Clinical Phytoscience

REVIEW Open Access

Ethnopharmacological review of medicinal plants used to manage diabetes in Morocco

Elhassan Idm'hand*, Fouad Msanda and Khalil Cherifi

Abstract

Diabetes is a chronic metabolic disorder which affects millions of people every year. If diabetes is not controlled, it can cause serious damage and a number of health complications. The aim of this paper was to review published ethnobotanical and ethnopharmacological evidences of Moroccan plants with antidiabetic potentials. Publications describing the medicinal plants used for the treatment of diabetes in Morocco were searched from the databases, including Google Scholar, Elsevier, Medline, Web of Science, SCOPUS and Pubmed. Other literature source was also used including books and theses available in library. About 750 literature references were studied, and only 240 research publications based on data from different Moroccan provinces published until June 2019 were included in this review. In total, 255 plants species belonging to 70 families were reported. Compositae and Lamiaceae were mentioned as the most represented families. The frequently used plant species in the dwellers of most regions of Morocco are *Trigonella foenum-graecum*, *Artemesia herba-alba*, *Nigella sativa*, *Olea europaea*, *Allium cepa* and *Marrubium vulgare*. This review provides useful information and current scientific knowledge on the medicinal plants used to manage diabetes in Morocco. Medicinal plants reported should be submitted to chemical, pharmacological and clinical studies to identify pharmacologically active metabolites and to confirm their antidiabetic activity.

Keywords: Medicinal plants, Diabetes, Ethnobotany, Pharmacology, Toxicology, Morocco

Introduction

Type 2 diabetes mellitus (T2DM), generally termed as diabetes, is one of the major endocrine diseases which affects millions of people in the industrial and developing countries [1, 2]. It is projected that the total number of people with diabetes worldwide is expected to increase to 592 million by 2035 [3]. Diabetes is a metabolic disease characterized by insufficient insulin secretion, impaired cellular action of the insulin or both [2, 4]. The characteristic symptoms of diabetes are pruritus, polydipsia, weight loss, polyphagia, wasting, blurred vision, polyuria, tachycardia and hypotension [5, 6]. Dietary and lifestyle factors (Obesity, weight gain, physical inactivity and low fiber diet with a high glycemic index) play a significant role in the development of diabetes [7]. Prolonged uncontrolled hyperglycemic level causes an increase in oxidative stress activation of the polyol pathway, coronary artery disease, peripheral arterial disease, stroke, diabetic nephropathy, neuropathy, peripheral neuropathy, retinopathy, retinopathy leading to vision loss, chronic kidney disease, urinary problems, sexual dysfunction, and skin infections [3, 8, 9]. The treatment of diabetes mellitus is based on insulin, diet modification and oral hypoglycemic agents. Herbal medicine has developed as an alternative for the treatment of diabetes because oral hypoglycemic agents are expensive and tagged with several side effects (nausea, skin reactions, liver disease, heart failure diarrhea, etc.) [10, 11]. In Morocco, there are numerous medicinal plants described for treatment of diabetes [2, 12–23].

* Correspondence: idmhand-h@hotmail.com
Laboratoire de Biotechnologies et Valorisation des Ressources Naturelles, Faculté des Sciences, B.P. 8106, Cité Dakhla, Agadir, Morocco

The aim of this review article was to collect data for species wellknown for their antidiabetic effect in Morocco.

Method

Three researchers searched Google Scholar, Elsevier, Medline, Web of Science, SCOPUS and Pubmed bibliographic databases from January 2019 to July 2019 to extract all data about the use of plants in folklore medicine for treatment and management of diabetes in Morocco published in the period from January 1980 to June 2019, using English, French and Arabic keywords. The search terms used were "Ethnobotanical survey", "Moroccan medicinal plants", "anti-diabetic medicinal plants in Morocco", "hypoglycemic plants in Morocco", "diabetes in Morocco". We reviewed the literature and collected data on the explored regions of Morocco (Beni Mellal region, Rabat, Western Anti-Atlas, Izarene forest, Oriental Morocco, Northwestern Morocco, Sefrou region, Central Middle Atlas, Tizi n' Test Region, Al Haouz-Rhamna, Tan-Tan, Meknes-Tafilalet and Fez–Boulemane). About 750 literature references were studied, and only 240 ethnobotanical articles and pharmacology papers were included in this review. We did not included articles related to taxonomy, morphological characters, pharmacology, toxicity, ethnobotany, phytochemistry, clinical studies, cultivation, physiological, and anatomical aspects of all the medicinal plants mentioned. We studied in detail only the six plants most used for the treatment of diabetes in Morocco. We also excluded the articles without accessible full text and duplicate articles. Plant taxonomy is confirmed through data available on site (www.theplantlist.org).

Results

Ethnobotanical studies

A total of 255 plant species belonging to 70 families were reported as being used in the treatment and management of diabetes in Morocco (Table 1). Among plant families, Compositae had the highest number of species followed by Lamiaceae, Leguminosae, Apiaceae, Poaceae and Brassicaceae. Compositae was the most frequently cited plant family, which is consistent with the predominance of this plant family in the results of various studies conducted in other countries [3, 27, 28]. Compositae has been designated as the largest plant family of flowering plants worldwide, comprising 23,000 species and 1535 genera, including many with considerable medicinal importance [29, 30]. The traditional medicinal applications of several Compositae species have been recorded in the literature. Several bioactive compounds have been evaluated for their biological activities [31]. A wide use of Compositae family plants in Morocco could be due to the large number of plant species belonging to this family. Further, plants belonging to the Compositae family contain a group of active phytochemical constituents and some bitter-tasting secondary metabolites such as sesquiterpene lactones [8, 30].

Our evaluation of literature showed that indigenous people used 19 plant parts (leaf, aerial part, fruit, leafy stem, seed, root, bark, calyce, flower, stem, clove, gum, inflorescence, bark, pericarp, rhizome, stigma, tuber and young sprout) as herbal therapies for curing diabetes, but with, however, some preference for the leaves. Several procedures modes are used by the population to create medicinal formulations (decoction, cooked, infusion, powder, maceration, juice, raw and cataplasm). However, extractions by decoction, powder or infusion remain the most common processes. Most medicinal formulations were used internally via oral route. The dose used varied considerably according to the patients questioned. The patients did not respect the precision of doses (some diabetics use specific doses, and others use non-specific doses). Often, people use a mixture of plants to treat diabetes. The duration of the use of plants was badly defined ranging from a few days to several years. The majority of people with diabetes have recourse in medicinal plants to treat diabetes. The percentage of use of phytotherapy varies between 51% and 90%, depending on the regions. The use of herbal medicine among certain diabetics was done in combination with their conventional treatment. Women frequently used more medicinal plants than men. Diabetics have discovered the disease by suggestive symptoms or by a screening test.

An ethnobotanical study was conducted out among 400 herbalists from the Beni Mellal region in order to identify the medicinal plants used for the traditional treatment by the diabetic patients. The results identified 45 species belonging to 25 botanical families. The most used species are: *Olea europaea*, *Salvia officinalis*, *Allium sativum* and *Trigonella foenum-graecum*. Leaves and roots are the most used parts [24].

To collect some information about antidiabetic plants used in Rabat (capital city of Morocco), a survey was undertaken from March 1st to April 30th 2018. The investigations revealed 30 species of plants belonging to 18 families. Lamiaceae and Leguminosae were the most commonly reported plant families. Interview results showed that the most frequently used plants were *Trigonella foenumgraecum*, *Salvia officinalis* and *Olea europaea* [25].

A survey was conducted by Barkaoui et al. [2], in Tiznit (Western Anti-Atlas), in central Morocco. This study showed the importance of the use of medicinal plants by local population in the treatment of diabetes. Results have identified 48 medicinal plant species, belonging to 25 families and 44 genera, used for treating diabetes in the region. Plants growing in wild are most commonly

