Medicinal Plants Used in Four Local Government Areas of Southwestern Nigeria for the Management of Diabetes and Its Comorbidities: An Ethnobotanical Survey

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Research

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Abstract

Background: Diabetes mellitus (DM) continues to pose a major global health threat with serious economic burden in sub-Saharan Africa, especially Nigeria. This condition is often worsened with accompanying comorbidities, further putting a strain on patient wellbeing. Medicinal plants are not only effective in DM, but some of them are also have beneficial effects on accompanying disease states. Such plants may be appropriate alternatives or adjuncts to available antidiabetic medications. This study aimed at accessing and documenting the medicinal plants used in four local government of southwestern Nigeria for the management of diabetes and its comorbidities.

Methods: Semi-structured questionnaires were used to obtain information from traditional medical practitioners, village elders and herb sellers. The data obtained were analyzed and discussed in relation to previously published literature. Fifty-three respondents mostly males (77.4%) provided information on medicinal plants useful for the management of diabetes and its comorbidities.

Results:A total of 77 medicinal plants belonging to 76 genera in 44 plant families were mentioned in the survey. In particular, 53 medicinal plants are mentioned for managing diabetes, 35 for hypertension, 28 for stroke, 17 for heart diseases and 25 for obesity. The most frequently cited plant family was Leguminosae (12%), followed by Euphorbiaceae (8%). The frequently used plant species includes*Vernonia amygdalina, Citrus aurantifolia*, *Viscum album*, *Carica papaya*, *Allium sativum*. It is interesting to note that only *Citrus aurantifolia*was mentioned severally for the management of the five ailments. The herbal recipes, methods of herbal preparation and administration were also recorded.

Conclusions: The survey shows that a significant number ofmedicinal plants are used for the management of diabetes and its comorbidities in the study area. These plants, apart from their hypoglycemic activity, may be useful against the most common complications of DM and may provide strategies for the development of less expensive therapies especially in low income communities.

Introduction

Medicinal plants have been used for several centuries for the treatment of various ailments and almost seventy thousand species of plant in the world have been screened for their pharmacological activities (1). The importance of the tropical rain forest as a source of raw materials for modern drug development cannot be overemphasized as about 11% of the 252 drugs considered to be essential drugs are exclusively of plant origin with several others synthesised using natural products template (2). In Nigeria, medicinal plants play prominent role in healthcare delivery as many of her residents, especially those dwelling in the rural areas, rely greatly on medicinal plants and visit traditional medical practitioners (TMPs) for their health care need (3). An earlier study reported that the ratio of TMPs to the population was 1:110, while the ratio of medical doctors to the population was 1:16,400; inferring that TMPs are more accessible to the populace (4). Therefore, herbal medicines continue to play vital role in healthcare delivery, especially in third world nations, where most people have great financial constraints with little or no access to orthodox therapies (3).

Diabetes mellitus (DM), a chronic metabolic disorder associated with abnormally high levels of glucose in the blood, affects approximately 8.3% of the adult world population and the number of suffers is expected to rise from 382 million in 2013 to 592 million in 2035 (5, 6). There has been an increasing incidence of DM worldwide and this ailment has been shown to pose major health threats and socioeconomic burdens (7). Of the DM sufferers, 22 million reside in sub-Saharan Africa, with Nigeria, the most populous black nation in the world, accounting for a fifth of all diabetes cases in the region (8).

Comorbidity, defined as a situation where one or more chronic ailments occurs in an individual with an index-disease is a common phenomenon amongst DM sufferers (9). In fact, DM has been reported to be a major predisposing factor to the formation of myocardial infarction, cerebrovascular accident and peripheral vascular diseases (10). Common diabetic related comorbidities include obesity, hypertension, chronic kidney diseases, cardiovascular diseases, hyperlipidemia, retinopathy, nephropathy and diabetic foot ulcers (11, 12). A recent study conducted in the US between July 2014 and June 2015 revealed that approximately 98% of DM patients had at least one comorbid condition, while about 89% had at least two (13).

