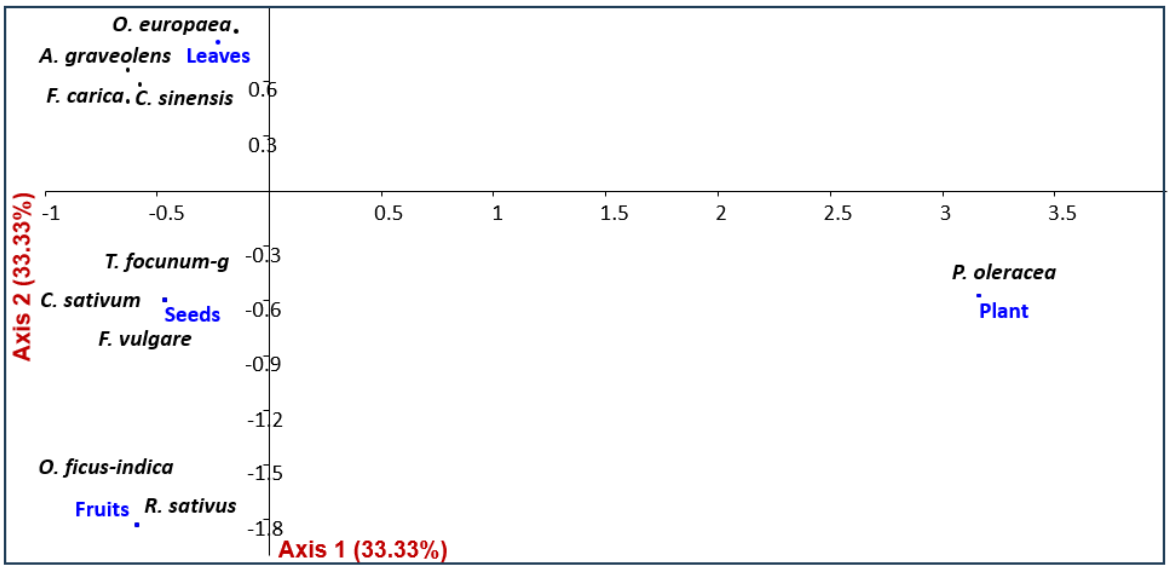

Figure 3. Correspondence Analysis of the relationship between medicinal plants and the parts used to manage diabetes among participants.

In Morocco, different parts of medicinal plants are traditionally employed to manage diabetes, reflecting both accessibility and bioactive compound distribution. Leaves are the most frequently used parts, as in *Olea europaea* (olive leaves), *Ficus carica* (fig leaves), and *Camellia sinensis* (tea leaves), which are rich in phenolics with hypoglycaemic effects (Brimson *et al.* 2023, El Ghouizi *et al.* 2023, Mansour *et al.* 2023). Seeds such as those of *Trigonella foenum-graecum* (fenugreek) and *Coriandrum sativum* (coriander) are also highly valued for their insulin-mimetic and glucose-lowering properties (Sharma and Raghuram 1990, Mahleyuddin *et al.* 2022). Stems and cladodes, notably from *Opuntia ficus-indica*, are consumed as juices or infusions to reduce postprandial glucose (El-Mostafa *et al.* 2014). Roots and bulbs, including those of *Raphanus sativus*, are prepared as decoctions for their starch-digesting enzyme inhibition (Banihani 2017). Aerial parts of *Portulaca oleracea and Apium graveolens* are also commonly used in salads, infusions, or extracts for its antidiabetic activity (Bai *et al.* 2016, Yusni *et al.* 2018). The use of various parts of plants reflects Morocco's extensive ethnobotanical knowledge while emphasizing the importance of standardizing practices and conducting clinical validation (Bouyahya *et al.* 2021).

Preparation mode

Figure 4 illustrates the different preparation methods for medicinal plants used by participants for diabetes management. Powdered preparations were the most frequently reported mode, accounting for 50% of participants, followed by maceration, which was reported by 29% of participants. In contrast, other preparation methods represented only 21% of responses, whereas no participant did not report decoction. Statistical comparison of the preparation modes was performed using one-way ANOVA followed by Tukey's post hoc test, revealing a significant difference among the reported percentages ($p < 0.05$).