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Aizoaceae	*Mesembryanthemum theurkauffii* (Maire) Maire	Afzu	Leaf and fruit	Decoction and powder	1	[18]
Amaranthaceae	*Anabasis aretioides* Moq. & Coss. ex Bunge	Chajra ma yeharrekha rih/sellii	Aerial parts	Decoction	3	[17, 18, 21]
Amaranthaceae	*Atriplex halimus* L.	Legtef	Leaf	Powder, decoction and maceration	1	[18]
Amaranthaceae	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Mkhinza	Leaf	Infusion	9	[12–14, 16, 18, 19, 22–24]
Amaranthaceae	*Hammada scoparia* (Pomel) Iljin	Assay	Seed	Decoction	1	[2]
Amaranthaceae	*Salsola tetragona* Delile	Laarad	Leaf and fruit	Powder	1	[18]
Amaryllidaceae	*Allium ampeloprasum* L.	Borro	Bulb	Raw	2	[18, 25]
Amaryllidaceae	*Allium cepa* L.	Basla	Bulb	Raw and juice	14	[2, 12–22, 24, 25]
Amaryllidaceae	*Allium sativum* L.	Tiskert /Touma	Bulb	Raw	9	[12, 13, 17–19, 21–24]
Anacardiaceae	*Pistacia atlantica* Desf.	Btem/Igg/Drou	Fruit	Decoction	1	[2]
Anacardiaceae	*Pistacia lentiscus* L.	Trou/Tidekt	Leaf, gum and ecorce	Infusion and decoction	3	[13, 14, 17]
Anacardiaceae	*Searsia albida* (Schousb.) Moffett	Zewaya/anaffis	Fruit	Raw	1	[18]
Anacardiaceae	*Searsia tripartita* (Ucria) Moffett	Jdari	Leaf	Powder	1	[18]
Apiaceae	*Ammi visnaga* (L.) Lam.	Bachnikha / Barghanisse	Inflorescence (umbel)	Decoction	11	[12–17, 19–23]
Apiaceae	*Ammodaucus leucotrichus* Coss.	Kamoun soufi	Seed	Infusion and decoction	3	[12, 17, 18]
Apiaceae	*Apium graveolens* L.	Krafess	Seed	Infusion	1	[12]
Apiaceae	*Carum carvi* L.	Lkarwya	Seed	Decoction	7	[2, 17–21, 24]
Apiaceae	*Coriandrum sativum* L	Kosbor	Seed	Infusion	6	[12, 15–17, 20, 25]
Apiaceae	*Cuminum cyminum* L.	Kamoun	Seed	Powder	2	[17, 18]
Apiaceae	*Daucus carota* L.	Khizou	Root	Juice and puree	3	[13, 17, 18]
Apiaceae	*Eryngium ilicifolium* Lam.	Tasnant/Iglifin	Stem and leaf	Decoction and powder	1	[2]
Apiaceae	*Foeniculum vulgare* Mill.	Nafaa	Seed	Decoction	9	[2, 12, 17–22, 24]
Apiaceae	*Pastinaca sativa* L.	Left Imahfour	Root	Raw	2	[2, 24]
Apiaceae	*Petroselinum crispm* (Mill.) Fuss	Maadnouss	Seed	Infusion	4	[12, 17, 18, 24]
Apiaceae	*Pimpinella anisum* L.	Habbat hlawa	Seed	Decoction and powder	7	[2, 12, 15, 17, 18, 24, 25]
Apiaceae	*Ptychotis verticillata* Duby	Nounkha	Aerial parts	Infusion	2	[13, 23]
Apiaceae	*Ridolfia segetum* (L.) Moris	Tebch	Seed	Powder	1	[17]
Apocynaceae	*Apteranthes europaea* (Guss.) Murb.	Oukan iddan	Stem	Decoction, infusion, and raw	1	[2]
Apocynaceae	*Calotropis procera* (Aiton) Dryand.	Turja	Leaf	Powder	1	[18]
Apocynaceae	*Caralluma europaea* (Guss.) N.E.Br.	Daghmous	Aerial parts	Maceration	3	[12, 17, 26]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Apocynaceae	*Nerium oleander* L.	Defla/Alili	Leaf	Fumigation and decoction	13	[2, 12, 14, 15, 17–24, 26]
Apocynaceae	*Periploca laevigata* subsp. *angustifolia* (Labill.) Markgr.	Asllif	Fruit	Decoction	2	[2, 26]
Arecaceae	*Chamaerops humilis* L.	Dum /Tiguezden / Ignadd	Root	Raw and cooked	2	[13, 17]
Arecaceae	*Hyphaene thebaica* (L.) Mart.	Dum/karur	Fruit	Powder	1	[18]
Arecaceae	*Phoenix dactylifera* L	Tmar	Fruit	Raw and decoction	5	[12, 17, 18, 20, 23]
Aristolochiaceae	*Aristolochia baetica* L.	Tiswik nigrane / Berztem	Root	Powder	1	[26]
Aristolochiaceae	*Aristolochia fontanesii* Boiss. & Reut.	Berztem	Seed	Decoction	4	[15, 17–19]
Asparagaceae	*Agave americana* L.	Ssabra/Sayber	Leaf	Decoction	1	[17]
Asparagaceae	*Asparagus albus* L.	Sekkum /Azzu	Young sprouts	Raw	1	[13]
Berberidaceae	*Berberis vulgaris subsp. australis* (Boiss.) Heywood	Arghis/Atizar	Leafy stem	Decoction	1	[17]
Brassicaceae	*Anastatica hierochuntica* L.	Chajarat Maryem/Ikemcha	Stem and leaf	Powder	2	[13, 18]
Brassicaceae	*Brassica napus* L.	Left	Rhizome	Juice	1	[18]
Brassicaceae	*Brassica nigra* (L.) K. Koch	Elkhardel	Flower	Powder and infusion	1	[17]
Brassicaceae	*Brassica oleracea* L.	Krunb mkawar/melfuf	Aerial parts and fruit	Raw and maceration	4	[12, 13, 17, 18]
Brassicaceae	*Brassica rapa* L.	Left beldi	Root and leaf	Decoction	2	[13, 17]
Brassicaceae	*Diplotaxis pitardiana* Maire	Kerkaz/Elharra	Flower	Powder	2	[17, 18]
Brassicaceae	*Eruca vesicaria* (L.) Cav.	Ljerjir	Aerial parts	Juice	1	[18]
Brassicaceae	*Lepidium sativum* L.	Hab errechad	Seed	Maceration, decoction and infusion	7	[12, 17–19, 21, 24, 25]
Brassicaceae	*Nasturtium officinale* R.Br.	Gernunes	Leafy steem	Maceration	1	[18]
Brassicaceae	*Ptilotrichum spinosum* (L.) Boiss.	Aguerbaz	Stem and leaf	Decoction	1	[13]
Brassicaceae	*Raphanus sativus* L.	Lfjel	Root	Raw	5	[2, 12, 17, 18, 24]
Buxaceae	*Buxus balearica* Lam.	Azazer /Ibakous	Leaf	Decoction	2	[13, 17]
Buxaceae	*Buxus sempervirens* L.	Lbeks	Leaf	Decoction	1	[19]
Cactaceae	*Opuntia ficus indica* (L.) Mill.	Lhndia/Aknari	Stem, root and flower	Decoction, juice and powder	10	[2, 12, 13, 15–18, 20, 22, 24]
Capparaceae	*Capparis decidua* (Forssk.) Edgew.	Ignin	Fruit	Powder	1	[18]
Capparaceae	*Capparis spinosa* L.	Kabar /Taylulut	Aerial parts, fruit and root	Powder, decoction and infusion	11	[13, 14, 16–23, 26]
Capparaceae	*Maerua crassifolia* Forssk.	Atil/Sedra Ikhadra	Leaf	Powder and decoction	1	[18]
Caryophyllaceae	*Herniaria glabra* L.	Hrasset lehjer	Aerial parts	Decoction	1	[22]
Caryophyllaceae	*Paronychia argentea* Lam.	Tahidourt n'imksaoum	Leafy stem	Infusion	1	[26]
Caryophyllaceae	*Silene vivianii* Steud.	Gern lebzal	Steem	Raw	1	[18]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Cistaceae	*Cistus albidus* L.	Boutour	Leaf	Decoction	1	[13]
Cistaceae	*Cistus creticus* L.	Irgel	Leaf	Decoction and powder	3	[2, 17, 26]
Cistaceae	*Cistus laurifolius* L.	Agullid	Seed and flower	Powder	2	[17, 26]
Cistaceae	*Cistus salviifolius* L.	Irgel/Tirgelt	Leaf and seed	Decoction and powder	2	[2, 17]
Colchicaceae	*Androcymbium gramineum* (Cav.) J.F.Macbr.	Temrate leghrab	Bulb	Infusion	1	[17]
Compositae	*Achillea odorata* L.	Elqorte	Leaf and flower	Infusion	1	[17]
Compositae	*Anacyclus pyrethrum* (L.) Lag.	Iguntas /Tagundecht	Root	Infusion and powder	1	[13]
Compositae	*Antennaria dioica* (L.) Gaertn.	Ouden elfar	Leaf	Decoction	1	[17]
Compositae	*Anvillea garcinii* subsp. *radiata* (Coss. & Durieu) Anderb.	Negd	Leaf	Decoction and powder	1	[18]
Compositae	*Artemisia abrotanum* L.	Chih	Aerial parts	Decoction	1	[17]
Compositae	*Artemisia absinthium* L.	Chiba	Aerial parts	Infusion	10	[12, 14, 16, 17, 19–24]
Compositae	*Artemisia atlantica* Coss. & Durieu	Chih ourika	Aerial parts	Infusion	1	[17]
Compositae	*Artemisia herba-alba* Asso	Izri/Chih dwidi	Steam, leaf and root	Decoction and infusion	15	[2, 12, 14–26]
Compositae	*Artemisia mesatlantica* Maire	Chih alaallssat/Chih elkhrayssi	Aerial parts	Decoction	1	[17]
Compositae	*Artemisia reptans* C.Sm. ex Link	Chihiya	Leaf	Decoction	1	[18]
Compositae	*Centaurea maroccana* Bal	Bejjaae nhal/Nogguir	Flower	Infusion	1	[17]
Compositae	*Chamaemelum nobile* (L.) All.	Babounj	Leaf	Decoction	2	[15, 17]
Compositae	*Cichorium intybus* L.	Buaggad	Root	Infusion	1	[18]
Compositae	*Cladanthus arabicus* (L.) Cass.	Taafs	Flower	Infusion	1	[17]
Compositae	*Cladanthus scariosus* (Ball) Oberpr. & Vogt	Arzgi/irzgi	Flower	Decoction	1	[26]
Compositae	*Cynara cardunculus* L.	Kharchouf	Aerial parts	Decoction	7	[12, 15, 17–20, 22]
Compositae	*Dittrichia viscosa* (L.) Greuter	Terehla/Bagraman	Leaf	Decoction	3	[13, 17, 26]
Compositae	*Echinops spinosissimus* Turra	Taskra	Flower	Decoction	3	[2, 15, 26]
Compositae	*Inula conyza* (Griess.) DC.	Terrehla	Root	Decoction	1	[17]
Compositae	*Inula helenium* L.	Terrehla damnatiya	Leaf and flower	decoction	1	[17]
Compositae	*Lactuca sativa* L.	Khes	Leaf	Raw	4	[12, 17, 21, 22]
Compositae	*Launaea arborescens* (Batt.) Murb.	Iferskel/Moulbna	Stem, leaf, root and flower	Powder, decoction and infusion	3	[2, 17, 18]
Compositae	*Matricaria chamomilla* L.	Mansania	Leaf and flower	Decoction and infusion	3	[14, 17, 24]
Compositae	*Pallenis spinosa* (L.) Cass.	Nugd	Aerial parts	decoction	1	[17]
Compositae	*Scolymus hispanicus* L.	Gumina /Taghdiut	Stem and leaf	Raw and decoction	3	[13, 17, 26]
Compositae	*Scorzonera undulata* Vahl	Tamtla	Flower	Raw	1	[2]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Compositae	*Sonchus arvensis* L.	Kettan elhench	Leaf	Infusion	1	[15]
Compositae	*Sonchus tenerrimus* L.	Tifaf	Leaf	Decoction	1	[18]
Compositae	*Tanacetum vulgare* L	Lbalssam	Stem	Infusion	1	[17]
Compositae	*Taraxacum campylodes* G.E.Haglund	Lhandba	Flower and root	Decoction	1	[17]
Compositae	*Warionia saharae* Benthem ex Benth. & Coss.	Afssas	Leaf	Infusion and powder	2	[2, 18]
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	Aferziz/lhdej	Seed and fruit	Decoction, cataplasm and powder	11	[2, 12, 13, 17–19, 21–23, 25, 26]
Cucurbitaceae	*Cucumis sativus* L.	Lkhiar	Fruit	Raw	6	[2, 12, 13, 17, 18, 24]
Cucurbitaceae	*Cucurbita maxima* Duchesne	Garaa lhamra	Leaf	Decoction	1	[18]
Cucurbitaceae	*Cucurbita pepo* L.	Takhsait/curjt	Fruit	Raw and decoction	5	[13, 14, 17, 18, 24]
Cupressaceae	*Juniperus phoenicea* L.	Araar finiqui	Leaf and aerial parts	Powder, decoction and maceration	4	[13, 17–19]
Cupressaceae	*Juniperus thurifera* L	Tawayt	Leaf	Decoction	1	[13]
Cupressaceae	*Tetraclinis articulata* (Vahl) Mast.	Araar	Leaf and aerial parts	Infusion and maceration	9	[12–15, 17, 21–24]
Cynomoriaceae	*Cynomorium coccinum* L.	Tertut	Steem	Powder	1	[18]
Cyperaceae	*Bolboschoenus maritimus* (L.) Palla	Ssmar	Seed	Decoction	1	[17]
Cyperaceae	*Cyperus rotundus* L.	Tara	Leaf	Powder	1	[18]
Dracaenaceae	*Dracaena draco subsp. ajgal* Benabid & Cuzin	Ajgal	Stem and leaf	Decoction	1	[2]
Ephedraceae	*Ephedra alata* Decne.	Chdida	Leafy stem	Decoction and powder	1	[18]
Ephedraceae	*Ephedra altissima* Desf.	Tougel argan	Stem, leaf and wholeplant	Decoction	2	[2, 24]
Ephedraceae	*Ephedra fragilis* Desf.	Amater	Leafy stem	Decoction	1	[26]
Ericaceae	*Arbutus unedo* L.	Sasnu	Leaf and root	Decoction	5	[13, 14, 22–24]
Euphorbiaceae	*Euphorbia officinarum* subsp. *echinus* (Hook. f. & Coss.) Vindt	Tikiout/Daghmouss/zakoum	Fruit, stem and leaf	Maceraion, decoction, powder and juice	4	[2, 16–18]
Euphorbiaceae	*Euphorbia officinarum* L	Tikiout/Daghmouss	Stem and leaf	Powder	1	[2]
Euphorbiaceae	*Euphorbia resinifera* O.Berg	Tikiwt	Leaf	A drop latex in a glass of water	4	[13, 19, 24, 26]
Euphorbiaceae	*Mercurialis annua* L.	Hurriga elmalssa	Leafy stem	Infusion, decoction and juice	2	[17, 18]
Euphorbiaceae	*Ricinus communis* L.	Awriwer/Lkharwaa	Seed	Poultice	1	[18]
Fagaceae	*Quercus coccifera* L.	Elqermez	Leaf	Decoction	1	[17]
Gentianaceae	*Centaurium erythraea* Rafn	Qusset elhayya / Ahchlaf ntawrra	Flowering and aerial parts	Infusion and decoction	4	[13, 14, 17, 22]
Iridaceae	*Crocus sativus* L.	Zaafran lhor	Stigma	Infusion	1	[18]
Juglandaceae	*Juglans regia* L.	Swak / Gargaa	Leaf and bark	Infusion and decoction	6	[13, 17, 18, 22, 23, 26]
Juncaceae	*Juncus maritimus* Lam.	Ssemar	Fruit and stem	Decoction	2	[17, 18]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Lamiaceae	*Ajuga iva* (L.) Schreb.	Timerna nzenkhad/ Chndkoura	Stem and leaf	Powder and decoction	12	[2, 12–15, 17–19, 22–24, 26]
Lamiaceae	*Ballota hirsuta* Benth	Merrou elhrami/Merrou	Leafy stem	Decoction	1	[17]
Lamiaceae	*Clinopodium alpinum (L.) Kuntze*	Ziitra	Leaf	Decoction	2	[18, 25]
Lamiaceae	*Clinopodium nepeta subsp. glandulosum* (Req.) Govaerts	Manta	Aerial parts	Infusion and decoction	2	[14, 15]
Lamiaceae	*Lavandula angustifolia* Mill	Elkhzama zerqa/ Elkhzama Fassiya	Aerial parts and leafy stem	Infusion and decoction	1	[17]
Lamiaceae	*Lavandula dentata* L.	Timzeria/Lakhzama/ Jaada	Stem and leaf	Decoction, powder, infusion and raw	6	[2, 14, 17, 21–23]
Lamiaceae	*Lavandula maroccana* Murb.	Igazioen	Stem and leaf	Decoction	2	[2, 26]
Lamiaceae	*Lavandula multifida* L	Khilt Ikheyl/ Kohayla	Leaf	Decoction	1	[18]
Lamiaceae	*Lavandula stoechas* L.	Imzeria/Tikenkert/Lhalhal	Leaf	Decoction	5	[2, 12, 13, 17, 18]
Lamiaceae	*Marrubium vulgare* L.	Mriwt/Ifzi	Leaf and aerial parts	Decoction and infusion	14	[2, 12–19, 21–25]
Lamiaceae	*Mentha pulegium* L.	Fliou	Leaf and aerial parts	Decoction and infusion	8	[2, 13, 15, 17–19, 21, 23, 25]
Lamiaceae	*Mentha spicata* L.	Nanaa/Liqama	Leaf and leafy stem	Infusion and decoction	2	[17, 18]
Lamiaceae	*Ocimum basilicum* L.	Lahbaq	Stem	Infusion	2	[13, 17]
Lamiaceae	*Origanum compactum* Benth.	Azukenni/Zaater/ Zaatar tadlawi	Stem and leaf	Decoction and infusion	8	[13–15, 17, 18, 21–23]
Lamiaceae	*Origanum elongatum* (Bonnet) Emb. & Maire	Zaater	Leaf	Infusion	1	[25]
Lamiaceae	*Origanum majorana L.*	Berdedouch	Leaf	Powder	1	[18]
Lamiaceae	*Origanum vulgare* L	Zaatar	Leaf	Infusion	1	[12]
Lamiaceae	*Rosmarinus officinalis* L.	Azir	Leaf	Powder, decoction and infusion	11	[2, 13–15, 17–19, 21–23, 25]
Lamiaceae	*Salvia officinalis* L.	Salmia	Leaf	Decoction and infusion	11	[2, 12, 13, 15–19, 22–24, 26]
Lamiaceae	*Teucrium polium* L.	Tawerart/Flyou Ibour/jaaidia	Leaf	Decoction and powder	3	[2, 19, 26]
Lamiaceae	*Thymus broussonetii* Boiss.	Zietra	Leaf and stem	Infusion and maceration	1	[25]
Lamiaceae	*Thymus algeriensis* Boiss. & Reut.	Aduchen /Azukni / Zaitra	Stem and leaf	Decoction and infusion	1	[13]
Lamiaceae	*Thymus munbyanus* Boiss. & Reut	Aduchen /Azukni / Zaitra	Stem and leaf	Decoction and infusion	1	[13]
Lamiaceae	*Thymus satureioides* Coss.	Asserkna/ Ziitra	Leaf	Infusion, decoction, powder, and maceration	2	[2, 17]
Lamiaceae	*Thymus vulgaris* L.	Aduchen /Azukni / Zaitra	Leaf	Decoction and infusion	3	[2, 13, 17]
Lamiaceae	*Thymus zygis* L.	Aduchen /Azukni / Zaitra	Stem and leaf	Decoction and infusion	1	[13]
Lauraceae	*Cinnamomum cassia* (L.) J.Presl	Qarfa	Bark	Decoction	5	[13, 15, 17, 19, 21]
Lauraceae	*Cinnamomum verum* J.Presl	Dar essini	Bark	Maceration	3	[17, 18, 25]
Lauraceae	*Laurus nobilis* L.	Ourak sidna moussa/ Rand	Leaf	Infusion and decoction	2	[12, 17]
Lauraceae	*Persea americana* Mill.	Lavoca	Seed	Powder	4	[16, 18, 19, 25]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Leguminosae	*Acacia nilotica* (L.) Delile	Amur/Sllaha	Fruit	Powder	1	[18]
Leguminosae	*Acacia senegal* (L.) Willd.	Laalek	Gum	Powder	1	[18]
Leguminosae	*Acacia tortilis* (Forssk.) Hayne	Telh/Tadoute	Root, fruit and leaf	Decoction and powder	2	[17, 18]
Leguminosae	*Anagyris foetida* L.	Ful gnawa	Seed	Powder	1	[18]
Leguminosae	*Arachis hypogaea L.*	Lgerta/Kawkaw	Seed	Powder	1	[18]
Leguminosae	*Ceratonia siliqua* L.	Tikida/Lkharoub	Leaf and seed	Decoction, infusion and powder	6	[2, 12, 17, 18, 24, 25]
Leguminosae	*Cicer arietinum* L.	Lhemmes	Seed	Decoction and powder	2	[18, 24]
Leguminosae	*Faidherbia albida* (Delile) A.Chev.	Chok/Talh/Mimouza	Root	Decoction	1	[17]
Leguminosae	*Glycine max* (L.) Merr.	Soja	Seed	Maceration and raw	5	[2, 12, 20, 24, 26]
Leguminosae	*Glycyrrhiza glabra* L	Ark souss	Bark	Infusion	1	[25]
Leguminosae	*Lupinus albus* L.	Tirms/Foul gnawa	Seed	Powder, Infusion and decoction	7	[16–19, 21, 22, 24]
Leguminosae	*Lupinus angustifolius* L.	Ibawn dekouk	Seed	Powder and decoction	3	[2, 17, 26]
Leguminosae	*Lupinus luteus* L.	Kikel/Semqala	Seed	Decoction	1	[17]
Leguminosae	*Medicago sativa* L.	Fassa	Aerial parts and seed	Infusion, maceration and cooked	5	[12, 13, 17, 18, 24]
Leguminosae	*Ononis natrix* L.	Hennet reg	Leaf	Decoction	1	[18]
Leguminosae	*Ononis tournefortii* Coss.	Afezdad	Leaf	Decoction	1	[18]
Leguminosae	*Phaseolus vulgaris* L.	Lubya	Fruit	Decoction, powder and Juice	4	[13, 16–18]
Leguminosae	*Retama raetam* (Forssk.) Webb	Rtam/Allug	Root and leaf	Decoction	1	[17]
Leguminosae	*Retama sphaerocarpa* (L.) Boiss.	Rtem	Root	Decoction	1	[20]
Leguminosae	*Trigonella foenum-graecum* L.	Lhelba/Tifidas	Seed	Decoction, infusion, maceration and powder	16	[2, 12–26]
Leguminosae	*Vicia faba* L.	Ful	Seed	Powder	1	[18]
Leguminosae	*Vicia sativa* L.	Ayn larnab	Seed	Powder	1	[18]
Leguminosae	*Vigna radiata* (L.) R.Wilczek	Soja	Seed	Powder	1	[18]
Leguminosae	*Vigna unguiculata (L.) Walp*	Ful gnawa	Seed	Decoction	1	[17]
Linaceae	*Linum usitatissimum* L.	Zariat elkattan	Seed	Decoction and powder	7	[2, 13, 15, 17, 18, 21, 25]
Lythraceae	*Lawsonia inermis* L.	Lhenna	Leaf	Decoction and cataplasme	2	[17, 21]
Lythraceae	*Punica granatum* L.	Rman	Pericarp	Decoction, infusion, and powder	8	[2, 13, 15, 17–21]
Malvaceae	*Abelmoschus esculentus* (L.) Moench	Lmloukhia	Fruit	Maceration	2	[13, 25]
Malvaceae	*Hibiscus sabdariffa* L.	Karkadi/Bissam	Calyces	Infusion	3	[17, 18, 26]
Molluginaceae	*Corrigiola litoralis subsp. telephiifolia* (Pourr.) Briq.	Sarghina / Tawsarghine	Root	Powder	2	[13, 17]
Moraceae	*Ficus carica* L.	Tazart/Lkarmous/Karma/chriha/ Elbakur	Fruit and leaf	Decoction	8	[2, 13, 15, 17, 20, 22–24]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Moraceae	*Morus alba* L.	Tut lbari	Leaf	Infusion	3	[13, 17, 19]
Musaceae	*Musa* × *paradisiaca* L.	Banan	Leaf	Decoction	1	[18]
Myristicaceae	*Myristica fragrans* Houtt.	Lgouza	Seed	Powder	1	[2]
Myrtaceae	*Eucalyptus camaldulensis* Dehnh.	Calitus	Leaf	Decoction	1	[18]
Myrtaceae	*Eucalyptus globulus* Labill.	Calitus	Leaf and fruit	Decoction	8	[13–15, 17, 21–24]
Myrtaceae	*Myrtus communis* L.	Rihane	Leaf and fruit	Decoction and infusion	8	[13, 14, 17, 20–24]
Myrtaceae	*Syzygium aromaticum* (L.) Merr. & L.M.Perry	Kranfal	Fruit and clove	Infusion, decoction, powder and maceration	8	[2, 14, 17–19, 22, 24, 25]
Nitrariaceae	*Peganum harmala* L.	Lharmel	Seed	Infusion and powder	7	[13, 15, 17, 20–23]
Oleaceae	*Fraxinus angustifolia* Vahl	Touzalt	Leaf	Infusion	2	[13, 23]
Oleaceae	*Olea europaea* L.	Jbouj/Azmour/Zitoun	Leaf, fruit and flower	Decoction, infusion, maceration and powder	15	[2, 12, 13, 15–26]
Papaveraceae	*Fumaria officinalis* L.	Hachichat assebyane	Root	Decoction	1	[17]
Papaveraceae	*Papaver rhoeas* L.	Belaaman	Seed	Powder	3	[2, 24, 26]
Pedaliaceae	*Sesamum indicum* L.	Janjlan	Seed	Powder, Infusion and decoction	7	[2, 14, 18, 20–22, 24]
Plantaginaceae	*Globularia alypum* L.	Ayen lerneb/ Taselgha	Flower,l eaf and stem	Infusion and decoction	10	[13, 15–19, 21–23, 26]
Plantaginaceae	*Globularia repens* Lam.	Ain lernab	Leaf	Decoction	1	[12]
Plumbaginaceae	*Limonium sinuatum* (L.) Mill.	Lgarsa	Leaf	Decoction	1	[18]
Poaceae	*Avena sativa* L.	Khortal	Seed	Powder, infusion and decoction	2	[13, 17]
Poaceae	*Avena sterilis* L.	Waskone/ Khortal	Seed	Powder	1	[26]
Poaceae	*Castellia tuberculosa* (Moris) Bor	Zwan lmkarkeb	Seed	Decoction	1	[17]
Poaceae	*Cynodon dactylon* (L.) Pers.	Njem	Root	Decoction	1	[18]
Poaceae	*Hordeum vulgare* L.	Chair/Zraa	Aerial parts and seed	Infusion, powder and maceration	3	[2, 17, 18]
Poaceae	*Lolium perenne* L.	Eziwane	Seed	Decoction	1	[26]
Poaceae	*Panicum miliaceum* L.	Tafssout	Seed	Decoction	1	[17]
Poaceae	*Panicum turgidum* Forssk.	Umm rekba	Stem	Decoction and powder	1	[18]
Poaceae	*Pennisetum glaucum* (L.) R.Br.	Illan	Seed	Infusion and powder	3	[12, 17, 18]
Poaceae	*Phalaris canariensis* L.	Zouan	Seed and fruit	Powder, infusion and decoction	6	[2, 13, 14, 16, 17, 24]
Poaceae	*Polypogon monspeliensis* (L.) Desf	Tugga	Fruit	Raw	1	[18]
Poaceae	*Sorghum bicolor* (L.) Moench	Bachna	Seed	Infusion and decoction	3	[13, 15, 23]
Poaceae	*Triticum durum* Desf.	Zraa	Seed	Decoction	1	[17]
Poaceae	*Zea mays* L.	Lahyat Adra	Stigmas	Powder	3	[14, 24, 26]
Polygonaceae	*Emex spinosa* (L.) Campd.	Lhenzab	Leaf and bulb	Powder	1	[18]
Portulacaceae	*Portulaca oleracea* L.	Rejla	Aerial parts	Decoction	3	[12, 17, 26]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Ranunculaceae	*Nigella sativa L.*	Haba souda /Sanouj	Seed	Infusion, decoction and powder	15	[2, 13–26]
Rhamnaceae	*Ziziphus lotus* (L.) Lam.	Nbeg/Azouggar/ssdra	Leaf, fruit and root	Decoction and powder	10	[2, 15, 17–20, 22–24, 26]
Rosaceae	*Cydonia oblonga* Mill.	Sferjel	Fruit	Raw	1	[20]
Rosaceae	*Chaenomeles sinensis* (Dum.Cours.) Koehne	Sferjel	Root	Decoction	2	[18, 22]
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	Mzah	Leaf	Infusion	3	[13, 15, 23]
Rosaceae	*Fragaria vesca* L	Fraiz berri	Fruit	Raw	1	[22]
Rosaceae	*Malus communis* (L.) Poir.	Etefah	Fruit	Juice	1	[26]
Rosaceae	*Prunus armeniaca* L.	Luz elhar	Seed	Decoction	1	[17]
Rosaceae	*Prunus dulcis* (Mill.) D.A. Webb	Louz imrzig/ Louz morr	Seed and leaf	Raw and decoction	12	[2, 14, 15, 17, 18, 20–26]
Rosaceae	*Rubus vulgaris* Weihe & Nees	Laalig	Leaf	Powder	1	[17]
Rubiaceae	*Rubia tinctorum* L.	Fowwa	Root	Powder	1	[18]
Rutaceae	*Citrus medica* L	Lhamed beldî	Fruit	Juice and infusion	1	[17]
Rutaceae	*Citrus paradisi* Macfad.	Pamblamus	Fruit	Juice	1	[17]
Rutaceae	*Citrus sinensis (L.) Osbeck*	Limun	Fruit	Raw and juice	2	[12, 18]
Rutaceae	*Citrus × aurantium* L	Larenj/Zenbue/trunj	Leaf, fruit and flower	Juice, infusion and decoction	7	[14, 16–21]
Rutaceae	*Ruta graveolens* L.	Lfijel	Root	Decoction	2	[17, 18]
Rutaceae	*Ruta montana* (L.) L.	LFijel /Iwermi	Stem and leaf	Decoction, infusion and powder	7	[13–15, 17, 19, 20, 23]
Salicaceae	*Salix alba* L.	Salef lma	Leaf	Decoction	1	[19]
Santalaceae	*Viscum album* L	Lenjbar	Seed	Infusion	1	[15]
Sapotaceae	*Argania spinosa* (L.) Skeels	Argan	Seed	Raw and powder	8	[2, 13, 15–18, 25, 26]
Schisandraceae	*Illicium verum* Hook.f.	Badiana	Fruit	Decoction	1	[17]
Solanaceae	*Capsicum annuum* L.	Felfel Hârr/ soudania	Fruit	Raw	3	[13, 14, 18]
Solanaceae	*Datura stramonium* L.	Sdag jmel/Metal	Seed	Decoction	1	[18]
Solanaceae	*Lycopersicon esculentum* Mill.	Maticha	Fruit	Raw	2	[17, 18]
Solanaceae	*Nicotiana tabacum* L.	Nefha	Leaf	Decoction	1	[14]
Solanaceae	*Solanum americanum* Mill.	Aneb dib	Leaf	Infusion	1	[17]
Taxaceae	*Taxus baccata* L.	Guelguem/Aguelguimt	Root	Decoction	1	[17]
Theaceae	*Camellia sinensis* (L.) Kuntze	Attay	Leaf	Infusion and decoction	6	[2, 12, 15, 17, 18, 24]
Thymelaeaceae	*Thymelaea hirsuta* (L.) Endl.	Metnan	Leafy stem	Powder	2	[17, 23]
Thymelaeaceae	*Thymelaea tartonraira* (L.) All.	Talazazt	Leaf	Decoction	1	[20]
Thymelaeaceae	*Thymelaea virgata* (Desf.) Endl.	Metnan	Leafy stem	Decoction	1	[17]
Urticaceae	*Urtica dioica* L.	Taznagt/Tigzenin/Lhriga	Stem and leaf	Decoction and infusion	8	[2, 14, 15, 17, 19, 23, 24, 26]
Urticaceae	*Urtica pilulifera* L.	Hurriga / Tisrakmaz	Leaf	Decoction	2	[13, 22]

Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies *(Continued)*

Family	Plant species	Vernacular name	Part used	Preparation	Number of citations	References
Verbenaceae	*Aloysia citriodora* Palau	Alwiza	Leaf	Decoction and infusion	4	[14–16, 18]
Verbenaceae	*Verbena officinalis* L.	Alwiza	Leaf	Decoction	1	[25]
Vitaceae	*Vitis vinifera* L.	Dalya/Zbib/Kerma/Adilite	Leaf	Decoction	3	[17, 18, 20]
Xanthorrhoeaceae	*Aloe succotrina* Lam.	Ssabra/Siber	Leaf	Powder	5	[15, 17, 18, 21, 22]
Xanthorrhoeaceae	*Asphodelus microcarpus* Salzm. & Viv.	Lberwag/blaluz/Tazia	Tuber	Raw	2	[17, 18]
Xanthorrhoeaceae	*Asphodelus tenuifolius* Cav.	Lehyat al aatrus/Tazya/Lberiwiga	Leaf	Decoction	1	[17]
Zingiberaceae	*Zingiber officinale* Roscoe	Sekinjbir	Rhizome	Decoction, infusion, powder and maceration	5	[14, 15, 18, 19, 25]
Zygophyllaceae	*Tetraena gaetula* (Emb. & Maire) Beier & Thulin	Aagaia	Leaf, root and seed	Powder, Infusion and decoction	10	[2, 13, 14, 17–23]

used for medicinal purposes in the study area (32 plant species). According to the authors, *Allium sativum* L., *Salvia officinalis* L., *Marrubium vulgare* L. and *Lavandula dentata* L were the most frequently used plants to treat diabetes. Six plants were reported for the first time as hypoglycemic plants: *Dracaena draco subsp. ajgal*, *Euphorbia officinarum* subsp. *officinarum*, *Eryngium ilicifolium* Lam., *Pastinaca sativa* L., *Scorzonera undulata*, *Ephedra altissima* Desf.

In Izarene forest (Northern Morocco), a survey was undertaken in order to inventory the main medicinal plants used in folk medicine to treat diabetes and arterial hypertension. The results obtained allowed an inventory of 40 medicinal plant species used against diabetes. The most cited plants for the treatment of diabetes were: *Trigonella foenum-graecum*, *Artemisia herba-alba*, *Ammi visnaga*, *Centaurium erythreae*, *Myrtus communis*, *Globularia alypum*, *Nigella sativa*, *Tetraena gaetula*, *Olea europaea*, *Rosmarinus officinalis*, *Marrubium vulgare*, *Allium cepa*, *Ajuga iva*, *Salvia officinalis*, *Artemesia absinthium*, *Prunus dulcis*, *Capsicum annuum*, *Origanum compactum*, *Nerium oleander*, and *Urtica dioica* [14].