The debilitating impact of DM comorbidities on patients' health status cannot be underestimated. Comorbidities can drain the financial resources of DM sufferers thereby increasing their out-of-pocket cost for medical care which eventually hinders the ability of the patient to manage their ailments (14, 15). In view of this, there is a need to explore alternative means, such as natural sources like medicinal plants, to discover bioactive molecules which may help tackle the menace caused by DM and its related comorbidities. The documentation of indigenous knowledge (IK) has helped in identifying promising medicinal plants; The IK of traditional healers is an asset in the discovery of medicinal plants with therapeutic potentials (16). Several ethnomedical studies on plants used in the management of diabetes have been reported in various parts of the world (17–20), In Nigeria, similar researches have been carried out (21–24) regions. However, only few researches have investigated the usage of medicinal plants in the treatment of DM along with its other co-morbidities of. Therefore, this study was carried out to document the various medicinal plants and herbal recipes used in the treatment of DM and its comorbidities and to establish existing relationships between the different recipes for the various diseases with the aim identifying plants that can serve as appropriate alternatives or adjuncts to available antidiabetic medications

Materials And Methods

Study area

The study was carried out in four local government areas (LGAs) namely: Ibadan (urban; Ibadan North LGA), Ago-Are (rural; Atisbo LGA), Ikare-Akoko (urban; Akoko North-East LGA) and Oba-Akoko (rural; Akoko South East LGA). The study area (Fig. 1) lies in Oyo and Ondo states of south western Nigeria (Fig. 1). Oyo state lies between latitude 8°.12' N and longitude 3° 42' E and covers an area of approximately 28,454 km^2 with a population of 110,792 (25), while Ondo state lies between latitude 6° 90' N and longitude 4° 89' E with a land mass of 15,500 km^2 and a population of 3, 440,000 as at the 2006 national census (25). The inhabitants of the urban settlers in the study area were mainly educated and involved in high skill jobs, while the rural dwellers were predominately farmers and local traders. The common language spoken by the residents of the study area is Yoruba. The study area has a tropical climate characterised by two distinct weather conditions; rainy season which begins in April and ends in September and the dry season which runs from October to March. The area experiences a relatively high rainfall and humidity for most parts of the year with an average temperature around 32 °C.

Ethnobotanical Survey

Informed consent

At the start of the interview, the objective of the study was clearly explained to the intending participants and informed consent to publish the research was sought orally. When the respondents granted consent, the questions contained in the questionnaire were asked and when consent was not given, the individuals were asked no further question.

Plants authentication

Medicinal plants used for the management of hypertension and its co-morbidities were collected with the aid of the TMP and authenticated by comparison with voucher specimens at the Forest Herbarium, Forestry Research Institute of Nigeria, Ibadan. The names of the plants were verified at the plant database website (www.theplantlist.org; accessed on September 22, 2018).

Data collection

The study was conducted carried out from May to October, 2014. The ethnomedicinal information of plants used for the management of DM and its comorbidities such as hypertension, obesity, stroke and heart disease were obtained by consulting TMPs, herb sellers and elders in the communities listed above. The use of semi-structured questionnaire via oral interview in the local dialect of the respondents was adopted to obtain the relevant data. Since the interviewer understood the local dialect of the respondents, no interpreter was used in this survey. The questionnaire was divided into three sections. Section 1 deals with demographic information such as age, sex, religion, local tribe, duration of practice, nationality and level of education. Section 2 captures plants used in the treatment of DM and its comorbidities and consisted questions such as frequency of treatment, accompanying side effects and duration of treatment. Section 3 centered on plant parts used, plant availability, local names of diseases, preparation of the recipe and mode of administration of the herbal recipe used in the treatment of diabetes and its comorbidities. Each plant sample was collected at the time of the survey. The botanical names and families of each collected plant samples were authenticated at the Forest Herbarium Ibadan (FHI), Nigeria.