The Correspondence Analysis of the relationship between the medicinal plants and preparation modes is presented in Figure 4. Data were presented in a plot with two axes, with an inertia estimated at 50% each. Maceration was the most used preparation in *A. gravelens, T. focunum-g,* and *O. europaea.* In *F. vulgare, F. carica, C. sativum,* and *C. sinensis*, the powder is the most dominant mode. In *P. oleracea, O. ficus-indica,* and *R. sativus*, other modes were used to prepare the medicinal plants for diabetes treatment.

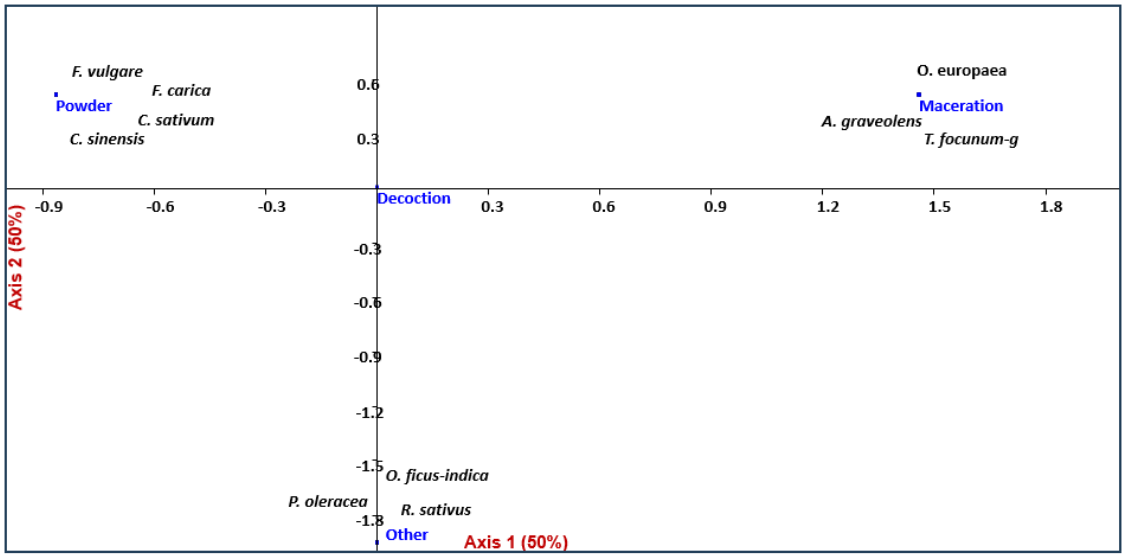

Figure 4. Correspondence Analysis of the relationship between the medicinal plants and preparation modes.

In Morocco, medicinal plants used in diabetes management are prepared through a variety of traditional methods that reflect both cultural heritage and empirical efforts to optimize the extraction of bioactive compounds. Decoction and infusion represent the most employed techniques, particularly for leaves of *Olea europaea* (olive), *Ficus carica* (fig), and *Camellia sinensis* (tea), which are boiled or steeped in hot water to facilitate+ the release of phenolic compounds and flavonoids associated with hypoglycaemic activity (Brimson *et al.* 2023, El Ghouizi *et al.* 2023, Mansour *et al.* 2023). Seeds such as *Trigonella foenum-graecum* (fenugreek) and *Coriandrum sativum* (coriander) are frequently processed into powders and administered with water, milk, or incorporated into food matrices to enhance glycemic regulation (Sharma & Raghuram 1990, Yusni *et al.* 2018). Likewise, *Portulaca oleracea* (purslane) and *Apium graveolens* (celery) aerial parts are consumed raw in salads, dried for infusion, or processed as juices, underscoring their dual role as both nutritional and therapeutic agents (Bai *et al.* 2016, Yusni *et al.* 2018).

Additional preparation forms include juices, syrups, and direct raw consumption, particularly for *Opuntia ficus-indica* (prickly pear) cladodes and fruits, which are ingested fresh or as juice to mitigate postprandial glucose excursions (El-Mostafa *et al.* 2014, Gouws *et al.* 2019). Roots and bulbs, such as those of *Raphanus sativus* (radish), are typically consumed raw in salads or extracted as juice, taking advantage of their reported enzyme-inhibitory and antioxidant properties (Banihani 2017). In some cases, traditional practitioners recommend cold maceration techniques, particularly for species containing heat-sensitive volatile compounds, such as *Foeniculum vulgare* (fennel) (Sayah *et al.* 2020). Collectively, these preparation methods reflect a refined body of indigenous knowledge and directly influence the bioavailability and therapeutic potential of active phytochemicals. Importantly, the present study extends previous literature by documenting, within a rural Moroccan pancreatic diabetes context, how preparation practices are not only culturally embedded but also selectively adapted by patients according to perceived efficacy and tolerability, an aspect rarely addressed in earlier studies focused mainly on type 2 diabetes populations. Nevertheless, the absence of standardized preparation protocols and dosage regimens remains a critical limitation, highlighting the need for rigorous phytochemical validation and well-controlled clinical trials prior to integration into evidence-based therapeutic frameworks (El Ghouizi *et al.* 2023).