An ethnobotanical survey by Ziyyat et al. [23] in different areas of Oriental Morocco reported that 34 plant species were used for the treatment of diabetes, of which the most used were *Trigonella foenum-graecum*, *Globularia alypum*, *Artemisia herba-alba*, *Citrullus colocynthis* and *Tetraclinis articulata*. Also a study was carried out in Oriental Morocco with 279 diabetic patients at the Department of Endocrinology and Metabolism of Mohammed VI Uneversity Hospitalin Oujda. The results showed that the local population uses medicinal plants for the treatment of diabetes. Fifty plants are reported to be used in the region for the treatment of diabetes. The five most common herbal medicines used were *Salvia officinalis*, *Trigonella foenum-graecum*, *Olea europaea*, *Artemisia herba-alba* and *Origanum vulgare* [15].

A study by Laadim et al. [12] in Sidi Slimane (northwestern Morocco) reported that 59 plant species were cited by 700 diabetic patients for management of diabetes. Five plants, *Trigonella foenum-graecum*, *Oreganum vulgare*, *Salvia officinalis*, *Marrubium vulgare* and *Olea europaea*, were most used. The survey revealed that seeds and leaves are the part of the plant most often used in herbal preparations.

In an ethnobotanical survey by Bousta et al. [16], 22 species of plants belonging to 19 families were reported for the treatment of diabetes in the Middle-Atlas region of Morocco (Sefrou region). The most prominent plants reported were *Olea europaea*, *Salvia officinalis*, *Trigonella foenum-graecum*, *Euphorbia officinarum subsp. echinus*, *Globularia alypum*, *Coriandrum sativum*. Respondents said that they inherited the knowledge of their practices from their parents, traditional healers, some books and nowadays from television programs.

Also in the Central Middle Atlas an ethnobotanical study identified 76 medicinal plants, divided into 67 genus and 40 families. Fourteen plants are reported for the first time intraditional treatment of diabetes in Morocco. They are: *Pistacia atlantica*, *Anacyclus pyrethrum*, *Ptilotrichum spinosum*, *Cistus albidus*, *Juniperus thurifera*, *Thymus algeriensis*, *Thymus munbyanus*, *Thymus zygis*, *Abelmoschus esculentus*, *Fraxinus angustifolia*, *Sorghum bicolor* and *Eriobotrya japonica* [13].

To inventory the medicinal plants used in traditional medicine to treat diabetes in the Tizi n' Test Region (Taroudant Province), a survey was carried using semi-structured and structured questionnaires. Thirty-nine plant species belonging to 24 botanical families were recorded for the treatment of diabetes. The most important species were *Artemisia herba-alba*, *Cistus creticus*, *Lavandula maroccana*, *Salvia officinalis* and *Olea europaea*. Leaves were the parts predominantly used and decoction was the most common method to prepare the formulations [26].

Another ethnobotanical survey among the local population in the region of Al Haouz-Rhamna (central Morocco) reported that a total of 150 plant species belonging to 54 families were used for the treatment of diabetes in the area. Among these species recorded 18 are cited for the first time in the region as an antidiabetic plants namely*: Chamaerops humilis*, *Cladanthus arabicus*, *Centaurea maroccana*, *Matricaria chamomilla*, *Tanacetum vulgare*, *Diplotaxis pitardiana*, *Berberis vulgaris subsp. australis*, *Corrigiola litoralis subsp. telephiifolia*, *Cistus laurifolius*, *Quercus coccifera*, *Ballota hirsuta*, *Buxus balearica*, *Lavandula stoechas*, *Ocimum basilicum*, *Thymus satureioides*, *Ruta montana*, *Taxus baccata* and *Thymelaea virgata* [17].

In the region of Tan-Tan (South of Morocco), a survey reported that 129 medicinal species belonging to 53 families were cited by 350 people for the treatment of diabetes with the dominance of the most represented families in the flora of Morocco. Some of the inventoried plant species are endemic to the Sahara such as *Cynomorium coccineum*, *Atriplex halimus* and *Salsola tetragona*, but others are toxic including *Aristolochia fontanesii*, *Euphorbia officinarum* and *Nerium oleander* [18].

In the region of Meknes-Tafilalet (North-central Morocco), an ethnobotanical study was undertaken in order to inventory the main medicinal plants used in folk medicine to treat diabetes. In this region, the most frequently used plants include *Allium cepa*, *Artemisia herba-alba* and *Trigonella foenum graecum* [19]. Also in the North central region of Morocco (Fez–Boulemane), an ethnobotanical study reported that 90 medicinal species are used in the treatment of diabetes, hypertension

and renal diseases. Among these species, 9 plants are toxic at high doses. For diabetes, 54 plants were cited, of which the most cited were: *Artemesia herba alba*, *Trigonella foenum-graecum* and *Tetraena gaetula* [22].

In the Errachidia province (South-eastern Morocco), a survey was carried out to catalog the plants traditionally used in the treatment of hypertension and diabetes mellitus. The authors have inventoried 64 species belonging to 33 families, of which 45 plants were used in the treatment of diabetes. The most frequently cited plant species by the local population for management of diabetes are *Ajuga iva*, *Allium cepa*, *Artemisia herba-alba*, *Carum carvi*, *Lepidium sativum*, *Nigella sativa*, *Olea europaea*, *Peganum harmala*, *Phoenix dactylifera*, *Rosmarinus officinalis*, and *Tetraena gaetula* [20]. Also in south-eastern Morocco (Tafilalet region), an ethnobotanical study identified 92 medicinal plants used in the treatment of diabetes mellitus, hypertension and cardiac diseases. The most frequently cited medicinal plants used for their antidiabetic effects were *Ammi visnaga*, *Artemesia herba-alba*, *Trigonella foeniculum-granum*, *Marrubium vulgare*, *Nigella sativa*, *Globularia alypum*, *Allium sativum*, *Olea europaea*, *Citrullus colocynthis*, *Aloe succotrina*, *Artemisia absinthium*, *Rosmarinus officinalis*, *Thymus vulgaris*, *Eucalyptus globulus*, *Mentha pulegium*, *Myrtus communis*, *Linum usitatissimum* and *Carum carvi* [21].

Pharmacological and toxicological studies

Among 255 plant species being used, 120 plants have neither been explored experimentally for antidiabetic activity. They are: *Mesembryanthemum theurkauffii*, *Salsola tetragona*, *Searsia albida*, *Searsia tripartita*, *Eryngium ilicifolium*, *Pastinaca sativa*, *Ptychotis verticillata*, *Ridolfia segetum*, *Apteranthes europaea*, *Periploca laevigata* subsp. *Angustifolia*, *Aristolochia fontanesii*, *Agave americana*, *Asparagus albus*, *Achillea odorata*, *Antennaria dioica*, *Anvillea garcinii* subsp. *radiata*, *Artemisia abrotanum*, *Artemisia atlantica*, *Artemisia mesatlantica*, *Artemisia reptans*, *Centaurea maroccana*, *Cladanthus arabicus*, *Cynara cardunculus*, *Dittrichia viscosa*, *Echinops spinosissimus*, *Inula conyza*, *Inula helenium*, *Launaea arborescens*, *Pallenis spinosa*, *Scolymus hispanicus*, *Scorzonera undulata*, *Sonchus arvensis*, *Sonchus tenerrimus*, *Tanacetum vulgare*, *Berberis vulgaris subsp. australis*, *Diplotaxis pitardiana*, *Eruca vesicaria*, *Ptilotrichum spinosum*, *Buxus balearica*, *Maerua crassifolia*, *Herniaria glabra*, *Silene vivianii*, *Cistus albidus*, *Cistus creticus*, *Cistus salviifolius*, *Androcymbium gramineum*, *Juniperus thurifera*, *Tetraclinis articulata*, *Cynomorium coccineum*, *Bolboschoenus maritimus*, *Dracaena draco subsp. ajgal*, *Ephedra alata*, *Ephedra altissima*, *Euphorbia officinarum* subsp. *echinus*, *Euphorbia officinarum* subsp. *officinarum*, *Hammada scoparia*, *Euphorbia resinifera*, *Mercurialis annua*, *Anagyris foetida*, *Ceratonia siliqua*, *Cicer arietinum*, *Lupinus angustifolius*, *Lupinus luteus*, *Ononis natrix*, *Ononis tournefortii*, *Retama sphaerocarpa*, *Vicia faba*, *Vicia sativa*, *Quercus coccifera*, *Juncus maritimus*, *Ballota hirsuta*, *Clinopodium alpinum*, *Clinopodium nepeta subsp. glandulosum*, *Lavandula dentata*, *Lavandula maroccana*, *Lavandula multifida*, *Mentha pulegium*, *Mentha spicata*, *Origanum compactum*, *Origanum majorana*, *Origanum vulgare*, *Thymus algeriensis*, *Thymus munbyanus*, *Thymus zygis*, *Corrigiola litoralis subsp. telephiifolia*, *Fumaria officinalis*, *Papaver rhoeas*, *Globularia repens*, *Limonium sinuatum*, *Avena sativa*, *Castellia tuberculosa*, *Panicum miliaceum*, *Panicum turgidum*, *Polypogon monspeliensis*, *Triticum durum*, *Emex spinosa*, *Fragaria vesca*, *Rubus vulgaris*, *Rubia tinctorum*, *Salix alba*, *Illicium verum*, *Taxus baccata*, *Thymelaea tartonraira*, *Thymelaea virgata*, *Aloysia citriodora*, *Aloe succotrina*, *Asphodelus microcarpus*, *Mesembryanthemum theurkauffii*, *Cladanthus scariosus*, *Paronychia argentea*, *Ephedra fragilis*, *Glycyrrhiza glabra*, *Origanum elongatum*, *Thymus broussonetii*, *Avena sterilis*, *Lolium perenne*, *Malus communis*, *Verbena officinalis*, *Asphodelus tenuifolius* and *Tetraena gaetula*. It is essential to study the effects of unexplored plant species on diabetes in more detail and to identify the active components and especially to study the mechanisms of action of these plant extracts, in order to obtain further data on the pharmacological effects of these plants.

Despite the therapeutic effects of medicinal plants, excessive consumption of some of the inventoried plants might lead to harmful effects which are related to a variety of causes. To avoid danger to patients, prudent use as well as safety precautions is required, such as using lower doses. The main toxic plants are, *Citrullus colocynthis* [32], *Datura stramonium* [33], *Euphorbia officinarum* [34], *Myristica fragrans* [35], *Artemisia herba alba* [36], *Peganum harmala* [37], *Ricinus communis* [38], *Tetraena gaetula* [39], *Nigella sativa* [40] and *Nerium oleander* [32]. Despite their toxic properties, patients do not suffer any adverse consequences. This indicates that the patients or the provider of the plants are skilled in recognizing the potential for toxicity and taking the appropriate precautions.

Of all medicinal plants reported in this study, 137 medicinal plants have been documented to demonstrate a potent anti-diabetic effect in vitro or in vivo or in clinical studies. We present in Table 2 pharmacological studies which have investigated directly or indirectly medicinal plants used in Morocco to treat diabetes. *Trigonella foenum-graecum, Artemesia herba-alba, Nigella sativa, Olea europaea, Allium cepa and Marrubium vulgare* were the most frequently used plants to treat diabetes based on number of citations. These plants are discussed in detail below.