Data analysis

The Microsoft Office Excel spreadsheet (2016) software was used to conduct descriptive statistical analysis on the socio-demographic data of the respondents, plant part used and plant families. The use-mentions index (UMi) was also calculated and was taken as the frequency of usage of a particular plant for the treatment of diseases divided by the total number of respondents interviewed.

Results And Discussion

Demographic data and treatment practice of respondents

Seventy individuals, including TMPs, herb sellers and village elders, who possess knowledge on the ethnomedicinal use of plants and/or had utilised them for DM and/or its comorbidities in the study area were identified and interviewed. However, only 53 respondents agreed to provide their valuable IK. The demographic information of the respondents is summarized in Table 1. As can be seen from the table, the majority of the

respondents were male (77.36%), a finding similar to other results obtained from several other ethnobotanical studies within the same region (3, 24, 26, 27). This may be unconnected to the cultural perception that the male gender is the heirloom of family heritage making them to easily acquire IK. In addition, it is perceived that the exhaustive and often dangerous practices associated with traditional medicine as exemplified with the collection of medicinal plant from the wild where many wild animals reside may also discourage many female individuals from embracing the practice. Most of the respondents (69.8%) were Muslims and more than half of the respondents were elderly. Inheritance was the major source of knowledge acquisition as the results presented in Table 1 revealed that 54.7% of the respondents inherited their knowledge from their parents/ancestors, while only 15.1% obtained their IK through training. In view of this, it is expedient to document the use of medicinal plant in the treatment of various ailments as this will go a long way in the preservation of IK. Majority of the respondents had the basic (primary) level of education (66%) with only four of them having no formal education.

Table 1
Demographic data of respondents (n = 53)

Parameter	Frequency	Percentage (%)
Specialty	16	30.19
Traditional medical practitioner	14	26.42
Herb seller	23	43.39
Traditional healers		
Sex	41	77.36
Male	12	22.64
Female		
Age (years)	19	35.85
31–50	27	50.94
51–60	7	13.21
>60		
Educational level	4	7.55
None	30	66.04
Primary	13	24.53
Secondary	1	1.89
Tertiary		
Religion	14	26.42
Christianity	37	69.81
Islam	2	3.77
Traditionalist		
Source of knowledge acquisition	29	54.72
Ancestral (Inherited)	8	15.09
Training	16	30.19
Ancestral and Training		

In view of the nature of the practice, the respondents commonly referred to DM as *'itosuga'* and claimed they were able to diagnose DM in their patients by examining the presence of sugar in urine which is detected when ants surround the spots of their clients' urine few minutes after urination. Other symptoms that also aided them in the diagnosis of DM included excessive urination, sweating and loss of weight. The respondents referred to hypertension as *'ifunpa giga'* and claimed that they normally relied on the laboratory results presented by their patients to diagnose the disease. Stroke, referred to as '*roparose*' by the respondents was diagnosed by observing the patient for partial paralysis of a side of the body or the complete paralysis of the body along with impaired speech or vision. For obesity (*isanraju*), respondents diagnosed the disease by visually observing the fatness of their patients relative to other individuals of the same age and sex.The respondents could not actually differentiate between being overweight and obeseas they claimed the herbal treatments, they prepared were administered to individuals who desired to reduce their body weight, not necessarily obese patients. Heart disease (*arunokan*) is diagnosed by the respondents when patients have

symptoms such as persistent irregular heartbeats, shortness of breath and dizziness. The respondents claimed to have successfully treated many patients suffering from these ailments using the various medicinal plant recipes.

Diversity of medicinal plants, herbal preparation and administration

In the Nigerian ethnomedicine, medicinal plants have been frequently used in the management of human degenerative ailments such as DM and its comorbidities. Medicinal plants have wide patronage due to their accessibility, potency and affordability. There have been several reports of successful treatment of various disease conditions with herbal therapy (28-31). In the present study, 77 medicinal plants belonging to76 genera in 44 plant families were used by the respondents in the management of DM and its co-morbidities. In particular, 53 medicinal plants were used for the management of DM, 35 for hypertension, 28 for stroke, 17 for heart diseases and 25 for obesity (Table 2). The plants mentioned in this survey were readily available as they were easily obtained from the forest, around homes and in the market places.