Administration approach

Figure 2D illustrates the variation of administration methods of medicinal plants used to manage diabetes by interviewed participants. Most of the participants (86%) use the infusions of medicinal plants to manage diabetes. In contrast, only 14% of participants used other administration methods to manage diabetes. Inhalation and external applications were not recorded.

In Morocco, the administration of medicinal plants for diabetes management relies on traditional practices passed down through generations, with oral consumption being the most dominant method. Decoctions and infusions are commonly administered, particularly for leaves such as *Olea europaea* (olive), *Ficus carica* (fig), and *Camellia sinensis* (tea), which are consumed as herbal teas to regulate blood glucose (Brimson *et al.* 2023, El Ghouizi *et al.* 2023, Mansour *et al.* 2023). Seeds of *Trigonella foenum-graecum* (fenugreek) and *Coriandrum sativum* (coriander) are often ingested in powdered form mixed with food, water, or milk, providing sustained hypoglycaemic effects (Sharma and Raghuram 1990, Mahleyuddin *et al.* 2022). Similarly, *Apium graveolens* (celery) leaves and *Portulaca oleracea* (purslane) aerial parts are administered raw in salads, dried and infused, or processed as juices, emphasizing their dual role as dietary and therapeutic remedies (Bai *et al.* 2016, Yusni *et al.* 2018).

Other administration methods include ingestion of fresh fruits, juices, or syrups, particularly for *Opuntia ficus-indica* (prickly pear), which is eaten raw or as pressed juice to control postprandial glucose (El-Mostafa *et al.* 2014, Gouws *et al.* 2019). Roots and bulbs of *Raphanus sativus* (radish) are consumed raw, cooked, or juiced, reflecting dietary integration with therapeutic purpose (Banihani 2017). In some cases, maceration in cold water is preferred, especially for plants with volatile or heat-sensitive compounds, such as *Foeniculum vulgare* (fennel), to preserve bioactivity (Sayah *et al.* 2020). While these methods facilitate patient adherence by aligning with daily food habits, they also lead to variations in dosage and bioactive availability. This heterogeneity highlights the importance of developing standardized administration protocols and clinical evaluations to confirm safety and efficacy before wider adoption in modern healthcare (Bouyahya *et al.* 2021).

Effect of sociodemographic parameters on medicinal uses

The 3D Correspondence Analysis reveals a multidimensional structure explaining approximately 41.47% of total inertia, with Axis 1 (22.42%) contributing the most, followed by Axis 2 (9.83%) and Axis 3 (9.22%). This indicates that the primary differentiation of responses is mainly driven by the first dimension, while secondary axes refine subgroup separation.

A clear spatial separation is observed between sociodemographic variables (green points) and medicinal plant practice variables (red points), suggesting structured associations rather than random distribution. Axis 1 appears to contrast socio-economic and demographic profiles (e.g., income, gender, education) with specific medicinal practices (plant parts and preparation methods). Axis 2 and Axis 3 further differentiate usage patterns linked to age, marital status, and income levels.

The present study highlights a clear association between sociodemographic characteristics and the use of medicinal plants for the management of pancreatic diabetes in the rural region of El Gharb, northwestern Morocco. Older age groups, lower levels of education, rural residence, and low-income categories were more strongly associated with reliance on herbal remedies, suggesting that traditional phytotherapy remains deeply embedded within vulnerable population segments. Limited educational attainment likely reduces access to biomedical information and strengthens reliance on culturally transmitted knowledge, while low income constrains access to conventional healthcare and pharmaceutical treatments,

thereby promoting the use of low-cost medicinal plants. Similarly, rural residence favors the persistence of ethnomedical practices due to easier access to local flora and stronger intergenerational knowledge transfer. These findings are consistent with previous ethnobotanical studies in Morocco reporting that age, education, and socioeconomic status significantly influence medicinal plant use for type 2 diabetes management (Adarmouch *et al.* 2019, Hajjaji *et al.* 2023, Elhanafi *et al.* 2025).