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Amaranthaceae	*Anabasis aretioides* Moq. & Coss. ex Bunge	Chajra ma yeharrekha rih/sellii	Aqueous extract of aerial part	5 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant reduction on blood glucose levels in STZ rats ($p < 0.0001$)	[41]
Amaranthaceae	*Atriplex halimus* L.	Legtef	Aqueous extract of the leaves	200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Aqueous extract produced 54% ($P < 0.001$) decrese in fasting blood glucose levels compared to the initial fasting blood glucose levels prior to the treatment	[42]
Amaranthaceae	*Dysphania ambrosioides* (L.) Mosyakin & Clemants	Mkhinza	Crude extract of the leaves	100, 200 and 300 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Reduction in blood glucose in case of crude treatment groups, as compared with that of the control group	[43]
Amaryllidaceae	*Allium ampeloprasum* L.	Borro	Essential oils from the green parts	150 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The essential oil of *A. ampeloprasum* decreased the blood glucose level significantly ($P < 0.05$) at the dose of 200 mg/kg.	[44]
Amaryllidaceae	*Allium cepa* L.	Basla	Aqueous extracts of the whole plant	200, 250 or 300 mg/kg BW	Alloxan- induced diabetic rats	*A.cepa* at 200 mg/kg reduced fasting blood glucose levels by 62.9% (292.3 ± 29.0 to 108.2 ± 4.6), at 250 mg/kg it reduced fasting blood glucose levels by 69.7% (296.3 ± 37.8 to 89.8 ± 4.3) whereas at 300 mg/kg it reduced it by 75.4% (297.8 ± 37.5 to 73.4 ± 3.0)	[45]
Amaryllidaceae	*Allium sativum* L.	Tiskert /Touma	Aqueous extract of the bulbs	500 mg / kg BW	Streptozotocin-induced diabetic rats (STZ)	At weeks 2, 5 and 7 of garlic extract treatment, the serum glucose levels of the garlic-treated diabetic rats were reduced by 29%, 68% and 57%, respectively in comparison to control diabetic rats.	[46]
Anacardiaceae	*Pistacia atlantica* Desf.	Btem/Igg/ Drou	N-hexane extract of the seeds	200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The administration of *P. atlantica* extracts body wt. tended to bring the blood glucose significantly toward normal values from the beginning of the experiment	[47]
Anacardiaceae	*Pistacia lentiscus* L.	Trou/Tidekt	Crude gum	100 mg / kg BW	Alloxan- induced diabetic rats	After 6 h, there was decreased in blood glucose (280.8 ± 9.0) but after 24 h crude *Pistacia* gum showed significant decrease(195.2 ± 20.4) as compared to diabetic untreated rats (352.4 ± 23.6)	[48]
Apiaceae	*Ammi visnaga* (L.) Lam.	Bachnikha / Barghanisse	Aqueous extract of fruits	20 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant decrease of blood glucose in normal rats 6 h after a single oral administration ($P < 0.005$) and 9 days after repeated oral administration ($P < 0.05$).	[49]
Apiaceae	*Ammodaucus leucotrichus* Coss.	Kamoun soufi	Aqueous extract of fruits	10 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant reduction in blood glucose levels after four ($p < 0.01$) and 6 h ($p < 0.001$) of treatment. This effect was more pronounced than glibenclamide which caused a significant decrease in blood glucose at the fourth ($p < 0.05$) and sixth ($p < 0.01$) hour after oral administration	[50]
Apiaceae	*Apium graveolens* L.	Krafess	Hexane, chloroform and methanol extracts of stalk and leaves	100, 200 and 400 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Maximum percentage of blood glucose reduction in normoglycemic mice at 8 h with 400 mg/kg doses of chloroform extract was 37%. However, hexane extract and methanol extract at the same doses produce only a small effect	[51]
Apiaceae	*Carum carvi* L.	Lkarwya	Ethanolic extract of the seeds	0.2, 0.4 and 0.6 g/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significantly decreased serum glucose and insulin in diabetic rats in 3 and 5 h but not in healthy rats.	[52]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Apiaceae	*Coriandrum sativum* L	Kosbor	Aqueous extract of fruits	250 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The aqueous extract of fruits decreased the blood glucose level statistically significant when compared with diabetic control	[53]
Apiaceae	*Cuminum cyminum* L.	Kamoun	Ethanolic extract of the seeds	250 mg / kg BW	Streptozotocin-induced diabetic rats (STZ)	Around 17.7% and 17.1% decline in blood glucose levels at 0–300 and 0–1440 min, respectively, on streptozotocin-induced diabetic rats	[54]
Apiaceae	*Daucus carota* L.	Khizou	Alcoholic extract of the seeds	100, 200, 300 mg / kg BW	Streptozotocin-induced diabetic rats (STZ)	The administration of *D. carota* seeds extract (300 mg/kg) for 3 days decreased glucose serum level ($p < 0.05$)	[55]
Apiaceae	*Foeniculum vulgare* Mill.	Nafaa	Essential oil extracted from the whole plant	30 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Ingestion of essential oil corrected the hyperglycemia from (162.5 ± 3.19 mg/dl) to (81.97 ± 1.97 mg/dl) with $p < 0.05$	[56]
Apiaceae	*Petroselinum crispum* (Mill.) Fuss	Maadnouss	Aqueous extract of the leaves	2 g/kg BW	Streptozotocin-induced diabetic rats (STZ)	Diabetic rats showed a gradual reduce in blood glucose levels over days 14—42. Maximum reduction in the blood glucose levels was observed on the day 42, and the reduction was about 50%.	[10]
Apiaceae	*Pimpinella anisum* L.	Habbat hlawa	Different fractions of methanolic extract (hexane, benzene, ethyl acetate, n-butanol, aqueous)	100, 200, 300, 400 and 500 μg/ml	α-amylase and α-glucosidase inhibition enzyme	At the concentration of 500 μg/ml, the sequence of inhibitory effects on α-amylase and α- glucosidase activities respectively had the order as follows: Ethyl acetate (94% and 87%) > hexane (93% and 86%) > benzene (91% and 85%) > methanol (84% and 83%) > aqueous (81% and 79%) > n-butanol (75% and 77%).	[57]
Apocynaceae	*Calotropis procera* (Aiton) Dryand.	Turja	Chloroform extract of leaves and flowers	10, 20 and 50 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The reduction in serum glucose levels was better on the 21st and 27th days of treatment	[58]
Apocynaceae	*Caralluma europaea* (Guss.) N.E.Br.	Daghmous	Methanolic extract of the aerial parts	250, 300 mg / kg BW	Alloxan-induced diabetes in mice	The methanolic extract exhibited a continuous marked reduction of blood glucose levels ($P < 0.001$) particularly 6–8–10 h after treatment in diabetic mice	[59]
Apocynaceae	*Nerium oleander* L.	Defla/Alili	Methanolic extract of the leaves	50 and 200 mg/kg BW	Alloxan-induced diabetes in mice	Glucose level was lowered from 255.66 ± 1.52 mg/dl on day 0 to 67.00 ± 6.24 mg/dl in day 20, accounting for a significant ($p < 0.001$) 73.79% decrease	[60]
Arecaceae	*Chamaerops humilis* L.	Dum /Tiguezden / Ignadd	Aqueous extract of the leaves	10 mg / kg BW	Experimentally induced obesity, hyperglycemia and hyperlidemia (OHH) in rats	The plasma glucose levels of the OHH rats decreased significantly with daily dosing with the plant-extract [from baseline 12.04 ± 0.94 mmol/L to 6.10 ± 0.27 mmol/L ($P < 0.05$) after 15 days, and to 4.84 ± 0.22 mmol/L ($P < 0.001$) after 30 days]	[61]
Arecaceae	*Hyphaene thebaica* (L.) Mart.	Dum/karur	Aqueous suspension of the pulp	1 g/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant reduction on blood glucose levels in STZ rats ($P < 0.05$)	[62]
Arecaceae	*Phoenix dactylifera* L.	Tmar	Ethanolic extract of the leaves	100, 200 and 400 mg/kg BW	Alloxan- induced diabetic rats	A significant antidiabetic effect at 400 mg/kg was observed starting from the 6th day onwards ($P < 0.05$), and from 10th days onwards for 200 mg/kg	[63]
Brassicaceae	*Anastatica hierochuntica* L.	Chajarat Maryem/ Ikemcha	Water extract of the aerial parts	12.5 mg/rat	Streptozotocin-induced diabetic rats (STZ)	The administration of the plant extract induced a hypoglycemic effect in both normoglycemic and diabetic rats. It also caused significant improvement in tissue injury induced by STZ	[64]
Brassicaceae	*Brassica napus* L.	Left	Hydro-alcoholic extract	16 ml/ kg BW	Alloxan- induced diabetic rats	Significantly decrease of blood glucose compared to diabetic control rats ($P < 0.05$)	[65]
Brassicaceae	*Brassica nigra* (L.) K.Koch	Elkhardel	Chloroform, acetone, ethanol and aqueous extracts of the seeds	200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The dministration of aqueous extract daily once for 1 month brought down fasting serum glucose levels	[66]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Brassicaceae	*Brassica oleracea* L.	Krunb mkawar/ melfuf	Different fractions (Petroleum ether, ethyl acetate and chloroform) of ethanolic extract of the leaves	150 mg/kg BW	Alloxan- induced diabetic rats	Significant reduction on blood glucose levels ($P < 0.05$)	[67]
Brassicaceae	*Brassica rapa* L.	Left beldi	Aqueous extract of the leaves	200 and 400 mg/kg BW	Alloxan- induced diabetic rats	Both doses significantly decreased ($p < 0.001$) blood glucose levels in diabetic rats after 28 days of administration	[68]
Brassicaceae	*Lepidium sativum* L.	Hab errechad	Seed powder	3 g / kg BW	Alloxan- induced diabetic rats	Significant decrease ($p \leq 0.05$) in fasting blood glucose levels	[69]
Brassicaceae	*Nasturtium officinale* R.Br.	Gernunes	Hydroalcoholic extract of the leaves	100 and 200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Treatment of diabetic rats for 4 weeks with *Nasturtium officinale* extract significantly decreased their serum glucose levels	[70]
Brassicaceae	*Raphanus sativus* L.	Lfjel	Root juice	100, 200, 300, and 400 mg/ kg BW	Streptozotocin-induced diabetic rats (STZ)	Maximum reduction of 15.9% ($p < 0.001$) in blood glucose level at 3 h in normal rats, whereas the reduction observed was by 23.8 and 28.3% ($p < 0.001$) in sub- and mild-diabetic rats, respectively	[71]
Buxaceae	*Buxus sempervirens* L.	Lbeks	Aqueous extract of the leaves	5 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The aqueous extract reduced the blood glucose of both healthy and diabetic rats. This extract was also able to improve oral glucose tolerance in diabetic rats and it ameliorated hepatic histology	[72]
Cactaceae	*Opuntia ficus indica* (L.) Mill.	Lhndia/ Aknari	Water extract of the whole plant	100 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significantly decrease of blood glucose compared to diabetic control rats ($P < 0.05$)	[73]
Capparaceae	*Capparis decidua* (Forssk.) Edgew.	Ignin	Aqueous and ethanolic extract of the stem	250 and 500 mg/kg BW	Alloxan- induced diabetic rats	The fasting blood glucose level decreases by 58.5, 83.6% (aqueous extract) and 60.2, 98.51 (ethanolic extract) after 21st day in diabetic rats treated with a different doses of 250 mg and 500 mg/kg BW respectively	[74]
Capparaceae	*Capparis spinosa* L.	Kabar /Taylulut	Hydroalcoholic extract of the root	0.2 and 0.4 g/ kg BW	Streptozotocin-induced diabetic rats (STZ)	Glucose levels significantly decreased after treating with plant extract ($p = 0.003$)	[75]
Cistaceae	*Cistus laurifolius* L.	Agullid	Aqueous and ethanol extracts of the leaves	250 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The blood glucose levels of the STZ-induced diabetic rats were decreased by ethanol extract as compared to control group (16%–34%)	[76]
Compositae	*Anacyclus pyrethrum* (L.) Lag.	Iguntas /Tagundecht	Aqueous extract of the roots	150 and 300 mg/kg BW	Alloxan- induced diabetic rats	The significant reduction ($p < 0.01$) of blood glucose was observed at 60 and 120 min of the experiment	[77]
Compositae	*Artemisia absinthium* L.	Chiba	Ethanol extract of the whole plant	250, 500 and 1000 mg/kg BW	Alloxan- induced diabetic rats	A time-dependent significant hypoglycemic activity in medium dose (500 mg/kg BW, $P < 0.01$) and high dose (1000 mg/kg BW, $P < 0.001$), which was clearly after day 10 treatment period	[78]
Compositae	*Artemisia herba-alba* Asso	Izri/Chih dwidi	Aqueous extract of the aerial parts	0.39 g/kg BW	Alloxan- induced diabetic rats	The administration of *Artemisia herba-alba* indicates significant ($P < 0.05$) reduction of blood glucose concentration and was found to be antidiabetic	[79]
Compositae	*Chamaemelum nobile* (L.) All.	Babounj	Aqueous extract of the aerial parts	20 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The blood glucose levels were decreased from 6.1 ± 0.06 mmol/l to 4.6 ± 0.17 mmol/l ($P < 0.01$) and from 21.1 ± 1.31 mmol/l to 13.7 ± 0.90 mmol/l ($P < 0.01$) in normal and STZ diabetic rats, respectively, after 15 days of treatment.	[80]
Compositae	*Cichorium intybus* L.	Buaggad	Ethanolic extract of the whole plant	125 mg / kg BW	Streptozotocin-induced diabetic rats (STZ)	The daily administration for 14 days to diabetic rats attenuated serum glucose by 20%, triglycerides by 91% and total cholesterol by 16%	[81]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Compositae	*Lactuca sativa* L.	Khes	Lactucaxanthin isolated from *Lactuca sativa*	6.854 μg	α-Amylase and α-glucosidase assays using streptozotocin -induced diabetic rat models	Lactucaxanthin significantly inhibited ($p < 0.05$) the activity of α-amylase and α-glucosidase	[82]
Compositae	*Matricaria chamomilla* L.	Mansania	Aqueous extract of the leaves	200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The administration of Matricaria chamomilla once daily for 21 days reduced the elevated Fasted Blood Glucose by 62.2% ($p < 0.001$)	[83]
Compositae	*Taraxacum campylodes* G.E.Haglund	Lhandba	Aqueous extract and methanol extract of roots, flowers and stems	20, 40, 60, 80 and 100 μg/ml	α-glucosidase and α-amylase enzyme inhibiting activity	The stem showed the highest overall inhibitory effect of both (alpha amylase + alpha glucosidase) as an average of about 87.2%	[84]
Compositae	*Warionia saharae* Benthem ex Benth. & Coss.	Afssas	Aqueous extract of the aerial parts	5 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The blood glucose levels were decreased in normal and STZ-induced diabetic rats after 15 days of treatment	[85]
Cucurbitaceae	*Citrullus colocynthis* (L.) Schrad.	Aferziz/lhdej	Chloroform, ethanol and aqueous extracts of the root	200 mg/kg BW	Alloxan- induced diabetic rats	Aqueous extract showed significant reduction in blood sugar level (58.70%) when compared with chloroform (34.72%) and ethanol extracts (36.60%) ($p < 0.01$)	[86]
Cucurbitaceae	*Cucumis sativus* L.	Lkhiar	Ethanol extract of the fruit	200 and 400 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The hyperglycemia was significantly ($P < 0.05$) lowered by the administration of 200 mg/kg and 400 mg/kg body weight ethanol extract	[87]
Cucurbitaceae	*Cucurbita maxima* Duchesne	Garaa lhamra	Petroleum ether, ethyl acetate and alcohol extract of the seeds	200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The blood glucose concentration was significantly ($P < 0.05$) decreased compared to control	[88]
Cucurbitaceae	*Cucurbita pepo* L.	Takhsait/ curjt	Fruit powder	2 g/kg BW	Alloxan- induced diabetic rats	Significantly decrease of blood glucose compared to diabetic control rats ($P < 0.05$)	[89]
Cupressaceae	*Juniperus phoenicea* L.	Araar finiqui	Essential oil, hexane and methanol extracts of the leaves	50, 100 and 200 μg/mL	α-Amylase inhibition assay	The IC50 values of essential oil, hexane and methanol extracts against α-amylase were 35.44, 30.15 and 53.76 μg/mL respectively, and those against pancreatic lipase were 66.15, 68.47 and 60.22 μg/mL respectively	[90]
Cyperaceae	*Cyperus rotundus* L.	Tara	Hydro-ethanolic extract of the tubers	200 and 500 mg/kg BW	Alloxan- induced diabetic rats	This hyperglycemia was significantly ($P < 0.05$) lowered by the administration of Hydro-ethanolic extract	[91]
Ericaceae	*Arbutus unedo* L.	Sasnu	Water extract of the roots	500 mg/kg BW	Oral glucose tolerance test in rats (OGTT)	The water extract produced a decrease of glycemia at 1 h and 3 h after glucose loading (21.1%, $p < 0.05$ and 14.1%, $p < 0.05$, respectively)	[92]
Euphorbiaceae	*Ricinus communis* L.	Awriwer/ Lkharwaa	Ethanolic extract of the root	125, 250, 500, 750, 1000 and 2000 mg/kg BW	Alloxan- induced diabetic rats	Five-hundred milligram per kilogram body weight appeared to be the effective dose as it caused the maximum lowering of the fasting blood glucose	[93]
Leguminosae	*Vigna radiata* (L.) R.Wilczek	Soja	Raw, boiled, and sprouted mung beans	Not mentioned	α-amylase and α-glucosidase inhibition enzyme	α-amylase and α-glucosidase inhibitory activities were higher ($p < 0.05$) in sprouted mung compared to raw mung and boiled mung.	[94]
Leguminosae	*Vigna unguiculata (L.) Walp*	Ful gnawa	Seed oil	100 and 200 mg/kg BW	Alloxan- induced diabetic rats	Significant reduction in blood glucose level was noted and at the dose of 200 mg/kg.b.wt serum glucose level was found to be very close to the non-diabetic control	[95]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Gentianaceae	*Centaurium erythraea* Rafn	Qusset elhayya / Ahchlaf ntawrra	Aqueous and butanolic extracts of the aerial parts	0,015 ml / 100 g and 0,66 ml / 100 g BW	Oral glucose tolerance test overload "OGTT"	The administration of extracts has reduced significantly glycemia compared to controls at t60, t90, t120 and t180 min	[96]
Iridaceae	*Crocus sativus* L.	Zaafran Ihor	Ethanolic Extract of stigma	20, 40 and 80 mg/kg BW	Alloxan- induced diabetic rats	The dose of 40 mg/kg was found to be more effective dose in intraperitoneally route for decreasing blood glucose level	[97]
Juglandaceae	*Juglans regia* L.	Swak / Gargaa	Alcoholic extract of the leaves	200 and 400 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The extract reduced the hyperglycemia significantly compared to control group ($P < 0.05$)	[98]
Lamiaceae	*Ajuga iva* (L.) Schreb.	Timerna nzenkhad/ Chndkoura	Lyophilised aqueous extract of the whole plant	10 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant reduction in blood glucose level in normal rats as compared to the untreated groups and to the pre-treatment levels (0 h) (793.96 mg/dl at 6 h vs 100.73.34 mg/dl at 0 h, $P < 0.01$)	[99]
Lamiaceae	*Lavandula angustifolia* Mill	Elkhzama zerqa/ Elkhzama Fassiya	Methanolic extract of the whole plant	12.5–400 µg/ml	Inhibitory effects on both hormone sensitive lipase (HSL) and pancreatic lipase (PL)	The extract inhibited HSL activity in a dose dependent manner with an IC50 of 175.5 µg/ml. Likewise, it inhibited the PL activity in a dose dependent manner with an IC50 of 56.5 µg/ml	[100]
Lamiaceae	*Lavandula stoechas* L.	Imzeria/ Tikenkert/ Lhalhal	Essential oil extracted from the aerial parts	50 mg / kg BW	Alloxan- induced diabetic rats	*Lavandula stoechas* essential oils significantly protected against the increase of blood glucose	[101]
Lamiaceae	*Marrubium vulgare* L.	Mriwt/Ifzi	Methanolic extract of the aerial parts	500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	a highly significant reduction in the plasma glucose level starting at the 14th day of treatment, compared to before treatment (day 0)	[102]
Lamiaceae	*Ocimum basilicum* L.	Lahbaq	Aqueous extract of the leaves	20, 18.2, 16.3 and 14.5 mg/ml	α-amylase and α-glucosidase inhibition enzyme	The aqueous extract showed strong a-glucosidase and a-amylase inhibiting activities	[103]
Lamiaceae	*Rosmarinus officinalis* L.	Azir	Ethanolic extract of the leaves	50, 100 and 200 mg/kg BW	Alloxan-diabetic rabbits	The highest dose (200 mg/kg) significantly lowered blood glucose level and increased serum insulin concentration in alloxan-diabetic rabbits	[104]
Lamiaceae	*Salvia officinalis* L.	Salmia	Ethanolic extract of the leaves	0.1, 0.2, and 0.4 g/kg BW	Streptozotocin-induced diabetic rats (STZ)	The effect of administration of extract and glibenclamide tended to bring serum glucose and insulin towards normal values	[105]
Lamiaceae	*Teucrium polium* L.	Tawerart/ Flyou lbour/ jaaidia	Aqueous decoction of the aerial parts	5 ml (20% w/v)	Streptozotocin-induced diabetic rats (STZ)	significant reductions in blood glucose concentration 4 h after intravenous administration and 24 h after intraperitoneal administration	[106]
Lamiaceae	*Thymus satureioides* Coss.	Asserkna/ Ziitra	Aqueous extract of the aerial parts	500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Administration of aqueous extract to diabetic rats for 28 d reduced their fasting blood glucose levels significantly compared to the diabetic control rats	[107]
Lamiaceae	*Thymus vulgaris* L.	Aduchen /Azukni / Zaitra	Methanol, ethanol and aqueous extract of the whole plant	2, 4, 8, 10, 15 µg/ml	α-amylase and α-glucosidase inhibition enzyme	The results of anti-diabetic activity produced by *Thymus vulgaris* showed that the volatile compounds were effective to α-glucosidase and α-amylase inhibition.	[108]
Lauraceae	*Cinnamomum cassia* (L.) J.Presl	Qarfa	Aqueous extract of the bark	60 mg/kg BW	Alloxan- induced diabetic rats	A highly significant ($P < 0.001$) decrease in mean fasting blood glucose level, 203.5 ± 13.47 on 10th and 191.5 ± 12.72 on15th day as compared to mean fasting blood glucose level	[109]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Lauraceae	*Cinnamomum verum* J.Presl	Dar essini	Aqueous extract of the bark	200, 400, 600 and 1200 mg/kg BW	Alloxan- induced diabetic rats	After 30 days, the administration of diabetic rats with the lowest dose (200 mg/kg BW) of extracts was the most efficient in affecting significant ($P < 0.05$) reduction in the levels of fasting blood glucose	[110]
Lauraceae	*Laurus nobilis* L.	Ourak sidna moussa/ Rand	Essential oil and its three main components	0.606 to 1.300 μl/mL	α-glucosidase inhibition enzyme	Essential oil was found to inhibit α-glucosidase over 90%. The IC50-value of the oil was determined to be 1.748 ± 0.021 μL/mL	[111]
Lauraceae	*Persea americana* Mill.	Lavoca	Aqueous extract of the seeds	20, 30, 40 g/l	Alloxan- induced diabetic rats	The extract possessed a significant hypoglycaemic ($P < 0.05$) in alloxan-induced diabetic rats, comparable to the effect glibenclamide	[112]
Leguminosae	*Acacia nilotica* (L.) Delile	*Amur/Sllaha*	*Aqueous* methanolic extract of pods	200, 300 and 400 mg/kg BW	Alloxan-induced diabetic rabbits	A dose of 400 mg/kg BW maximally reduced the blood glucose levels as compared to the diabetic group ($p < 0.001$).	[113]
Leguminosae	*Acacia senegal* (L.) Willd.	Laalek	Ethyl acetate extract of stem bark	200 and 400 mg/kg BW	Alloxan- induced diabetic rats	In diabetic rats, both the doses (200 mg/kg and 400 mg/kg) of ethyl acetate extract were found to be significantly ($P < 0.05$) active in comparison to control	[114]
Leguminosae	*Acacia tortilis* (Forssk.) Hayne	Telh/ Tadoute	Aqueous extract of the leaves	800 mg/kg BW	Diagnostic kits Spectrophotometrically in rats	The administration of aqueous extract for seven consecutive days caused significant ($P < 0.05$) decrease in blood glucose	[115]
Leguminosae	*Arachis hypogaea L.*	Lgerta/ Kawkaw	Aqueous extract of the seeds	2 ml	Alloxan- induced diabetic rats	The extract caused a significant ($P < 0.05$) decrease of fasting blood glucose of both normal and alloxan-induced diabetic rats	[116]
Leguminosae	*Faidherbia albida* (Delile) A.Chev.	Chok/Talh/ Mimouza	Aqueous extract of stem bark	125, 250 and 500 mg/kg BW	Alloxan- induced diabetic rats	The queous extract possessed anti-hyperglycemic effect in al-loxan induced diabetic rats	[117]
Leguminosae	*Glycine max* (L.) Merr.	Soja	Petroleum ether, alcoholic and aqueous extract of seeds	100, 200 and 400 mg/kg BW	Alloxan- induced diabetic rats	The antihyperglycemic effect of aqueous extract showed onset at the 2nd h; peak effect at the 4th h and the antihyperglycemic effect was sustained till the 24th h	[118]
Leguminosae	*Lupinus albus* L.	Tirms/Foul gnawa	Aqueous extract of seed coat	18.4 and 36.8 mg/kg BW	Glucose Resistant Mice	Decrease in blood glucose at 30 min relative to control, but this difference was not significant for either concentration	[119]
Leguminosae	*Medicago sativa* L.	Fassa	Aqueous extract of seeds	7 mg/100 g BW	Alloxan- induced diabetic rats	The aqueous extract has hypoglycemic effect by increasing insulin level and decreasing insulin resistance	[120]
Leguminosae	*Phaseolus vulgaris* L.	Lubya	Seeds	100, 200 and 300 mg/kg BW	Induction of hyperglycemia in rats by administration of glucose	Seeds of *P. vulgaris* at a dosage of 300 g/kg bw is showing maximal blood glucose lowering effect in diabetic rats after third hour	[121]
Leguminosae	*Retama raetam* (Forssk.) Webb	Rtam/Allug	Methanolic extract of the fruits	100, 250 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The extracts at 250 or 500 mg/kg significantly lowered blood glucose levels at the 3rd and 1st week of treatment, respectively	[63]
Leguminosae	*Trigonella foenum-graecum* L.	Lhelba/ Tifidas	Alcoholic extract of the seeds	1, 2 and 4 g	Alloxan- induced diabetic rats	Significant reduction on blood glucose levels was seen with alcoholic extract (74.33 ± 4.77 to 60.56 ± 1.9 in normal rats and 201.25 ± 7.69 to 121.25 ± 6.25 in diabetic rats) ($P < 0.001$)	[122]
Linaceae	*Linum usitatissimum* L.	Zariat elkattan	Ethanolic extract of the seeds	200 and 400 mg/kg BW	Alloxan- induced diabetic rats	The extract significantly reduced serum glucose level. The antihyperglycaemic effects showed onset at 4th h ($P < 0.001$) and peak effect at 6th h ($P < 0.001$)	[123]
Lythraceae	*Lawsonia inermis* L.	Lhenna	Ethanolic extract of the whole plant	150, 300 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significantly decreased level of blood glucose. The effect of dose o 500 mg/kg BW was found to be better then 150 and 300 mg/kg BW	[124]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Lythraceae	*Punica granatum* L.	Rman	Ethanolic extract of the leaves	500 mg/kg BW	Alloxan- induced diabetic rats	Significant decrease ($P < 0.01$) in blood glucose level in comparison to control group	[125]
Malvaceae	*Abelmoschus esculentus* (L.) Moench	Lmloukhia	Peel and seed powder	100 and 200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant ($P < 0.001$) reduction in blood glucose level and increase in body weight than diabetic control rats	[126]
Malvaceae	*Hibiscus sabdariffa* L.	Karkadi/ Bissam	Aqueous extracts of the calyces	10–80 µg/mL	α-amylase and α-glucosidase inhibition enzyme	The extracts caused inhibition of α-amylase and α-glucosidase activities in vitro	[127]
Moraceae	*Ficus carica* L.	Tazart/ Lkarmous/ Karma/ chriha/ Elbakur	Aqueous extract of the leaves	2.5 g/100 ml	Streptozotocin-induced diabetic rats (STZ)	The extract decreased ($p < 0,025$) plasma glucose in diabetic (27.9 ± 4.5 mmol/L to 19.6 ± 9.9 mmol/L) while not in normal rats	[128]
Moraceae	*Morus alba* L.	Tut Ibari	Alcohol extract of the root bark	200, 400 and 600 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	A significant decline in serum glucose level to a value of 155 mg/dl, $P < 0.05$ as compared to STZ-diabetic rats	[129]
Musaceae	*Musa* × *paradisiaca* L.	Banan	Ethanolic extracts of leaves, fruit peels, stems and roots	100, 250 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Only leaves and ripe fruit peels showed promising antidiabetic effect	[130]
Myristicaceae	*Myristica fragrans* Houtt.	Lgouza	Petroleum ether extract of the seeds	100 and 200 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	A significant decrease in blood glucose level from 56.5 ± 3.19 (0 h) to 49.75 ± 2.05 mg% (4 h) in normoglycaemic rats	[131]
Myrtaceae	*Eucalyptus camaldulensis* Dehnh.	Calitus	Essential oil extracted from the leaves	0.10 and 0.25 ml	α-amylase and α-glucosidase inhibition enzyme	Both α-amylase and α-glucosidase were inhibited by a non-competitive mechanism	[132]
Myrtaceae	*Eucalyptus globulus* Labill.	Calitus	Aqueous extract of the leaves	150 and 300 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The aqueous extract exhibited a significant and dose-dependent effect on the blood glucose levels ($P < 0.001$). The highest dose (300 mg/kg) produced the most pronounced lowering of blood glucose levels	[133]
Myrtaceae	*Myrtus communis* L.	Rihane	Hydroalcoholic, water, and ethanol extracts of the leaves	2 and g/kg BW	Streptozotocin-induced diabetic rats (STZ)	The ethanolic extract of leaves (2 g/kg) had a better hypoglycemic effect in diabetic rats compared with the aqueous extract ($p < 0.05$)	[134]
Myrtaceae	*Syzygium aromaticum* (L.) Merr. & L.M.Perry	Kranfal	Essential oil extracted from the buds and seeds	1 to 100 µg/ mL	α-amylase inhibition enzyme	The maximum antidiabetic activity for *S. aromaticum* essential oils was noted at the highest dose (100 µg/mL).	[135]
Nitrariaceae	*Peganum harmala* L.	Lharmel	Ethanolic extract of the seeds	150 and 250 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The oral administration of ethanolic extract causes maximum fall of blood glucose level to 22.9% ($p < 0.05$) and 29.4% ($p < 0.01$) respectively with the two doses in normal and 30.3% ($p < 0.01$) and 48.4% ($p < 0.001$) in diabetic rats	[11]
Oleaceae	*Fraxinus angustifolia* Vahl	Touzalt	Hydroalcoholic extracts of leaves and bark	25 and 50 mg/ kg BW	Streptozotocin-induced diabetic rats (STZ)	A considerable hypoglycemic effect was noticed 2 h after the STZ-induction, with a higher efficiency ($P < 0.05$) for leaf extract (68%) as compared with bark extract (57%)	[136]
Oleaceae	*Olea europaea* L.	Jbouj/ Azmour/ Zitoun	Alcohol extract of the leaves	0.1, 0.25 and 0.5 g/kg BW	Streptozotocin-induced diabetic rats (STZ)	The antidiabetic effect of the extract was more effective than that observed with glibenclamide	[137]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Pedaliaceae	*Sesamum indicum* L.	Janjlan	Ethanolic extract of the seeds	500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	A significant decrease in the elevated blood glucose and increase in the lowered insulin and glycogen levels	[138]
Plantaginaceae	*Globularia alypum* L.	Ayen lerneb/ Taselgha	Aqueous extract of the leaves	100 and 20 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	In the diabetic rats, the blood glucose levels was mostly reduced, due to repeated oral treatment of *G.alypum* leaves (20 mg/kg ($P < 0.001$)	[139]
Poaceae	*Cynodon dactylon* (L.) Pers.	Njem	Aqueous extract of the whole plant	250, 500 and 1000 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The dose of 500 mg/kg was identified as the most effective dose. It lowers blood glucose level around 31% after 4 h of administration in normal rats	[140]
Poaceae	*Hordeum vulgare* L.	Chair/Zraa	Hydroalcoholic extract of the seeds	0.1, 0.25, 0.5 g/ kg BW	Streptozotocin-induced diabetic rats (STZ)	The extract at doses of 0.25 and 0.5 g/kg, were only effective in detracting blood glucose levels of diabetic rats after 11 days of continued daily therapy	[141]
Poaceae	*Pennisetum glaucum* (L.) R.Br.	Illan	Hexane, ethylacetate, methanolic and aqueous extracts of the seeds	250 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The aqueous extract has shown maximal blood glucose lowering effect in diabetic rats	[142]
Poaceae	*Phalaris canariensis* L.	Zouan	Encrypted peptides released after gastrointestinal digestion of seed proteins	0, 200, 400, 600, 800, 1000, 1200, and 1400 μg/mL	Assay for Inhibitory Activity of Dipeptidyl Peptidase IV	The peptides showed 43.5% inhibition of dipeptidyl peptidase IV	[143]
Poaceae	*Sorghum bicolor* (L.) Moench	Bachna	Dried extract of the whole plant	0.4 g/kg BW	Hepatic gluconeogenesis of streptozotocin-induced diabetic rats	The hypoglycemic effect of extract was related to hepatic gluconeogenesis but not the glucose uptake of skeletal muscle, and the effect was similar to that of anti-diabetic medication	[144]
Poaceae	*Zea mays* L.	Lahyat Adra	Corn silk aqueous extract	0.25–10.0 mg/ mL 0.25–8.0 mg/mL	α-amylase and α-glucosidase inhibition enzyme	In vitro analysis of the extract showed that it exhibited potent and moderate inhibitory potential against α-amylase and α-glucosidase, respectively. The inhibition was concentration-dependent with respective half-maximal inhibitory concentration (IC50) values of 5.89 and 0.93 mg/mL	[145]
Portulacaceae	*Portulaca oleracea* L.	Rejla	Aqueous extract of the whole plant	200 and 400 mg/kg BW	Alloxan- induced diabetic rats	The hypoglycaemic effect of extract became significant following oral administration 1 h, reached the peak at 1.5 h ($p < 0.01$), and was still significant at 4 h	[6]
Ranunculaceae	*Nigella sativa L.*	Haba souda /Sanouj	Hydroalcholic extract of the seeds	5, 10, and 20 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	5 mg/kg BW is the most effective dose for assessing the anti-hyperglycemic potential of hydroalcholic extract of *N. sativa* in diabetic rats	[146]
Rhamnaceae	*Ziziphus lotus* (L.) Lam.	Nbeg/ Azouggar/ ssdra	Aqueous extract of leaves and fruits	250 μL 150 μL	α-amylase and α-glucosidase inhibition enzyme	*Z. lotus* leaves and fruits, demonstrated inhibitory effects against α-amylase (IC50: 20.40–31.91 μg/mL), and α-glucosidase (IC50: 8.66–27.95 μg/mL)	[147]
Rosaceae	*Cydonia oblonga* Mill.	Sferjel	Aqueous extract of the fruits	80, 160, and 240 mg/kg	Streptozotocin-induced diabetic rats (STZ)	The oral administration of the extract prevented diabetes-induced increase in serum urea and creatinine levels as the markers of renal dysfunction	[148]
Rosaceae	*Chaenomeles sinensis* (Dum.Cours.) Koehne	Sferjel	Ethyl acetate fraction from the fruits	50 and 100 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The administration of *C. sinensis* fruits extract (100 mg/kg BW) restored the blood glucose to almost normal level	[149]
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	Mzah	Alcoholic extract of the leaves	100, 150 and 200 mg/kg	Alloxan- induced diabetic rats	The extract exerted a significant ($P < 0.05$) hypoglycaemic effect in normal rabbits which was however short-lived. The hypoglycaemic effect was not significant ($P > 0.1$) in alloxan-treated rabbits	[150]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Rosaceae	*Prunus armeniaca* L.	Luz elhar	The pomace and the detoxified kernel extract	4, 6 and 8 mg/kg 2, 3 and 4 mg/kg	Alloxan- induced diabetic rats	Pomace extract showed significant ($p \leq 0.05$) antidiabetic-activity more prominent thandetoxified kernel extract acutely, subchronically and on longer-terms	[151]
Rosaceae	*Prunus dulcis* (Mill.) D.A. Webb	Louz imrzig/ Louz morr	Ethanol extract, ethyl acetate fraction, hexane fraction, chloroform fraction, n-butanol fraction, water fraction and almond oil	Not mentioned	Protein tyrosine phosphatase-1B (PTP1B) inhibition	The alcoholic extract showed strong anti-diabetic (PTP1B inhibition) activity with an IC_{50} 0.46 μg/mL	[152]
Rutaceae	*Citrus medica* L	Lhamed beldî	Petroleum ether extract of the. Seeds	200 and 400 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant reduction ($p < 0.05$) of fasting blood glucose in dose dependent manner after 15 days of drug administration	[153]
Rutaceae	*Citrus paradisi* Macfad.	Pamblamus	Phenolic extract from grapefruit peels	500 mL 50 mL 50 mL	Interaction with α-amylase, α-glucosidase and angiotensin-I-converting enzyme (ACE)	The phenolic extracts inhibited α-amylase, α-glucosidase and ACE enzyme activities	[154]
Rutaceae	*Citrus sinensis (L.) Osbeck*		Peel ethanolic extract	250 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Diabetic rats treated with 250 and 500 mg/kg of extract showed a significant reduction in blood glucose levels of 11 and 25%, respectively	[155]
Rutaceae	*Citrus* × *aurantium* L	Larenj/ Zenbue/ trunj	The alcoholic extract of fruit peel	300 and 500 mg/kg BW	Alloxan- induced diabetic rats	On repeated administration of ethanolic extract for 21 days, a significant ($P < 0.001$) dose-dependent decrease in blood glucose of the diabetic rats was seen as compared to control group	[156]
Rutaceae	*Ruta graveolens* L.	Lfijel	Water extract of the whole plant	125 and 50 mg/kg BW	Nicotinamide-streptozotocin-induced (type 2) diabetic albino rats	Significant amelioration of glucose tolerance	[157]
Rutaceae	*Ruta montana* (L.) L.	LFijel /Iwermi	Aqueous extract of the aerial parts	5 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Both single and repeated oral doses produced significant reductions in the blood glucose levels in normal and STZ-induced rats	[158]
Santalaceae	*Viscum album* L	Lenjbar	Aqueous extract of the leaves	100 and 200 mg/kg BW	Alloxan- induced diabetic animals	Doses of 200 mg/kg and 400 mg/kg BW produced significant ($p < 0.05$) lowering of blood sugar in fasted normal white albino rats and alloxanized rabbits respectively	[159]
Sapotaceae	*Argania spinosa* (L.) Skeels	Argan	Aqueous extract of the fruits	10 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Single oral administration reduced blood glucose levels 6 h after administration in STZ diabetic rats. Furthermore, blood glucose levels were decreased in STZ diabetic rats after 7 days of treatment	[160]
Solanaceae	*Capsicum annuum* L.	Felfel Hârr/ soudania	Water extract of nine types of pepper	500 mL 50 mL	α-amylase and α-glucosidase inhibition enzyme	Several pepper extracts had high a-glucosidase inhibitory activity. Select extracts such as Green pepper and Long hot pepper had less or no inhibitory effect on the a-amylase activity	[161]
Solanaceae	*Datura stramonium* L.		Aqueous extract of the leaves	100–1000 μl	α-amylase inhibition enzyme	The assay carried out on alpha-amylase enzyme showed the dose-dependent increase in inhibitory effect with IC_{50} 730 μg	[162]
Solanaceae	*Lycopersicon esculentum* Mill.	Sdag jmel/ Metal	The supernatant (juice fraction)	0 to 0.8 mg/ml	α-amylase and α-glucosidase inhibition enzyme	Stronger inhibition of α-glucosidase than α-amylase activity	[163]
Solanaceae	*Nicotiana tabacum* L.	Nefha	Acetone, ethanol and water extract of the leaves	250 μL	α-amylase and α-glucosidase inhibition enzyme	The aqueous extract was most effective inhibitor of α-amylase (IC50 5.7 mg/mL) while acetone extract exhibited the best inhibitory potential on α-glucosidase (IC50 4.5 mg/mL)	[164]