Table 2
List of plants used for the management of diabetes and its co-morbidities in the study area

S/N	Family	Plant Name (Voucher specimen no)	Common Name	Local Name (Y)	Part Used	Therapeutic Use					UMi
						D	HTN	S	HD	O	
1.		Acanthaceae	*Acanthus montanus* (Nees) T. Anderson (FHI 106492)	Mountain thistle	Ahon-ekun	l			X		0.019
2.		Amaryllidaceae	*Allium cepa* L. (FHI 107561)	Onion	Alubosa	bu, l		X		X	X	0.075
3.		Amaryllidaceae	*Allium sativum* L. (FHI 107576)	Garlic	Ayuu	bu	X	X		X	X	0.132
4.		Anacardiaceae	*Anacardium occidentale* L. (FHI 109858)	Cashew	Kaju	s	X					0.038
5.		Anacardiaceae	*Mangifera indica* L. (FHI 109451)	Mango tree	Mangoro	l, s	X				X	0.038
6.		Anacardiaceae	*Spondias mombin* L. (FHI 106132)	Hog plum	Iyeye	s	X					0.019
7.		Annonaceae	*Uvaria afzelii* G.F. Scott-Elliot (FHI 107332)	Monkey finger	Gbogbonise	s					X	0.019
8.		Annonaceae	*Xylopia aethiopica* (Dunal) A. Rich. (FHI 10897)	Ethiopian pepper	Eru	s, f	X	X		X	X	0.113
9.		Apocynaceae	*Alstonia boonei* De Wild. (FHI 107254)	Cheese wood	Ahun	s, f				X	X	0.038
10.		Apocynaceae	*Holarrhena floribunda* (G. Don) T. Durand & Schinz (FHI 110053)	False rubber tree	Dagba	l		X				0.019
11.		Apocynaceae	*Picralima nitida* (Stapf) T. Durand & H. Durand (FHI 108794)	Akaumma plant	Abere	s	X	X		X		0.019
12.		Apocynaceae	*Rauvolfia vomitoria* Afzel. (FHI 108987)	Swizzle stick	Asofeyeje	s, r	X	X			X	0.094
13.		Apocynaceae	*Parquetina nigrescens* (Afzel.) Bullock (FHI 110044)	African Parquentina	Ogbo	l	X	X				0.075
14.		Araceae	*Anchomanes difformis* (Blume) Engl. (FHI 109585)		Aburushoko	l, t	X	X				0.057
15.		Bignoniaceae	*Kigelia africana* (Lam.) Benth. (FHI 107654)	Sausage tree	Pandoro	f	X	X	X		X	0.094
16.		Bignoniaceae	*Newbouldia laevis* (P. Beauv.) Seem. (FHI 107753)	Fertility tree	Akoko	l, s, r	X		X		X	0.094

Key: ae = aerial part; bu = bulb, f = fruits; l = leaves; rhi = rhizome; r = root; s = stem bark; t = tuber