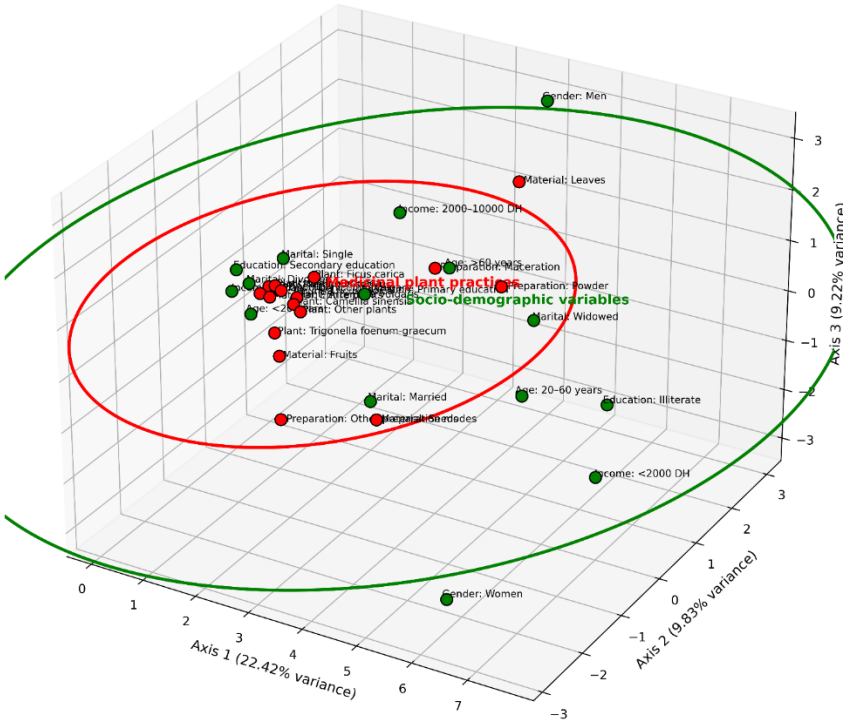

Figure 5. 3D correspondence analysis (CA) of diabetes medicinal plant practices

However, the specificity of the present study lies in its focus on pancreatic diabetes, a condition rarely investigated in ethnopharmacological research, particularly within rural African contexts. Unlike earlier studies centered on type 2 diabetes in urban or mixed populations, this research provides novel insights into how social determinants shape therapeutic behaviors in a neglected disease category. The findings underscore the need for targeted health education programs, culturally adapted awareness campaigns, and integration of safe phytotherapy guidance into primary healthcare systems to improve diabetes management and reduce potential misuse of medicinal plants in underserved rural communities.

Conclusion

This study provides a comprehensive insight into the sociodemographic determinants and ethnobotanical practices associated with medicinal plant use among patients with pancreatic diabetes in the rural region of El Gharb, northwestern Morocco. The results demonstrated a widespread reliance on traditional herbal remedies for diabetes management, with medicinal plant use being particularly prevalent among women, older individuals, participants with low educational levels, and low-income households. The findings further revealed that locally accessible species, notably *Trigonella foenum-graecum, Olea europaea,* and *Nigella sativa*, constituted the most frequently utilized plants, predominantly administered as infusions. Moreover, education, income, and rural residence emerged as key factors influencing the adoption and transmission of traditional phytotherapeutic knowledge. These patterns emphasize the enduring role of ethnomedicine as an essential component of healthcare in underserved rural communities.

A major contribution of this study is its focus on pancreatic diabetes, a neglected and insufficiently documented form of diabetes, thereby filling an important knowledge gap in the ethnobotanical and public health literature. The results underscore the necessity of strengthening collaboration between traditional and modern healthcare systems through culturally adapted educational interventions aimed at promoting the safe and rational use of medicinal plants. In addition, the preservation and documentation of indigenous knowledge should be prioritized as valuable cultural and therapeutic

resources. Future investigations should focus on the phytochemical characterization, pharmacological validation, toxicological assessment, and clinical evaluation of the most used species to establish their efficacy, safety, and potential integration into evidence-based diabetes management strategies.

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

Availability of data and materials: The datasets used and/or analysed during the current study are study are included within the article.

Competing interests: Not applicable

Funding: Not applicable

Author contributions: M.M., Y.M., and D.H. designed the paper and conceived the idea. M.M., H.A., Y.A., and D.H. was responsible for writing and editing the manuscript, and H.A., Y.M., and Y.A. provided technical support. All authors discussed and revised the manuscript.

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