Table 2 In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco *(Continued)*

Family	Plant species	Vernacular name	Plant extracts used	Dose (s) used	Models used in the study	Results	References
Solanaceae	*Solanum americanum* Mill.	Aneb dib	Aqueous extract of the leaves	200, 400 mg/kg BW	Alloxan- induced diabetic rats	Significant antihyperglycemic and hypolipidemic effects when compared to diabetic control rats ($p < 0.0001$)	[165]
Theaceae	*Camellia sinensis* (L.) Kuntze	Attay	Water extract	2 ml/100 g BW	Streptozotocin-induced diabetic rats (STZ)	The inhibitory effect of extract on hyperglycemia induced by STZ was statistically significant	[166]
Thymelaeaceae	*Thymelaea hirsuta* (L.) Endl.	Metnan	Aqueous extract of the aerial parts	250 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	In STZ-induced diabetic rats, single oral administration of *T. hirsuta* produced a significant decrease of blood glucose levels	[167]
Urticaceae	*Urtica dioica* L.	Taznagt/ Tigzenin/ Lhriga	Aqueous extract of the aerial parts	500 mg/kg BW	Alloxan- induced diabetic rats	The amount of glucose absorbed in a segment jejunum in situ was 8.05 ± 0.68 mg in presence of nettle extract vs. 11.11 ± 0.75 mg in control rats during 2 h ($P < 0.05$)	[168]
Urticaceae	*Urtica pilulifera* L.	Hurriga / Tisrakmaz	Lectin isolated from the seeds	100 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Significant hypoglycemic effect was found at the dose of 100 mg/kg after administration for 30 days	[169]
Vitaceae	*Vitis vinifera* L.	Dalya/Zbib/ Kerma/ Adilite	Ethanolic extract of the leaves	250 and 500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	The data show that 250 mg/kg of the *V.vinifera* extract has possessed remarkable effect on blood glucose level as equal as reference drug. (11.8–26.0%)	[170]
Zingiberaceae	*Zingiber officinale* Roscoe	Sekinjbir	Aqueous extract of the root	500 mg/kg BW	Streptozotocin-induced diabetic rats (STZ)	Raw ginger was significantly effective in lowering serum glucose, cholesterol and triacylglycerol levels in the ginger-treated diabetic rats compared with the control diabetic rats	[171]

Plants used most frequently for the treatment of diabetes in Morocco

Trigonella foenum-graecum L.

Trigonella foenum-graecum L. (Fenugreek), is an annual plant, in the family Leguminosae, extensively cultivated in many countries (Morocco, Egypt, China, India, Ethiopia,Turkey, Ukraine, Greece, etc.) [172]. Apart from the usage as an edible species and spice herb, fenugreek is known for its nutraceutical, medicinal, and pharmaceutical features. It has been reported that fenugreek is a valuable medicinal plant with potential for curing abscesses, wounds, arthritis, bronchitis, digestive disorders, fever and sinusitis. It is cited as used in the treatment of diabetes by Moroccan ethnobotanical studies [2, 12–23]. Fenugreek is known to have several pharmacological effects such as antidiabetic, lactation aid, antibacterial, gastric stimulant, for anorexia, galactogogue, hepatoprotective effect, anticancer, anticarcinogenic, hypocholesterolemic, antioxidant, and immunological activities. Fenugreek is an excellent source of neutral detergent fiber, proteins, vitamins as well as chemical constituents [172–176].

Hypoglycaemic activity of alcoholic extract of seeds of *Trigonella foenum-graecum* was tested in both normal and alloxan-induced diabetic rats. Significant decrease in glycaemia was seen with alcoholic extract (74.33 ± 4.77 to 60.56 ± 1.9 in normal rats and 201.25 ± 7.69 to 121.25 ± 6.25 in diabetic rats) ($P < 0.001$) [122].

Fenugreek water seed extract was found to increase the body weight and decrease the fasting blood glucose in streptozocin-induced diabetic rats [177]. Similar results were obtained in the study done by Abdelatif et al. [178] who found that there was a weight gain in fenugreek treated rabbits as compared to the group that received only alloxan monohydrate. Plasma glucose level was reduced as compared to the alloxan monohydrate induced diabetic rabbits.

Administration of *Trigonella foenum-graecum* seeds (2.5 and 5 g) for 4 weeks to sixty newly diagnosed diabetic patients, improved blood glucose level in dose-dependent. The medium dose (5 g) of fenugreek seeds reduces significantly the glycemia (8.83 vs 6.45, $p < 0.05$) [179].

An active compound (G_{II}), isolated from water extract of seeds of fenugreek orally administered to the subdiabetic and mild diabetic rabbits, was capable of reduce blood glucose in glucose tolerance test [180].

Artemisia herba-alba Asso

Artemisia herba-alba Asso. (Compositae), known as the desert wormwood (Shih in arabic), is a dwarf, semi shrub,, strongly aromatic herb, growing widely in arid and semiarid areas of the Mediterranean basin and in Western Asia spreading into middle east, north-western Himalayas and India [181, 182]. This species is used medicinally to treat various diseases such as hypertension, diarrhoea, diabetes, colds, muscle tensions, coughing, intestinal distress and fever [183, 184]. It is cited as used in the treatment of diabetes in Morocco [2, 12, 14–23].

Numerous scientists have showed various biological and pharmacological effects in *Artemisia herba-alba* essential oils, especially antibacterial, antispasmodic, antidiabetic, antioxidant, leishmanicidal, and antifungal properties [185–188]. In essential oils, monoterpenes were the major components, essentially α- and β-thujones, camphor, 1,8-cineole and chrysanthenyl derivatives, but sesquiterpenes also were found in some countries [189–192].

Taştekin et al. [79] reported the hypoglycaemic effect of aqueous extract of *Artemisia herba-alba* in alloxan-induced diabetic rats. Aqueous extract of the aerial parts at the dose of 0.39 g/kg BW (body weight) significantly reduced ($P < 0.05$) blood glucose concentration. Its hypoglycaemic effect was comparable with that of insulin and repaglinide.

In vitro screening of hypoglycemic activity of *Artemisia herba-alba* using α-amylase inhibition technique emphasized its activity in hypoglycemic remedy. The 70% ethyl alcohol extract and mucilage of 70% ethyl alcohol inhibited the activity of α-amylase by 11% and 2% respectively [193].

A dose of 2 g/kg of hydro-alcoholic extracts of *Artemisia herba-alba*, orally administered daily for 18 weeks, to male mice fed high fat diet, significantly decreased the blood glucose level (143.8 ± 23.9 vs. 229.0 ± 20.8 mg/dl, $p < 0.05$), triglyceride (18.9 ± 11.1 vs. 62.8 ± 18.3 mg/dl, $p < 0.05$), total cholesterol (1.2 ± 0.1 vs. 1.8 ± 1.1 g/L, $p < 0.05$) and serum insulin concentrations (1.7 ± 0.7 vs. 3.3 ± 14.3 ng/ml, $p < 0.05$) [194].

Nigella sativa L.

Nigella sativa L. (Family Ranunculaceae), commonly known as black seed or Kalonji seed, is widely grown medicinal plant throughout the world. Seeds and their oil have many food and medicinal uses [195, 196]. It has received attention for its potential application in the treatment and prevention of a number of diseases, such as fever, asthma, diarrhoea, dyslipidaemia, common cold, headache, warts, stings of scorpions, bites of snake and rheumatic diseases [197–199]. Moreover, a variety of secondary metabolites has been identified in this species, such as fixed oil, protein, alkaloid, saponin, isochinoline alkaloids (nigellimin and nigellimin-N-oxide), pyrazol alkaloids (nigellidin and nigellicin), thymoquinone, p-cymene, pinene, dithymoquinone, thymohydroquinone, carvacrol, carvone, limonene, 4-terpineol and citronellol [195, 196]. It has been reported to possess potent anti-inflammatory, anti-hyperlipidemic, anti-microbial, anti-cancer, anti-oxidant, anti-diabetic, anti-hypertensive, hepatoprotective, antiparasitic, analgesic, anti-nociceptive, anti-ulcer, anti-histaminic and wound healing activities

[196, 200]. *Nigella sativa* used in Morocco in the treatment of diabetes [2, 13–23].

Alimohammadi et al. [146] reported the hypoglycaemic effect of hydroalcholic extract of *Nigella sativa* seeds (5, 10, and 20 mg/kg BW) in streptozotocin-induced diabetic rats (STZ). *Nigella sativa* at 5 mg/kg reduced blood glucose concentration level from (565.4 ± 30.9 mg/dl) to (323.2 ± 32.2 mg/dl), at 10 mg/kg it reduced blood glucose concentration level from (565.4 ± 30.9 mg/dl) to (513.2 ± 42.7 mg/dl), whereas at 20 mg/kg it reduced it from (565.4 ± 30.9 mg/dl) to (517.6 ± 27.3 mg/dl).

The antidiabetic activity of methanolic crude extract and the commercial oil of *Nigella sativa* seeds in alloxan- induced diabetic rats was examined by Houcher et al. [201]. Administration of the crude methanolic extract at a dose of 810 mg/kg/day and the oil at a dose of 2.5 ml/kg/day decreased significantly the blood glucose (decreases of 58.09 and 73.27% respectively) after 10 days of treatment.

Administration of the volatile oil extracted from *Nigella sativa* seeds experimentally caused a significant decrease in blood glucose level in alloxan-diabetic rabbits (2% and 21% decreases in the fasting glucose levels at the 4 h and the 6 h time intervals, respectively) [202].

Olea europaea L.

Olea europaea L. (Olive) belongs to the plant family Oleaceae, is a small tree that produces the olive fruit, cultivated in the coastal areas of the eastern Mediterranean basin, the contiguous coastal areas of southeastern Europe, northern Iran at the south end of the Caspian Sea, western Asia, and northern Africa [203, 204]. Phytochemical investigations on *Olea europaea* have revealed the presence of various phytochemicals including phenolic compounds (oleuropein, hydroxytyrosol, verbascoside, apigenin-7-glucoside and luteolin-7-glucoside), flavonoids, secoiridoids, triterpenes, biophenols, benzoic acid derivatives, xylitol, sterols, isochromans and sugars [204, 205]. *Olea europaea* has a variety of medicinal properties and traditional uses. The plant has been used to treat diabetes, high blood pressure, cardiovascular diseases, influenza, chronic fatigue syndrome, to support time of recovery, immune system, stomach and intestinal diseases, common cold, malaria, dengue, severe diarrhoea, respiratory and urinary tract infections, and as mouth cleanser [204, 206]. Various biological activities of *Olea europaea* have been extensively studied like antihypertensive, analgesic, antimicrobial, anticancer, antihyperglycemic, antidiabetic, anticonvulsant, antioxidant, anti-inflammatory, immunomodulatory, antiviral, antinociceptive, and gastroprotective activities [203, 204]. It is cited in the ethnobotanical surveys that the plant is used in the treatment of diabetes in Morocco [2, 12, 13, 15–23].

Eidi et al. [137] showed the antidiabetic effect of alcohol extract of *Olea europaea* leaves in normal and streptozotocin-induced diabetic rats. Rats were divided into nine groups, group1: normal control rats, groups 2, 3, 4: normal ratstreated with *Olea europaea*, group 5: diabetic control rats, group 6, 7, 8: diabetic rats treated with *Olea europaea*, group 9: diabetic rats treated with glibenclamide. The administration of extract at a dose of 0.1, 0.25 and 0.5 g/kg BW for 14 days significantly decreased the blood glucose in diabetic rats ($p < 0.05$).

Another study was conducted to check the antidiabetic potential of oleanolic acid (an agonist for TGR5), isolated from Olea europeaea leaves in mice fed with a high fat diet. Oleanolic acid cause a decrease in blood glucose concentration and insulin levels and it enhances glucose tolerance [207].

Several other studies demonstrated the antidiabetic effect of *Olea europaea* in streptozotocin diabetic rats [208–214], in alloxan diabetic rats [215–219], in alloxan diabetic rabbits [215], in human diabetic subjects [209] and in vitro α-amylase and α-glucosidase inhibitory activities [220, 221].

Allium cepa L.

Allium cepa L., commonly known as onion, botanically classified under the Amaryllidaceae family, is a biennial plant widely cultivated around the world. Onion is utilized as both vegetable and flavouring [222, 223].