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S/N	Family	Plant Name (Voucher specimen no)	Common Name	Local Name (Y)	Part Used	Therapeutic Use					UMi
						D	HTN	S	HD	O	
17.		Bombacaceae	*Adansonia digitata* L. (FHI 109806)	Baobab	Ose	f		X	X		0.038
18.		Boraginaceae	*Heliotropium indicum* L. (FHI 110156)	Indian heloitrope	Apari Igun	ae	X	X	X		0.057
19.		Bromeliaceae	*Ananas comosus* (L.) Merr. (FHI 107515)	Pineapple	Ope oyinbo	f	X	X			0.057
20.		Caricaceae	*Carica papaya* L. (FHI 109462)	Pawpaw	Ibepe	l, r	X	X	X	X	0.151
21.		Combretaceae	*Anogeissus leiocarpa* (DC.) Guill. & Perr. (FHI 107122)	Axle wood tree	Ayin	r			X	X	0.038
22.		Compositae	*Acanthospermum hispidum* DC. (FHI 110050)	Goat's head	Dagunro gogoro	ae	X	X			0.038
23.		Compositae	*Ageratum conyzoides* (L.) L. (FHI 109634)	Goat's weed	Imi-esu	l	X	X			0.057
24.		Compositae	*Tithonia diversifolia* (Hemsl.) A. Gray (FHI 108055)	Mexican sunflower	Sepeleba	l	X		X		0.038
25.		Compositae	*Vernonia amygdalina* Delile (FHI 109061)	Bitter leaf	Ewuro	l	X	X	X	X	0.208
26.		Convolvulaceae	*Ipomoea asarifolia* (Desr.) Roem. & Schult. (FHI 110052)	Morning glory	Gboroayaba	l		X		X	0.057
27.		Crassulaceae	*Bryophyllum pinnatum* (Lam.) Oken (FHI 107762)	Wonder plant	Odundun	l	X	X			0.113
28.		Cucurbitaceae	*Lagenaria breviflora* (Benth.) Roberty (FHI 109040)	Bottle gourd	Tagiri	s				X	0.057
29.		Cucurbitaceae	*Momordica charantia* L. (FHI 109638)	African cucumber	Ejinrin	l, s	X			X	0.075
30.		Euphorbiaceae	*Alchornea laxiflora* (Benth.) Pax & K. Hoffm. (FHI 110155)	Lowved bead-string	Pepe	l		X	X		0.038
31.		Euphorbiaceae	*Bridelia ferruginea* Benth. (FHI 109985)	Bridelia plant	Irasa	l, s	X				0.038
32.		Euphorbiaceae	*Croton gratissimus* Burch. (FHI 109041)	Lavender croton	Ajeobale	r		X		X	0.038
33.		Euphorbiaceae	*Euphorbia poissonii* Pax (FHI 109035)	Cactus	Oro Adete	s			X	X	0.057

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						D	HTN	S	HD	O	
34.		Euphorbiaceae	*Jatropha curcas* L. (FHI 109020)	Nettlespurge	Lapalapa	l	X		X		0.057
35.		Euphorbiaceae	*Macaranga barteri* Müll. Arg. (FHI 107230)	Macaranga plant	Agbasa	r	X				0.019
36.		Gentianaceae	*Anthocleista djalonensis* A. Chev. (FHI 109007)	Cabbage tree	Sapo	r, s	X			X	0.075
37.		Hypoxidaceae	*Curculigo pilosa* (Schumach. & Thonn.) Engl. (FHI 109047)	English African Crocus	Epakun	rhi				X	0.094
38.		Lamiaceae	*Ocimum gratissimum* L. (FHI 108057)	Tea bush	Efinrin	l	X		X		0.113
39.		Lamiaceae	*Solenostemon monostachyus* (P. Beauv.) Briq. (FHI 108913)	Painted nettle	Olojonguru	ae				X	0.038
40.		Lauraceae	*Persea americana* Mill. (FHI 109444)	Avocado tree	Igba	l		X	X		0.094
41.		Leguminosae	*Abrus precatorius* L. (FHI 107452)	Cat's eye	Ominsinmisi	l	X			X	0.057
42.		Leguminosae	*Acacia nilotica* (L.) Delile (FHI 108425)	Prickly acacia	Boonii	s	X	X			0.057
43.		Leguminosae	*Baphia nitida* Lodd. (FHI 106544)	Camwood	Irosun	l		X			0.019
44.		Leguminosae	*Cassia fistula* L. (FHI 110261)	Purging cassia	Aidantoro	s			X		X	0.057
45.		Leguminosae	*Dialium guineense* Willd. (FHI 109509)	Velvet tamarind	Irede	s, l			X			0.038
46.		Leguminosae	*Parkia biglobosa* (Jacq.) G. Don (FHI 107939)	African locust beans	Igi iru	s	X	X			0.094
47.		Leguminosae	*Piliostigma thonningii* (Schum.) Milne-Redh. (FHI 107815)	Camel's foot	Abafe	l			X		0.019
48.		Leguminosae	*Senna alata* (L.) Roxb. (FHI 108062)	Candle bush	Asunwon	l	X				0.038
49.		Leguminosae	*Tetrapleura tetraptera* (Schum. & Thonn.) Taub. (FHI 110141)	Aidan tree	Aidan	f		X		X	0.095
50.		Malvaceae	*Gossypium barbadense* L. (FHI 107327)	Cotton plant	Owu	l, s	X				X	0.038