According to traditional medicine experts, Onion is one of the oldest medicinal plants used to relieve several ailments including metabolic disease, wound healer, pneumonia fighters, digestive problems, skin diseases and insect bites, diabetes and asthma [224, 225]. *Allium cepa* used in Morocco in the treatment of diabetes [2, 12–22].

There are many chemical constituents in *Allium cepa*, including vitamins and minerals. Moreover, a variety of secondary metabolites has been identified in this species, such as phenolic compounds (particularly ferulic acid, gallic acid, protocatechuic acid, quercetin, and kaempferol), flavonoids (particularly quercetin aglycon, quercetin-3,4′-diglucoside, quercetin-4′-monoglucoside, quercetin-3-monoglucoside, quercetin 3-glycosides, delphinidin 3,5-diglycosides, quercetin 3,7,4′-triglucoside, quercetin 7,4′-diglucoside, quercetin 3,4′-diglucoside and isorhamnetin 3,4′-diglucoside), phytosterols and saponins [226–230].

Recent studies have shown that this plant has different biological properties, such as hypolipidemic, antihypertensive, antimicrobial, antioxidant, analgesic, anti-inflammatory, immunoprotective, and anti-diabetic effects [222, 224].

The hypoglycemic effect of *Allium cepa* was confirmed by aqueous extracts of the whole plant in alloxan (150 mg/Kg BW) rat model of diabetes. *Allium cepa* at 200 mg/kg reduced fasting blood glucose levels by 62.9%

(292.3 ± 29.0 to 108.2 ± 4.6), at 250 mg/kg it reduced fasting blood glucose levels by 69.7 (296.3 ± 37.8 to 89.8 ± 4.3) whereas at 300 mg/kg it reduced it by 75.4% (297.8 ± 37.5 to 73.4 ± 3.0) [45].

Another study showed the hypoglycemic effect of onion juice on alloxan-induced diabetic rats. After 4 week treatment of onion juice (1 ml/100 g body weight), significant anti-hyperglycaemic effect were observed in treated rats [231].

The antidiabetic effect of 200 mg/kg body weight for 60 days of S-methyl cysteine sulfoxide (SMCS) isolated from *Allium cepa* was studied and compared in alloxan-induced diabetic rats. Results suggested that the administration of SMCS reduced blood glucose level [232].

In another experiment conducted by El-Soud and Khalil [233], they found that treatment with onion essential oil caused a significant decrease in serum lipids, lipid peroxide formation, blood glucose and increase in serum insulin in streptozotocin induced diabetic albino rats.

Marrubium vulgare L.

Marrubium vulgare L. is a perennial herb of the Lamiaceae family, popularly known as white horehound. This aromatic plant is native to the Mediterranean Sea region can be found in many temperate regions of Europe, North of Africa and Asia [234, 235]. It could be used to cure and treat several diseases, such as laryngitis, bronchitis, skin abrasions, wounds, bronchial asthma, non-productive cough, hepatic affections and in phthisis [235, 236]. *Marrubium vulgare* is rich in phytochemicals like amino acids, polysaccharides, tannins, phenols, flavonoids, alkaloids, steroids, lactones and, in particular, terpenes [237, 238]. The plant is reported to possess hypoglycemic, vasorelaxant, analgesic, antioxidant, anti-erdematogenic, anti-inflammatory, vasodilator and anti-hypertensive properties [236, 238]. Horehound used in Morocco in the treatment of diabetes [2, 12–19, 21–23].

Elberry et al. [102] showed that methanolic extract of the aerial parts of *Marrubium vulgare* can have beneficial effect in diabetes and its complication. They showed on a streptozotocin rat model the antidiabetic effect of a daily single oral dose of 500 mg/kg/day of *Marrubium vulgare* for 28 days. The methanolic extract produced a significant decrease in blood glucose starting on the second week and a significant increase in plasma insulin and tissue glycogen contents.

The administration of an aqueous extract from aerial parts infusion at dose 100, 200 and 300 mg/kg BW to alloxan-induced diabetic rats decreased significantly the blood glucose level in a dose dependent manner (a decrease by 50% for the dose 100 mg/kg and more than 60% for doses 200 and 300 mg/kg) [239].

The antidiabetic activity of various ethanolic extracts (root, leaf and stem) from *Marrubium vulgare* on normoglycemic rats was examined by Vergara-Galicia et al. [240].The intragastric administration of both extracts (root and stem), at 100 mg/kg BW, significantly reduced blood glucose level in healthy rat. Furthermore, the increase in plasma glucose level was significantly suppressed by the ethanolic root extract after substrate oral administration.

Conclusion

Many Moroccan medicinal plants are reported to have blood sugar lowering properties that make them useful for the management of diabetes. We have reported 255 medicinal plants species belonging to 70 families in this study for the treatment of diabetes. Plants from the Compositae family were used most often in Morocco. The role of 135 Moroccan medicinal plants in the treatment of diabetes has been reviewed by several authors. However, 120 medicinal plants that are used for the treatment of diabetes in Morocco have not yet been studied in great detail for their antidiabetic properties. Furthermore, there are very few scientific reports of toxicological properties of these plants which would guarantee the safety of patients. In general, the literature search showed that some users of medicinal plants have only little information about toxic plants. In order to prevent the usage of toxic plants by the greater population, we have reported the major plants that have side effects according to toxicological documentations. Despite the therapeutic effects of medicinal plantsthey may have a toxicity risk which is related to a variety of causes including, contamination, misidentification, mistaken use of the wrong species, incorrect dosing and errors in use. Another problem, which may occur, is the possibility of adverse interaction between conventional medication and plant remedies. In conclusion, this review provides baseline data for plant species that have the potential antidiabetic activity and their associated knowledge in Morocco. However, many of the plant species mentioned require further pharmacological and clinical studies in order to validate any effective plant remedies to treat diabetes.

Abbreviations

BW: Body weight; DM: Diabetes mellitus; SMCS: S-methyl cysteine sulfoxide; STZ: Streptozotocin-induced diabetic rats

Acknowledgements

Not applicable.

Authors' contributions

EI Manuscript preparation. FM Manuscript review. KC Supervising the whole work. All authors read and approved the final manuscript.

Funding

There is no funding for review article.

Availability of data and materials

Not applicable.

Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 26 October 2019 Accepted: 25 March 2020
Published online: 31 March 2020

References

1. Yaseen G, Ahmad M, Zafar M, Sultana S, Kayani S, Cetto AA, et al. Traditional management of diabetes in Pakistan: ethnobotanical investigation from traditional health practitioners. J Ethnopharmacol. 2015;174:91–117.
2. Barkaoui M, Katiri A, Boubaker H, Msanda F. Ethnobotanical survey of medicinal plants used in the traditional treatment of diabetes in Chtouka Ait Baha and Tiznit (Western anti-atlas), Morocco. J Ethnopharmacol. 2017; 198:338–50.
3. Giovannini P, Howes M-JR, Edwards SE. Medicinal plants used in the traditional management of diabetes and its sequelae in Central America: a review. J Ethnopharmacol. 2016;184:58–71.
4. Yagi SM, Yagi AI. Traditional medicinal plants used for the treatment of diabetes in the Sudan: a review. Afr J Pharm Pharmacol. 2018;12(3):27–40.
5. Surya S, Salam AD, Tomy DV, Carla B, Kumar RA, Sunil C. Diabetes mellitus and medicinal plants-a review. Asian Pac J Trop Dis. 2014;4(5):337–47.
6. Gao D, Li Q, Fan Y. Hypoglycemic effects and mechanisms of Portulaca oleracea L. in alloxan-induced diabetic rats. J Med Plant Res. 2010;4(19): 1996–2003.
7. Rahati S, Shahraki M, Arjomand G, Shahraki T. Food pattern, lifestyle and diabetes mellitus. Int J High Risk Behav Addict. 2014;3(1):e8725.
8. Mahomoodally MF, Mootoosamy A, Wambugu S. Traditional therapies used to manage diabetes and related complications in Mauritius: a comparative ethnoreligious study. Evid Based Complement Alternat Med. 2016;2016: 4523828.
9. Nazarian-Samani Z, Sewell RD, Lorigooini Z, Rafieian-Kopaei M. Medicinal plants with multiple effects on diabetes mellitus and its complications: a systematic review. Curr Diab Rep. 2018;18(10):72.
10. Yanardağ R, Bolkent Ş, Tabakoğlu-Oğuz A, Özsoy-Saçan Ö. Effects of Petroselinum crispum extract on pancreatic B cells and blood glucose of streptozotocin-induced diabetic rats. Biol Pharm Bull. 2003;26(8):1206–10.
11. Singh AB, Chaturvedi J, Narender T, Srivastava AK. Preliminary studies on the hypoglycemic effect of Peganum harmala L. seeds ethanol extract on normal and streptozotocin induced diabetic rats. Indian J Clin Biochem. 2008;23(4):391–3.
12. Laadim M, Ouahidi M, Zidane L, El Hessni A, Ouichou A, Mesfioui A. Ethnopharmacological survey of plants used for the treatment of diabetes in the town of Sidi Slimane (Morocco). J Pharmacogn Phytother. 2017;9(6): 101–10.
13. Hachi M, Ouafae B, Hachi T, Imane B, Atmane R, Zidane L. Contribution to the ethnobotanical study of antidiabetic medicinal plants of the central middle atlas region (Morocco). Lazaroa. 2016;37:1.
14. Douira A, Zidane L. Étude ethnobotanique des plantes médicinales utilisées dans le traitement du diabète, et des maladies cardiaques dans la région d'Izarène (Nord du Maroc). J Appl Biosci. 2015;86(1):7940–56 [French with abstract in English].
15. Alami Z, Aynaou H, Alami B, Hdidou Y, Latrech H. Herbal medicines use among diabetic patients in oriental Morocco. J Pharmacogn Phytother. 2015;7(2):9–17.
16. Bousta D, Boukhira S, Aafi A, Ghanmi M, El-Mansouri L. Ethnopharmacological study of anti-diabetic medicinal plants used in the middle-atlas region of Morocco (Sefrou region). Int J Pharm Res Health Sci. 2014;2(1):75–9.
17. Benkhnigue O, Ben Akka F, Salhi S, Fadli M, Douira A, Zidane L. Catalogue des plantes médicinales utilisées dans le traitement du diabète dans la région d'Al Haouz-Rhamna (Maroc). J Anim Plant Sci. 2014;23:3539–68 [French with abstract in English].
18. Ghourri M, Zidane L, Douira A. Usage des plantes médicinales dans le traitement du Diabète Au Sahara marocain (Tan-Tan). J Anim Plant Sci. 2013;17(1):2388–411 [French with abstract in English].
19. El Amrani F, Rhallab A, Alaoui T, El Badaoui K, Chakir S. Étude ethnopharmacologique de quelques plantes utilisées dans le traitement du diabète dans la région de Meknès-Tafilalet (Maroc). Phytothérapie. 2010;8(3): 161–5 [French with abstract in English].
20. Tahraoui A, El-Hilaly J, Israili Z, Lyoussi B. Ethnopharmacological survey of plants used in the traditional treatment of hypertension and diabetes in South–Eastern Morocco (Errachidia province). J Ethnopharmacol. 2007;110(1):105–17.
21. Eddouks M, Maghrani M, Lemhadri A, Ouahidi M-L, Jouad H. Ethnopharmacological survey of medicinal plants used for the treatment of diabetes mellitus, hypertension and cardiac diseases in the south-east region of Morocco (Tafilalet). J Ethnopharmacol. 2002;82(2–3):97–103.
22. Jouad H, Haloui M, Rhiouani H, El Hilaly J, Eddouks M. Ethnobotanical survey of medicinal plants used for the treatment of diabetes, cardiac and renal diseases in the North Centre region of Morocco (fez–Boulemane). J Ethnopharmacol. 2001;77(2–3):175–82.
23. Ziyyat A, Legssyer A, Mekhfi H, Dassouli A, Serhrouchni M, Benjelloun W. Phytotherapy of hypertension and diabetes in oriental Morocco. J Ethnopharmacol. 1997;58(1):45–54.
24. Mrabti HN, Jaradat N, Kachmar MR, Ed-Dra A, Ouahbi A, Cherrah Y, et al. Integrative herbal treatments of diabetes in Beni Mellal region of Morocco. J Integr Med. 2019;17(2):93–9.
25. Skalli S, Hassikou R, Arahou M. An ethnobotanical survey of medicinal plants used for diabetes treatment in Rabat, Morocco. Heliyon. 2019;5(3):e01421.
26. Katiri A, Barkaoui M, Msanda F, Boubaker H. Ethnobotanical survey of medicinal plants used for the treatment of diabetes in the Tizi n'Test region (Taroudant Province, Morocco). J Pharmacogn Nat Prod. 2017;3(1):2472–0992.
27. Hamza N, Berke B, Umar A, Cheze C, Gin H, Moore N. A review of Algerian medicinal plants used in the treatment of diabetes. J Ethnopharmacol. 2019; 238:111841.
28. Oridupa O, Saba A. Diabetes mellitus in Nigeria and the on-going search for a cure from medicinal plants: a review. Afr J Diabetes Med. 2017;25(2):1–3.
29. Shen Q, Zhang L, Liao Z, Wang S, Yan T, Shi P, et al. The genome of Artemisia annua provides insight into the evolution of Compositae family and artemisinin biosynthesis. Mol Plant. 2018;11(6):776–88.
30. Uttra AM, Ahsan H, Hasan UH, Chaudhary MA. Traditional medicines of plant origin used for the treatment of inflammatory disorders in Pakistan: a review. J Tradit Chin Med. 2018;38(4):636–56.
31. Bessada SM, Barreira JC, Oliveira MBP. Compositae species with most prominent bioactivity and their potential applications: a review. Ind Crop Prod. 2015;76:604–15.
32. Al-Yahya M, Al-Farhan A, Adam S. Preliminary toxicity study on the individual and combined effects of Citrullus colocynthis and Nerium oleander in rats. Fitoterapia. 2000;71(4):385–91.
33. Boumba VA, Mitselou A, Vougiouklakis T. Fatal poisoning from ingestion of Datura stramonium seeds. Vet Hum Toxicol. 2004;46(2):81–2.
34. Daoubi M, Marquez N, Mazoir N, Benharref A, Hernández-Galán R, Munoz E, et al. Isolation of new phenylacetylingol derivatives that reactivate HIV-1 latency and a novel spirotriterpenoid from Euphorbia officinarum latex. Bioorg Med Chem. 2007;15(13):4577–84.
35. El Malti J, Bourhim N, Amarouch H. Toxicity and antibacterial effect of Mace of Myristica fragrans used in Moroccan gastronomy: biochemical and histological impact. J Food Saf. 2008;28(3):422–41.
36. Almasad MM, Qazan WS, Daradka H. Reproductive toxic effects of Artemisia herba alba ingestion in female Spague-Dawley rats. Pak J Biol Sci. 2007; 10(18):3158–61.
37. Mohammadi RS, Bidaki R, Mirdrikvand F, Yazdi SNM, Anari PY. Peganum Harmala (Aspand) intoxication; a case report. Emerg. 2016;4(2):106.
38. Worbs S, Köhler K, Pauly D, Avondet M-A, Schaer M, Dorner MB, et al. Ricinus communis intoxications in human and veterinary medicine—a summary of real cases. Toxins. 2011;3(10):1332–72.
39. El AHEY, Bousta D, Ouahidi I, Aarab L. Primary pharmacological screening of an endemic plant from the Southern Morocco (Tetraena gaetula [Emb. & Maire] Beier & Thulin). C R Biol. 2010;333(10):736–43 [French with abstract in English].
40. Zaoui A, Cherrah Y, Mahassini N, Alaoui K, Amarouch H, Hassar M. Acute and chronic toxicity of Nigella sativa fixed oil. Phytomedicine. 2002;9(1):69–74.
41. Farid O, Hajji L, Eddouks M. Aqueous extract of anabasis aretioides ameliorates Streptozotocininduced diabetes mellitus in rats. Nat Prod J. 2018;8(2):139–46.
42. Chikhi I, Allali H, Dib MEA, Medjdoub H, Tabti B. Antidiabetic activity of aqueous leaf extract of Atriplex halimus L.(Chenopodiaceae) in streptozotocin–induced diabetic rats. Asian Pac J Trop Dis. 2014;4(3):181–4.

43. Song M-J, Lee S-M, Kim D-K. Antidiabetic effect of Chenopodium ambrosioides. Phytopharm. 2011;1:12–5.
44. Selim YA, Sakeran MI. Effect of time distillation on chemical constituents and anti-diabetic activity of the essential oil from dark green parts of Egyptian Allium ampeloprasum L. J Essent Oil Bear Pl. 2014;17(5):838–46.
45. Ozougwu JC. Anti-diabetic effects of Allium cepa (onions) aqueous extracts on alloxan-induced diabetic Rattus novergicus. J Med Plant Res. 2011;5(7): 1134–9.
46. Thomson M, Al-Amin ZM, Al-Qattan KK, Shaban LH. Anti-diabetic and hypolipidaemic properties of garlic (Allium sativum) in streptozotocin-induced diabetic rats. Int J Diabetes Metab. 2007;15:108–15.
47. Hashemnia M, Nikousefat Z, Yazdani-Rostam M. Antidiabetic effect of Pistacia atlantica and Amygdalus scoparia in streptozotocin-induced diabetic mice. Comp Clin Pathol. 2015;24(6):1301–6.
48. Rehman MSU, Kamran SH, Ahmad M, Akhtar U. Anti-diabetic activity of crude Pistacia lentiscus in alloxan-induced diabetes in rats. Bangl J Pharmacol. 2015;10(3):543–7.
49. Jouad H, Maghrani M, Eddouks M. Hypoglycemic effect of aqueous extract of Ammi visnaga in normal and streptozotocin-induced diabetic rats. J Herb Pharmacother. 2002;2(4):19–29.
50. El-Ouady F, Eddouks M. Glucose lowering activity of aqueous Ammodaucus leucotrichus extract in diabetic rats. Cardiovasc Hematol Disord Drug Targets. 2019;19:1–8.
51. Gutierrez RMP, Juarez VA, Sauceda JV, Sosa IA. In vitro and in vivo antidiabetic and antiglycation properties of apium graveolens in type 1 and 2 diabetic rats. Int J Pharmacol. 2014;10(7):368–79.
52. Eidi A, Eidi M, Haeri Rohani A, Basati F. Hypoglycemic effect of ethanolic extract of *Carum carvi* L. seeds in normal and streptozotocin-induced diabetic rats.113–106:(35)3 ;2010. فـ لنامه لم پ وهشی گیاهان داروی.
53. Naquvi KJ, Ali M, Ahmad J. Antidiabetic activity of aqueous extract of Coriandrum sativum L. fruits in streptozotocin induced rats. Indian J Exp Biol. 2004;42(9):909–12.
54. Srivsatava R, Srivastava SP, Jaiswal N, Mishra A, Maurya R, Srivastava AK. Antidiabetic and antidyslipidemic activities of Cuminum cyminum L. in validated animal models. Med Chem Res. 2011;20(9):1656–66.
55. Pouraboli I, Ranjbar B. Effect of Daucus carota seeds extract on serum levels of glucose, lipids and lipoproteins in type I diabetic male rats. Iranian J Biol. 2011;24(5):679–87.
56. El-Soud N, El-Laithy N, El-Saeed G, Wahby M, Khalil M, Morsy F, et al. Antidiabetic activities of Foeniculum vulgare mill. Essential oil in streptozotocin-induced diabetic rats. Maced J Med Sci. 2011;4(2):139–46.
57. Shobha R, Rajeshwari C, Andallu B. Anti-peroxidative and anti-diabetic activities of aniseeds (Pimpinella anisum L.) and identification of bioactive compounds. Am J Phytomed Clin Ther. 2013;1(5):516–27.
58. Rathod NR, Chitme HR, Irchhaiya R, Chandra R. Hypoglycemic effect of Calotropis gigantea Linn. Leaves and flowers in streptozotocin-induced diabetic rats. Oman Med J. 2011;26(2):104–8.
59. Dra LA, Sellami S, Rais H, Aziz F, Aghraz A, Bekkouche K et al. Antidiabetic potential of Caralluma europaea against alloxan-induced diabetes in mice. Saudi J Biol Sci. 2018;26(6):1–28.
60. Dey P, Saha MR, Chowdhuri SR, Sen A, Sarkar MP, Haldar B, et al. Assessment of anti-diabetic activity of an ethnopharmacological plant Nerium oleander through alloxan induced diabetes in mice. J Ethnopharmacol. 2015;161:128–37.
61. Gaamoussi F, Israili ZH, Lyoussi B. Hypoglycemic and hypolipidemic effects of an aqueous extract of *Chamaerops humilis* leaves in obese, hyperglycemic and hyperlipidemic *Meriones shawi* rats. Pak J Pharm Sci. 2010;23(2):121–9.
62. Tohamy AA, Abdalla MS, Ibrahim AK, Mahran KF, Mohammed RS. The effect of Lupinus Albus (Termis) and Hyphaene Thebaica (Doum) on some biochemical parameters in Streptozotocin induced diabetic rats. Egypt J Hosp Med. 2013;31(914):1–6.
63. Algandaby MM, Alghamdi HA, Ashour OM, Abdel-Naim AB, Ghareib SA, Abdel-Sattar EA, et al. Mechanisms of the antihyperglycemic activity of Retama raetam in streptozotocin-induced diabetic rats. Food Chem Toxicol. 2010;48(8–9):2448–53.
64. Rahmy TR, El-Ridi MR. Action of Anastatica hierochuntica plant extract on islets of Langerhans in normal and diabetic rats. Egypt J Biol. 2002;4(1):87–94.
65. Akbari F, Khodadadi S, Asgari S, Shirzad H, Mirhoseini M, Shahinfard N, et al. A comparative study on hypoglycemic properties, lipid profile and bioactive components of hydro-alcoholic extracts of cooked and raw Brassica napus. J Nephropharmacol. 2016;5(2):86.
66. Anand P, Murali K, Tandon V, Chandra R, Murthy P. Preliminary studies on antihyperglycemic effect of aqueous extract of Brassica nigra (L.) Koch in streptozotocin induced diabetic rats. Indian J Exp Biol. 2007;45(8):696–701.
67. Asadujjaman M, Hossain M, Khan M, Anisuzzaman A, Ahmed M, Islam A. Antihyperglycemic and glycogenesis effects of different fractions of brassica oleracea in Alloxan induced diabetic rats. Int J Pharm Sci Res. 2011;2(6):1436.
68. Fard MH, Naseh G, Lotfi N, Hosseini SM, Hosseini M. Effects of aqueous extract of turnip leaf (Brassica rapa) in alloxan-induced diabetic rats. Avicenna J Phytomed. 2015;5(2):148.
69. Chauhan K, Sharma S, Agarwal N, Chauhan S, Chauhan B. A study on potential hypoglycemic and hypolipidemic effects of Lepidium Sativum (garden cress) in Alloxan induced diabetic rats. Am J PharmTech Res. 2012; 2:522–35.
70. Mousa-Al-Reza Hadjzadeh ZR, Moradi R, Ghorbani A. Effects of hydroalcoholic extract of watercress (Nasturtium officinale) leaves on serum glucose and lipid levels in diabetic rats. Indian J Physiol Pharmacol. 2015;59: 223–30.
71. Shukla S, Chatterji S, Mehta S, Rai PK, Singh RK, Yadav DK, et al. Antidiabetic effect of Raphanus sativus root juice. Pharm Biol. 2011;49(1):32–7.
72. Ajebli M, Eddouks M. Buxus sempervirens L improves Streptozotocin-induced diabetes mellitus in rats. Cardiovasc Hematol Disord Drug. 2017; 17(2):142–52.
73. Hwang SH, Kang IJ, Lim SS. Antidiabetic effect of fresh nopal (Opuntia ficus-indica) in low-dose streptozotocin-induced diabetic rats fed a high-fat diet. Evid Based Complement Alternat Med. 2017;2017:4380721.
74. Rathee S, Mogla O, Sardana S, Vats M, Rathee P. Antidiabetic activity of Capparis decidua Forsk Edgew. J Pharm Res. 2010;3:231–4.
75. Kazemian M, Abad M, Reza Haeri M, Ebrahimi M, Heidari R. Anti-diabetic effect of *Capparis spinosa* L. root extract in diabetic rats. Avicenna J Phytomed. 2015;5(4):325.
76. Orhan N, Aslan M, Şüküroğlu M, Orhan DD. In vivo and in vitro antidiabetic effect of Cistus laurifolius L. and detection of major phenolic compounds by UPLC–TOF-MS analysis. J Ethnopharmacol. 2013;146(3):859–65.
77. Satyanand Tyagi M, Mansoori H, Singh NK, Shivhare MK, Bhardwaj P, Singh RK. Antidiabetic effect of Anacyclus pyrethrum DC in alloxan induced diabetic rats. Eur J Biol Sci. 2011;3(4):117–20.
78. Daradka HM, Abas MM, Mohammad MA, Jaffar MM. Antidiabetic effect of Artemisia absinthium extracts on alloxan-induced diabetic rats. Comp Clin Pathol. 2014;23(6):1733–42.
79. Taştekin D, Atasever M, Adigüzel G, Keleş M, Taştekİn A. Hypoglycaemic effect of Artemisia herba-alba in experimental hyperglycaemic rats. Bull Vet Inst Pulawy. 2006;50:235–8.
80. Eddouks M, Lemhadri A, Zeggwagh N, Michel J. Potent hypoglycaemic activity of the aqueous extract of Chamaemelum nobile in normal and streptozotocin-induced diabetic rats. Diabetes Res Clin Pract. 2005;67(3):189–95.
81. Pushparaj P, Low H, Manikandan J, Tan B, Tan C. Anti-diabetic effects of Cichorium intybus in streptozotocin-induced diabetic rats. J Ethnopharmacol. 2007;111(2):430–4.
82. Gopal SS, Lakshmi MJ, Sharavana G, Sathaiah G, Sreerama YN, Baskaran V. Lactucaxanthin–a potential anti-diabetic carotenoid from lettuce (Lactuca sativa) inhibits α-amylase and α-glucosidase activity in vitro and in diabetic rats. Food Funct. 2017;8(3):1124–31.
83. Najla O, Olfat A, Kholoud S, Enas N, Hanan S. Hypoglycemic and biochemical effects of Matricaria chamomilla leave extract in streptozotocin-induced diabetic rats. J Health Sci. 2012;2(5):43–8.
84. Mir MA, Sawhney S, Jassal M. In-vitro antidiabetic studies of various extracts of *Taraxacum officinale*. Pharm Innov. 2015;4(1, Part B):61.
85. Hebi M, Eddouks M. Glucose lowering activity of the aqueous extract of Warionia saharae in Normal and diabetic rats. Cardiovasc Hematol Agents Med Chem. 2018;16(1):66–72.
86. Agarwal V, Sharma AK, Upadhyay A, Singh G, Gupta R. Hypoglycemic effects of Citrullus colocynthis roots. Acta Pol Pharm. 2012;69(1):75–9.
87. Karthiyayini T, Kumar R, Kumar KS, Sahu RK, Roy A. Evaluation of antidiabetic and hypolipidemic effect of Cucumis sativus fruit in streptozotocin-induced-diabetic rats. Biomed Pharmacol J. 2015;2(2):351–5.
88. Sharma A, Sharma AK, Chand T, Khardiya M, Yadav KC. Antidiabetic and antihyperlipidemic activity of Cucurbita maxima Duchense (pumpkin) seeds on streptozotocin induced diabetic rats. J Pharmacogn Phytochem. 2013; 1(6):108–16.
89. Asgary S, Moshtaghian SJ, Setorki M, Kazemi S, Rafieian-Kopaei M, Adelnia A, et al. Hypoglycaemic and hypolipidemic effects of pumpkin (Cucurbita

pepo L.) on alloxan-induced diabetic rats. Afr J Pharm Pharmacol. 2011; 5(23):2620–6.
90. Keskes H, Mnafgui K, Hamden K, Damak M, El Feki A, Allouche N. In vitro anti-diabetic, anti-obesity and antioxidant proprieties of Juniperus phoenicea L. leaves from Tunisia. Asian Pac J Trop Biomed. 2014;4:S649–S55.
91. Raut NA, Gaikwad NJ. Antidiabetic activity of hydro-ethanolic extract of Cyperus rotundus in alloxan induced diabetes in rats. Fitoterapia. 2006;77(7–8):585–8.
92. Bnouham M, Merhfour F, Legssyer A, Mekhfi H, Maâllem S, Ziyyat A. Antihyperglycemic activity of Arbutus unedo, Ammoides pusilla and Thymelaea hirsuta. Pharmazie. 2007;62(8):630–2.
93. Shokeen P, Anand P, Murali YK, Tandon V. Antidiabetic activity of 50% ethanolic extract of Ricinus communis and its purified fractions. Food Chem Toxicol. 2008;46(11):3458–66.
94. Liyanage R, Kiramage C, Visvanathan R, Jayathilake C, Weththasinghe P, Bangamuwage R, et al. Hypolipidemic and hypoglycemic potential of raw, boiled, and sprouted mung beans (*Vigna radiata* L. Wilczek) in rats. J Food Biochem. 2018;42(1):e12457.
95. Ashraduzzaman M, Alam M, Khatun S, Banu S, Absar N. Vigna unguiculata Linn. Walp. Seed oil exhibiting antidiabetic effects in alloxan induced diabetic rats. Malays J Pharm Sci. 2011;9(1):13–23.
96. Mansar-Benhamza L, Djerrou Z, Pacha H. Evaluation of anti-hyperglycemic activity and side effects of Erythraea centaurium (L.) Pers. in rats. Afr J Biotechnol. 2013;12(50):6980–5.
97. Mohajeri D, Mousavi G, Doustar Y. Antihyperglycemic and pancreas-protective effects of Crocus sativus L.(saffron) stigma ethanolic extract on rats with alloxan-induced diabetes. J Biol Sci. 2009;9(4):302–10.
98. Mohammadi J, Saadipour K, Delaviz H, Mohammadi B. Anti-diabetic effects of an alcoholic extract of Juglans regia in an animal model. Turk J Med Sci. 2011;41(4):685–91.
99. El Hilaly J, Lyoussi B. Hypoglycaemic effect of the lyophilised aqueous extract of Ajuga Iva in normal and streptozotocin diabetic rats. J Ethnopharmacol. 2002;80(2–3):109–13.
100. Issa A, Mohammad M, Hudaib M, Tawah K, Rjai TA, Oran S, et al. A potential role of Lavandula angustifolia in the management of diabetic dyslipidemia. J Med Plant Res. 2011;5(16):3876–82.
101. Sebai H, Selmi S, Rtibi K, Souli A, Gharbi N, Sakly M. Lavender (*Lavandula stoechas* L.) essential oils attenuate hyperglycemia and protect against oxidative stress in alloxan-induced diabetic rats. Lipids Health Dis. 2013; 12(1):189.
102. Elberry AA, Harraz FM, Ghareib SA, Gabr SA, Nagy AA, Abdel-Sattar E. Methanolic extract of Marrubium vulgare ameliorates hyperglycemia and dyslipidemia in streptozotocin-induced diabetic rats. Int J Diabetes Mellitus. 2015;3(1):37–44.
103. El-Beshbishy H, Bahashwan S. Hypoglycemic effect of basil (Ocimum basilicum) aqueous extract is mediated through inhibition of α-glucosidase and α-amylase activities: an in vitro study. Toxicol Ind Health. 2012;28(1):42–50.
104. Bakırel T, Bakırel U, Keleş OÜ, Ülgen SG, Yardibi H. In vivo assessment of antidiabetic and antioxidant activities of rosemary (Rosmarinus officinalis) in alloxan-diabetic rabbits. J Ethnopharmacol. 2008;116(1):64–73.
105. Eidi A, Eidi M. Antidiabetic effects of sage (Salvia officinalis L.) leaves in normal and streptozotocin-induced diabetic rats. Diabetes Metab Syndr. 2009;3(1):40–4.
106. Gharaibeh MN, Elayan HH, Salhab AS. Hypoglycemic effects of Teucrium polium. J Ethnopharmacol. 1988;24(1):93–9.
107. Kabbaoui M, Chda A, Mejrhit N, Azdad O, Farah A, Aarab L, et al. Antidiabetic effect of Thymus satureioides aqueous extract in streptozotocin-induced diabetic rats. Int J Pharm Pharm Sci. 2016;8(9):140–5.
108. Aljarah AK, Hameed IH. In vitro anti-diabetic properties of Methanolic extract of Thymus vulgaris using α-glucosidase and α-amylase inhibition assay and determination of its bioactive chemical compounds. Indian J Public Health Res Dev. 2018;9(3):388–92.
109. Kamble S, Rambhimaiah S. Antidiabetic activity of aqueous extract of Cinnamomum cassia in alloxan-induced diabetic rats. Biomed Pharmacol J. 2015;6(1):83–8.
110. El-Desoky GE, Aboul-Soud MA, Al-Numair KS. Antidiabetic and hypolipidemic effects of Ceylon cinnamon (Cinnamomum verum) in alloxan-diabetic rats. J Med Plant Res. 2012;6(9):1685–91.
111. Basak SS, Candan F. Effect of *Laurus nobilis* L. essential oil and its main components on α-glucosidase and reactive oxygen species scavenging activity. Iran J Pharm Res. 2013;12(2):367.
112. Ezejiofor AN, Okorie A, Orisakwe OE. Hypoglycaemic and tissue-protective effects of the aqueous extract of Persea americana seeds on alloxan-induced albino rats. Malays J Med Sci. 2013;20(5):31.
113. Ahmad M, Zaman F, Sharif T, Ch MZ. Antidiabetic and hypolipidemic effects of aqueous methanolic extract of Acacia nilotica pods in alloxan-induced diabetic rabbits. Scand J Lab Anim Sci. 2008;35(1):29–34.
114. Batra S, Batra N, Nagori BP. Preliminary phytochemical studies and evaluation of antidiabetic activity of stem bark of Acacia Senegal (L.) Willd. In alloxan induced diabetic albino rats. Int J Med Res Rev. 2013;1(8):611–6.
115. Alharbi WDM, Azmat A. Hypoglycemic and hypocholesterolemic effects of Acacia tortilis (Leguminosae) growing in Makkah. Pak J Pharmacol. 2011; 28(1):1–8.
116. Bilbis L, Shehu R, Abubakar M. Hypoglycemic and hypolipidemic effects of aqueous extract of Arachis hypogaea in normal and alloxan-induced diabetic rats. Phytomedicine. 2002;9(6):553–5.
117. Umar I, Mohammad A, Ndidi U, Abdulazeez A, Olica W, Adam M. Antihyperglycemic and antihyperlipidemic effect of aqueous stem bark extract of Acacia albida Delile in alloxan-induced diabetic rats. Asian J Biochem. 2014;9:170–8.
118. Badole SL, Bodhankar SL. Investigation of antihyperglycemic activity of Glycine max (L.) Merr. on serum glucose level in diabetic mice. J Complement Integr Med. 2009;6(1):1–15.
119. Knecht KT, Nguyen H, Auker AD, Kinder DH. Effects of extracts of lupine seed on blood glucose levels in glucose resistant mice: antihyperglycemic effects of Lupinus albus (white lupine, Egypt) and Lupinus caudatus (tailcup lupine, Mesa Verde National Park). J Herb Pharmacother. 2006;6(3–4):89–104.
120. Helal EG, Abd El-Wahab SM, Atia TA. Hypoglycemic effect of the aqueous extracts of Lupinus albus, Medicago sativa (seeds) and their mixture on diabetic rats. Egypt J Hosp Med. 2013;31(708):1–15.
121. Atchibri A, Brou K, Kouakou T, Kouadio Y, Gnakri D. Screening for antidiabetic activity and phytochemical constituents of common bean (Phaseolus vulgaris L.) seeds. J Med Plant Res. 2010;4(17):1757–61.
122. Vats V, Grover J, Rathi S. Evaluation of anti-hyperglycemic and hypoglycemic effect of Trigonella foenum-graecum Linn, Ocimum sanctum Linn and Pterocarpus marsupium Linn in normal and alloxanized diabetic rats. J Ethnopharmacol. 2002;79(1):95–100.
123. Ghule AE, Jadhav SS, Bodhankar SL. Effect of ethanolic extract of seeds of Linum usitatissimum (Linn.) in hyperglycaemia associated ROS production in PBMNCs and pancreatic tissue of alloxan induced diabetic rats. Asian Pac J Trop Dis. 2012;2(5):405–10.
124. Choubey A, Ojha M, Mishra A, Mishra S, Patil U. Hypoglycemic and antihyperglycemic effect of ethanolic extract of whole plant of Lawsonia inermis (henna) in streptozotocin induced diabetic rats. Int J Pharm Sci Res. 2010;1:74–7.
125. Das S, Barman S. Antidiabetic and antihyperlipidemic effects of ethanolic extract of leaves of Punica granatum in alloxan-induced non–insulin-dependent diabetes mellitus albino rats. Indian J Pharm. 2012;44(2):219.
126. Sabitha V, Ramachandran S, Naveen K, Panneerselvam K. Antidiabetic and antihyperlipidemic potential of *Abelmoschus esculentus* (L.) Moench. in streptozotocin-induced diabetic rats. J Pharm Bioallied Sci. 2011;3(3):397.
127. Ademiluyi AO, Oboh G. Aqueous extracts of Roselle (Hibiscus sabdariffa Linn.) varieties inhibit α–amylase and α–glucosidase activities in vitro. J Med Food. 2013;16(1):88–93.
128. Perez C, Dominguez E, Canal J, Campillo J, Torres M. Hypoglycaemic activity of an aqueous extract from Ficus carica (fig tree) leaves in streptozotocin diabetic rats. Pharm Biol. 2000;38(3):181–6.
129. Singab ANB, El-Beshbishy HA, Yonekawa M, Nomura T, Fukai T. Hypoglycemic effect of Egyptian Morus alba root bark extract: effect on diabetes and lipid peroxidation of streptozotocin-induced diabetic rats. J Ethnopharmacol. 2005;100(3):333–8.
130. Lakshmi V, Agarwal S, Ansari JA, Mahdi AA, Srivastava A. Antidiabetic potential of Musa paradisiaca in Streptozotocin-induced diabetic rats. J Phytopharmacol. 2014;3:77–81.
131. Somani R, Singhai A. Hypoglycaemic and antidiabetic activities of seeds of Myristica fragrans in normoglycaemic and alloxan-induced diabetic rats. Asian J Exp Sci. 2008;22(1):95–102.
132. Basak SS, Candan F. Chemical composition and in vitro antioxidant and antidiabetic activities of Eucalyptus camaldulensis Dehnh. Essential oil. J Iran Chem Soc. 2010;7(1):216–26.
133. Jouad H, Maghrani M, Hassani RE, Eddouks M. Hypoglycemic activity of aqueous extract of Eucalyptus globulus in normal and streptozotocin-induced diabetic rats. Int J Geogr Inf Syst. 2004;10(4):19–28.

134. Panjeshahin MR, Azadbakht M, Akbari N. Antidiabetic activity of different extracts of Myrtus communis in streptozotocin induced diabetic rats. Rom J Diabetes Nutr Metab Dis. 2016;23(2):183–90.
135. Tahir HU, Sarfraz RA, Ashraf A, Adil S. Chemical composition and antidiabetic activity of essential oils obtained from two spices (Syzygium aromaticum and Cuminum cyminum). Int J Food Prop. 2016;19(10):2156–64.
136. Medjahed Z, Atman-Kilani D, Fauconnier M-L, Richard G, Atmani D. Hepatoprotective and antidiabetic activities of Fraxinus angustifolia Vahl extracts in animal models: characterization by high performance liquid chromatography analysis. Turk J Med Sci. 2016;46(3):910–20.
137. Eidi A, Eidi M, Darzi R. Antidiabetic effect of Olea europaea L. in normal and diabetic rats. Phytother Res. 2009;23(3):347–50.
138. Bhuvaneswari P, Krishnakumari S. Antihyperglycemic potential of Sesamum indicum (Linn) seeds in streptozotocin induced diabetic rats. Int J Pharm Pharm Sci. 2012;4(1):527–31.
139. Jouad H, Maghrani M, Eddouks M. Hypoglycaemic effect of Rubus fructicosis L. and Globularia alypum L. in normal and streptozotocin-induced diabetic rats. J Ethnopharmacol. 2002;81(3):351–6.
140. Singh SK, Kesari AN, Gupta RK, Jaiswal D, Watal G. Assessment of antidiabetic potential of Cynodon dactylon extract in streptozotocin diabetic rats. J Ethnopharmacol. 2007;114(2):174–9.
141. Minaiyan M, Ghannadi A, Movahedian A, Hakim-Elahi I. Effect of *Hordeum vulgare* L.(Barley) on blood glucose levels of normal and STZ-induced diabetic rats. Res Pharm Sci. 2014;9(3):173.
142. Prasad SV, Natava R, Sirasanagandla S, Rao CA. Anti hyperglycemic and antioxidant effects of Pennisetum glaucum seed extracts in STZ induced diabetic rats. J Pharm Chem. 2012;6(3):36–42.
143. Estrada-Salas PA, Montero-MoráN GM, Martínez-Cuevas PP, GonzáLez C. Barba De La Rosa AP. Characterization of antidiabetic and antihypertensive properties of canary seed (Phalaris canariensis L.) peptides. J Agric Food Chem. 2014;62(2):427–33.
144. Kim J, Park Y. Anti-diabetic effect of sorghum extract on hepatic gluconeogenesis of streptozotocin-induced diabetic rats. Nutr Metab. 2012;9(1):106.
145. Sabiu S, O'neill F, Ashafa A. Kinetics of α-amylase and α-glucosidase inhibitory potential of Zea mays Linnaeus (Poaceae), stigma maydis aqueous extract: an in vitro assessment. J Ethnopharmacol. 2016;183:1–8.
146. Alimohammadi S, Hobbenaghi R, Javanbakht J, Kheradmand D, Mortezaee R, Tavakoli M, et al. Protective and antidiabetic effects of extract from Nigella sativa on blood glucose concentrations against streptozotocin (STZ)-induced diabetic in rats: an experimental study with histopathological evaluation. Diagn Pathol. 2013;8(1):137.
147. Marmouzi I, Kharbach M, El Jemli M, Bouyahya A, Cherrah Y, Bouklouze A, et al. Antidiabetic, dermatoprotective, antioxidant and chemical functionalities in Zizyphus lotus leaves and fruits. Ind Crop Prod. 2019;132:134–9.
148. Mirmohammadlu M, Hosseini SH, Kamalinejad M, Gavgani ME, Noubarani M, Eskandari MR. Hypolipidemic, hepatoprotective and renoprotective effects of *Cydonia oblonga* Mill. fruit in streptozotocin-induced diabetic rats. Iran J Pharm Res. 2015;14(4):1207.
149. Sancheti S, Sancheti S, Seo S-Y. Antidiabetic and antiacetylcholinesterase effects of ethyl acetate fraction of Chaenomeles sinensis (Thouin) Koehne fruits in streptozotocin-induced diabetic rats. Exp Toxicol Pathol. 2013;65(1–2):55–60.
150. Wadood N, Wadood A, Hidayat H, Wahid S. Effect on Eriobotrya japonica on blood glucose levels of normal and alloxan diabetic rabbits. Planta Med. 1988;25:1–6.
151. Raafat K, El-Darra N, Saleh FA, Rajha HN, Maroun RG, Louka N. Infrared-assisted extraction and HPLC-analysis of Prunus armeniaca L. pomace and detoxified-kernel and their antidiabetic effects. Phytochem Anal. 2018;29(2):156–67.
152. Qureshi MN, Numonov S, Abudurexiti A, Aisa HA. Phytochemical investigations and evaluation of antidiabetic potential of Prunus dulcis nuts. LWT Food Sci Technol. 2016;66:311–7.
153. Sah AN, Joshi A, Juyal V, Kumar T. Antidiabetic and hypolipidemic activity of Citrus medica Linn. Seed extract in streptozotocin induced diabetic rats. Pharm J. 2011;3(23):80–4.
154. Oboh G, Ademosun A. Phenolic extracts from grapefruit peels (Citrus paradisi) inhibit key enzymes linked with type 2 diabetes and hypertension. J Food Biochem. 2011;35(6):1703–9.
155. Kumar PRZA, Bhaskar A. Evaluation of antihyperglycaemic and antihyperlipidemic activity of Citrus sinensis peel extract on streptozotocin-induced diabetic rats. Int J Diabetes Dev C. 2015;35(4):448–53.
156. Sharma M, Fernandes J, Ahirwar D, Jain R. Hypoglycemic and hypolipidimic activity of alcoholic extract of Citrus aurantium in normal and alloxan-induced diabetic rats. Pharmacologyonline. 2008;3:161–71.
157. Ahmed OM, Moneim AA, Yazid IA, Mahmoud AM. Antihyperglycemic, antihyperlipidemic and antioxidant effects and the probable mechanisms of action of Ruta graveolens infusion and rutin in nicotinamide-streptozotocin-induced diabetic rats. Diabetol Croat. 2010;39(1):15–35.
158. Farid O, Hebi M, Ajebli M, Hidani AE, Eddouks M. Antidiabetic effect of Ruta montana L. in streptozotocin-induced diabetic rats. J Basic Clin Physiol Pharmacol. 2017;28(3):275–82.
159. Ohiri F, Esimone C, Nwafor S, Okoli C, Ndu O. Hypoglycemic properties of Viscum album (mistletoe) in alloxan-induced diabetic animals. Pharm Biol. 2003;41(3):184–7.
160. Hebi M, Khallouki F, Haidani A, Eddouks M. Aqueous extract of Argania spinosa L. fruits ameliorates diabetes in streptozotocin-induced diabetic rats. Cardiovasc Hematol Agents Med Chem. 2018;16(1):56–65.
161. Kwon YI, Apostolidis E, Shetty K. Evaluation of pepper (Capsicum annuum) for management of diabetes and hypertension. J Food Biochem. 2007;31(3):370–85.
162. Shobha G, Soumya C, Shashidhara K, Moses V. Phytochemical profile, antibacterial and antidiabetic effects of crude aqueous leaf extract of datura stramonium. Pharmacophore. 2014;5(2):273–8.
163. Ademosun A, Oboh G, Adewuni T, Akinyemi A, Olasehinde T. Antioxidative properties and inhibition of key enzymes linked to type-2 diabetes by snake tomato (Tricosanthes cucumerina) and two tomato (Lycopersicon esculentum) varieties. Afr J Pharm Pharmacol. 2013;7(33):2358–65.
164. Kazeem MI, Ogungbe SM, Saibu GM, Aboyade OM. In vitro study on the hypoglycemic potential of Nicotiana tabacum leaf extracts. Bangl J Pharmacol. 2014;9(2):140–5.
165. Poongothai K, Ahmed KSZ, Ponmurugan P, Jayanthi M. Assessment of antidiabetic and antihyperlipidemic potential of Solanum nigrum and Musa paradisiaca in alloxan induced diabetic rats. J Pharm Res. 2010;3(9):2203–5.
166. Gomes A, Vedasiromoni J, Das M, Sharma R, Ganguly D. Anti-hyperglycemic effect of black tea (Camellia sinensis) in rat. J Ethnopharmacol. 1995;45(3):223–6.
167. El Amrani F, Rhallab A, Alaoui T, El Badaoui K, Chakir S. Hypoglycaemic effect of Thymelaea hirsuta in normal and streptozotocin-induced diabetic rats. J Med Plant Res. 2009;3(9):625–9.
168. Bnouham M, Merhfour F-Z, Ziyyat A, Mekhfi H, Aziz M, Legssyer A. Antihyperglycemic activity of the aqueous extract of Urtica dioica. Fitoterapia. 2003;74(7–8):677–81.
169. Kavalalı G, Tuncel H, Göksel S, Hatemi H. Hypoglycemic activity of Urtica pilulifera in streptozotocin-diabetic rats. J Ethnopharmacol. 2003;84(2–3):241–5.
170. Şendoğdu N, Aslan M, Orhan DD, Ergun F, Yeşilada E. Antidiabetic and antioxidant effects of Vitis vinifera L. leaves in streptozotocin-diabetic rats. Turkish J Pharm Sci. 2006;3(1):7–18.
171. Al-Amin ZM, Thomson M, Al-Qattan KK, Peltonen-Shalaby R, Ali M. Anti-diabetic and hypolipidaemic properties of ginger (Zingiber officinale) in streptozotocin-induced diabetic rats. Br J Nutr. 2006;96(4):660–6.
172. Aher R, Belge S, Kadam S, Kharade S, Misal A, Yeole P. Therapeutic importance of fenugreek (*Trigonella foenum-graecum* L.): a review. J Plant Sci Res. 2016;3(1):149.
173. Shashikumar J, Champawat P, Mudgal V, Jain S, Deepak S, Mahesh K. A review: food, medicinal and nutraceutical properties of fenugreek (Trigonella Foenum-Graecum L.). Int J Chem Stud. 2018;6(2):1239–45.
174. Wani SA, Kumar P. Fenugreek: a review on its nutraceutical properties and utilization in various food products. J Saudi Soc Agric Sci. 2018;17(2):97–106.
175. Goyal S, Gupta N, Chatterjee S. Investigating therapeutic potential of Trigonella foenum-graecum L. as our defense mechanism against several human diseases. J Toxicol. 2016;2016:1–10.
176. Zameer S, Najmi AK, Vohora D, Akhtar M. A review on therapeutic potentials of Trigonella foenum graecum (fenugreek) and its chemical constituents in neurological disorders: complementary roles to its hypolipidemic, hypoglycemic, and antioxidant potential. Nutr Neurosci. 2018;21(8):539–45.
177. Xue WL, Li XS, Zhang J, Liu YH, Wang ZL, Zhang RJ. Effect of Trigonella foenum-graecum (fenugreek) extract on blood glucose, blood lipid and hemorheological properties in streptozotocin-induced diabetic rats. Asia Pac J Clin Nutr. 2007;16(S1):422–6.
178. Abdelatif AM, Ibrahim MY, Mahmoud AS. Antidiabetic effects of fenugreek (Trigonella foenum-graecum) seeds in the domestic rabbit (Oryctolagus cuniculus). Res J Med Plant. 2012;6(6):449–55.

179. Khlifi S, Ben Jemaa H, Ben Hmad H, Abaza H, Karmous I, Abid A, et al. Antioxidant, antidiabetic and antihyperlipidemic effects of Trigonella foenum-graecum seeds. Int J Pharmacol. 2016;12:394–400.
180. Puri D, Prabhu K, Murthy P. Mechanism of action of a hypoglycemic principle isolated from fenugreek seeds. Indian J Physiol Pharmacol. 2002; 46(4):457–62.
181. Bertella A, Benlahcen K, Abouamama S, Pinto DC, Maamar K, Kihal M, et al. Artemisia herba-alba Asso. Essential oil antibacterial activity and acute toxicity. Ind Crop Prod. 2018;116:137–43.
182. Nedjimi B, Zemmiri H. Salinity effects on germination of Artemisia herba–alba Asso: important pastoral shrub from north African rangelands. Rangel Ecol Manag. 2019;72(1):189–94.
183. Hamad HM. Evaluation of Allelopathic Potential of Artemisia herba-alba on Germination and Seedling Growth of Raphanus sativus and Trigonella foenum-graecum. Asian J Biol. 2019;8(1):1–7.
184. Laadraoui J, Aboufatima R, El Gabbas Z, Ferehan H, Bezza K, Laaradia MA, et al. Effect of Artemisia herba-alba consumption during pregnancy on fertility, morphological and behaviors of mice offspring. J Ethnopharmacol. 2018;226:105–10.
185. Yashphe J, Segal R, Breuer A, Erdreich-Naftali G. Antibacterial activity of Artemisia herba-alba. J Pharm Sci. 1979;68(7):924–5.
186. Hatimi S, Boudouma M, Bichichi M, Chaib N, Idrissi NG. Evaluation in vitro de l'activité antileishmanienne d'Artemisia herba-alba Asso. Bull Soc Pathol Exot. 2001;94:29–31.
187. Mighri H, Hajlaoui H, Akrout A, Najjaa H, Neffati M. Antimicrobial and antioxidant activities of Artemisia herba-alba essential oil cultivated in Tunisian arid zone. C R Chim. 2010;13(3):380–6.
188. Yashphe J, Feuerstein I, Barel S, Segal R. The antibacterial and antispasmodic activity of Artemisia herba alba Asso. II. Examination of essential oils from various chemotypes. Int J Crude Drug Res. 1987;25(2):89–96.
189. Dob T, Benabdelkader T. Chemical composition of the essential oil of Artemisia herba-alba Asso grown in Algeria. J Essent Oil Res. 2006;18(6):685–90.
190. Hudaib MM, Aburjai TA. Composition of the essential oil from Artemisia herba-alba grown in Jordan. J Essent Oil Res. 2006;18(3):301–4.
191. Feuerstein I, Danin A, Segal R. Constitution of the essential oil from an Artemisia herba-alba population of Spain. Phytochemistry. 1988;27(2):433–4.
192. Salido S, Valenzuela LR, Altarejos J, Nogueras M, Sánchez A, Cano E. Composition and infraspecific variability of Artemisia herba-alba from southern Spain. Biochem Syst Ecol. 2004;32(3):265–77.
193. Awad NE, Seida AA, Shaffie Z, El-Aziz AMA, Awad N. Hypoglycemic activity of Artemisia herba-alba (Asso.) used in Egyptian traditional medicine as hypoglycemic remedy. J Appl Pharm Sci. 2012;2(03):30–9.
194. Hamza N, Berke B, Cheze C, Le Garrec R, Lassalle R, Agli A-N, et al. Treatment of high fat diet induced type 2 diabetes in C57BL/6J mice by two medicinal plants used in traditional treatment of diabetes in the east of Algeria. J Ethnopharmacol. 2011;133(2):931–3.
195. Sharma N, Ahirwar D, Jhade D, Gupta S. Medicinal and phamacological potential of nigella sativa: a review. Ethnobot Leafl. 2009;2009(7):11.
196. Tembhurne S, Feroz S, More B, Sakarkar D. A review on therapeutic potential of Nigella sativa (kalonji) seeds. J Med Plant Res. 2014;8(3):167–77.
197. Mollazadeh H, Hosseinzadeh H. The protective effect of Nigella sativa against liver injury: a review. Iran J Basic Med Sci. 2014;17(12):958.
198. Ali B, Blunden G. Pharmacological and toxicological properties of Nigella sativa. Phytother Res. 2003;17(4):299–305.
199. Ahmad A, Husain A, Mujeeb M, Khan SA, Najmi AK, Siddique NA, et al. A review on therapeutic potential of Nigella sativa: a miracle herb. Asian Pac J Trop Biomed. 2013;3(5):337–52.
200. Kooti W, Hasanzadeh-Noohi Z, Sharafi-Ahvazi N, Asadi-Samani M, Ashtary-Larky D. Phytochemistry, pharmacology, and therapeutic uses of black seed (Nigella sativa). Chin J Nat Med. 2016;14(10):732–45.
201. Houcher Z, Boudiaf K, Benboubetra M, Houcher B. Effects of methanolic extract and commercial oil of Nigella sativa L. on blood glucose and antioxidant capacity in alloxan-induced diabetic rats. Pteridines. 2007;18(1):8–18.
202. Al-Hader A, Aqel M, Hasan Z. Hypoglycemic effects of the volatile oil of Nigella sativa seeds. Int J Pharmacogn. 1993;31(2):96–100.
203. Guo Z, Jia X, Zheng Z, Lu X, Zheng Y, Zheng B, et al. Chemical composition and nutritional function of olive (Olea europaea L.): a review. Phytochem Rev. 2018;17(5):1091–110.
204. Hashmi MA, Khan A, Hanif M, Farooq U, Perveen S. Traditional uses, phytochemistry, and pharmacology of Olea europaea (olive). Evid Based Complement Alternat Med. 2015;2015:1–29.
205. Özcan MM, Matthäus B. A review: benefit and bioactive properties of olive (Olea europaea L.) leaves. Eur Food Res Technol. 2017;243(1):89–99.
206. Şahin S, Bilgin M. Olive tree (Olea europaea L.) leaf as a waste by-product of table olive and olive oil industry: a review. J Sci Food Agric. 2018;98(4): 1271–9.
207. Sato H, Genet C, Strehle A, Thomas C, Lobstein A, Wagner A, et al. Anti-hyperglycemic activity of a TGR5 agonist isolated from Olea europaea. Biochem Biophys Res Commun. 2007;362(4):793–8.
208. El-Amin M, Virk P, Elobeid M, Almarhoon ZM, Hassan ZK, Omer SA, et al. Anti-diabetic effect of Murraya koenigii (L) and Olea europaea (L) leaf extracts on streptozotocin induced diabetic rats. Pak J Pharm Sci. 2013;26(2): 359–65.
209. Wainstein J, Ganz T, Boaz M, Bar Dayan Y, Dolev E, Kerem Z, et al. Olive leaf extract as a hypoglycemic agent in both human diabetic subjects and in rats. J Med Food. 2012;15(7):605–10.
210. Kaeidi A, Esmaeili-Mahani S, Sheibani V, Abbasnejad M, Rasoulian B, Hajializadeh Z, et al. Olive (Olea europaea L.) leaf extract attenuates early diabetic neuropathic pain through prevention of high glucose-induced apoptosis: in vitro and in vivo studies. J Ethnopharmacol. 2011;136(1):188–96.
211. Al-Attar AM, Alsalmi FA. Effect of Olea europaea leaves extract on streptozotocin induced diabetes in male albino rats. Saudi J Biol Sci. 2017; 26(1):118–28.
212. Choudhury M, Mostofa M, Awal M. Antidiabetic effects of *Azadirachta indica*, Trigonella foenumgraecum, Olea europea and Glibenclamide in experimentally diabetic induced rat. J Bangladesh Agric Univ. 2005;3(452-2018-3844):277–82.
213. Sangi SMA, Sulaiman MI, El-Wahab MFA, Ahmedani EI, Ali SS. Antihyperglycemic effect of thymoquinone and oleuropein, on streptozotocin-induced diabetes mellitus in experimental animals. Pharmacogn Mag. 2015;11(Suppl 2):S251.
214. Afify A, El-Beltagi HS, Fayed SA, El-Ansary AE. Hypoglycemic and iron status ameliorative effects of Olea europea CV.'Picual'leaves extract in streptozotocin induced diabetic rats. Fresenius Environ Bull. 2017;26:6898–908.
215. Al-Azzawie HF, Alhamdani MS. Hypoglycemic and antioxidant effect of oleuropein in alloxan-diabetic rabbits. Life Sci. 2006;78(12):1371–7.
216. Jemai H, El Feki A, Sayadi S. Antidiabetic and antioxidant effects of hydroxytyrosol and oleuropein from olive leaves in alloxan-diabetic rats. J Agric Food Chem. 2009;57(19):8798–804.
217. Qadir NM, Ali KA, Qader SW. Antidiabetic effect of oleuropein from olea europaea leaf against alloxan induced type 1 diabetic in rats. Braz Arch Biol Technol. 2016;59:1–10.
218. Benhabyles N, Arab K, Bouchenak O, Baz A. Phytochemical screening, hypoglycemic and antihyperglycemic effect of flavonoids from the leaves of Algerian Olea europaea L. in normal and alloxan-induced diabetic rats. Int J Pharm. 2015;11:477–83.
219. Gonzalez M, Zarzuelo A, Gamez M, Utrilla M, Jimenez J, Osuna I. Hypoglycemic activity of olive leaf. Planta Med. 1992;58(06):513–5.
220. Hadrich F, Bouallagui Z, Junkyu H, Isoda H, Sayadi S. The α-glucosidase and α-amylase enzyme inhibitory of hydroxytyrosol and oleuropein. J Oleo Sci. 2015;64(8):835–43.
221. Khlif I, Hamden K, Damak M, Allouche N. A new triterpene from Olea europea stem with antidiabetic activity. Chem Nat Compd. 2012;48(5):799–802.
222. Marrelli M, Amodeo V, Statti G, Conforti F. Biological properties and bioactive components of *Allium cepa* L.: Focus on potential benefits in the treatment of obesity and related comorbidities. Molecules. 2019;24(1):119.
223. Etana MB, Aga MC, Fufa BO. Major onion (Allium cepa L.) production challenges in Ethiopia: a review. J Biol Agric Healthc. 2019;9(7):42–7.
224. Teshika JD, Zakariyyah AM, Zaynab T, Zengin G, Rengasamy KR, Pandian SK, et al. Traditional and modern uses of onion bulb (*Allium cepa* L.): a systematic review. Crit Rev Food Sci Nutr. 2019;59(sup1):S39–70.
225. Kumar KS, Bhowmik D, Chiranjib B, Tiwari P. Allium cepa: a traditional medicinal herb and its health benefits. J Chem Pharm Res. 2010;2(1):283–91.
226. Prakash D, Singh BN, Upadhyay G. Antioxidant and free radical scavenging activities of phenols from onion (Allium cepa). Food Chem. 2007;102(4): 1389–93.
227. Vian MA, Fabiano-Tixier A-S, Elmaataoui M, Dangles O, Chemat F. A remarkable influence of microwave extraction: enhancement of antioxidant activity of extracted onion varieties. Food Chem. 2011;127(4):1472–80.
228. Zhang SL, Peng D, Xu YC, Lü SW, Wang JJ. Quantification and analysis of anthocyanin and flavonoids compositions, and antioxidant activities in onions with three different colors. J Integr Agric. 2016;15(9):2175–81.

229. Pérez-Gregorio RM, García-Falcón MS, Simal-Gándara J, Rodrigues AS, Almeida DP. Identification and quantification of flavonoids in traditional cultivars of red and white onions at harvest. J Food Compos Anal. 2010; 23(6):592–8.
230. Griffiths G, Trueman L, Crowther T, Thomas B, Smith B. Onions—a global benefit to health. Phytother Res. 2002;16(7):603–15.
231. El-Demerdash F, Yousef M, El-Naga NA. Biochemical study on the hypoglycemic effects of onion and garlic in alloxan-induced diabetic rats. Food Chem Toxicol. 2005;43(1):57–63.
232. Kumari K, Augusti K. Antidiabetic and antioxidant effects of S-methyl cysteine sulfoxide isolated from onions (Allium cepa Linn) as compared to standard drugs in alloxan diabetic rats. Indian J Exp Biol. 2002;40(9):1005–9.
233. El-Soud N, Khalil M. Antioxidative effects of Allium cepa essential oil in streptozotocin induced diabetic rats. Maced J Med Sci. 2010;3(4):344–51.
234. Bahammou Y, Tagnamas Z, Lamharrar A, Idlimam A. Thin-layer solar drying characteristics of Moroccan horehound leaves (*Marrubium vulgare* L.) under natural and forced convection solar drying. Sol Energy. 2019;188:958–69.
235. Zawiślak G. The chemical composition of the essential oil of Marrubium vulgare L. from Poland. Farm. 2012;60(2):287–92.
236. Bokaeian M, Saboori E, Saeidi S, Niazi AA, Amini-Borojeni N, Khaje H, et al. Phytochem anal, antibacterial activity of Marrubium vulgare L against Staphylococcus aureus in vitro. Zahedan J Res Med Sci. 2014;16(10):60–4.
237. Paula De Oliveira A, Santin JR, Lemos M, Klein Júnior LC, Couto AG, Meyre Da Silva Bittencourt C, et al. Gastroprotective activity of methanol extract and marrubiin obtained from leaves of *Marrubium vulgare* L.(Lamiaceae). J Pharm Pharmacol. 2011;63(9):1230–7.
238. Amri B, Martino E, Vitulo F, Corana F, Kaâb LB-B, Rui M, et al. *Marrubium vulgare* L. Leave extract: Phytochemical composition, antioxidant and wound healing properties. Molecules. 2017;22(11):1851.
239. Boudjelal A, Henchiri C, Siracusa L, Sari M, Ruberto G. Compositional analysis and in vivo anti-diabetic activity of wild Algerian Marrubium vulgare L. infusion. Fitoterapia. 2012;83(2):286–92.
240. Vergara-Galicia J, Aguirre-Crespo F, Tun-Suarez A, Aguirre-Crespo A, Estrada-Carrillo M, Jaimes-Huerta I, et al. Acute hypoglycemic effect of ethanolic extracts from Marrubium vulgare. Phytopharm. 2012;3(1):54–60.

Publisher's Note