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51.		Malvaceae	*Hibiscus sabdariffa* L. (FHI 107622)	Roselle	Isapa	f	X				X	0.075
52.		Meliaceae	*Azadirachta indica* L. (FHI 109461)	Neem tree	Dongoyaro	l	X					0.038
53.		Mimosaseae	*Mimosa pudica* L. (FHI 100332)	Sensitive plant	Patanmo	l	X					0.038
54.		Moraceae	*Artocarpus altilis* (Parkinson ex F. A. Zorn) Fosberg (FHI 110483)	Breadfruit	Gberebuutu/Epa Oyinbo	l	X		X			0.038
55.		Moraceae	*Ficus exasperata* Vahl (FHI 109453)	Fig tree	Epin	l		X		X		0.057
56.		Musaceae	*Musa paradisiaca* L. (FHI 110122)	Banana	Ogede agbagba	f	X		X			0.095
57.		Myrtaceae	*Psidium guajava* L. (FHI 109454)	Guava tree	Gurofa	s, l	X	X				
58.		Olacaceae	*Olax subscorpioides* Oliv. (FHI 109065)	Stink ant forest	Ifon	l, s	X				X	0.057
59.		Orchidaceae	*Calyptrochilum christyanum* (Rchb. f.) Summerh. (FHI 110054)	Calyptrochilum plant	Ela	l	X					0.038
60.		Phyllanthaceae	*Phyllanthus amarus* Schumach. & Thonn. (FHI 109059)	Black catnip	Eyin olobe	l, t	X	X				0.057
61.		Piperaceae	*Piper guineense* Schumach. & Thonn. (FHI 110051)	West African pepper	Iyere	f			X	X		0.057
62.		Poaceae	*Bambusa vulgaris* Schrad. (FHI 109052)	Bamboo	Oparun	l	X		X			0.038
63.		Poaceae	*Zea mays* L. (FHI 109082)	Maize	Agbado	l				X		0.038
64.		Polygalaceae	*Securidaca longipedunculata* Fresen. (FHI 109972)	Violet tree	Ipeta	s, r	X	X				0.057
65.		Rubiaceae	*Morinda lucida* Benth. (FHI 106992)	Brime stone tree	Oruwo	l	X					0.075
66.		Rubiaceae	*Nauclea diderrichii* (De Wild.) Merr. (FHI 110049)	Leichhardt tree	Egbesi	s	X		X			0.113
67.		Rutaceae	*Citrus aurantifolia* (Christm.) Swingle (FHI 110009)	Lime	Osanwewe	f	X	X	X	X	X	0.170

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68.		Santalaceae	*Viscum album* L. (FHI 108411)	Mistletoe	Afomo	l	X	X			X	0.151
69.		Sapindaceae	*Lecaniodiscus cupanioides* Planch. ex Benth. (FHI 110081)	Lecaniodiscus	Akika	s	X		X			0.038
70.		Sapotaceae	*Vitellaria paradoxa* C. F. Gaertn. (FHI 107924)	Shea butter	Ori	s				X	X	0.057
71.		Solanaceae	*Datura metel* L. (FHI 106922)	Thorn apple	Gegemu	l	X		X			0.075
72.		Solanaceae	*Solanum erianthum* D. Don (FHI 106923)	Potato tree	Asimau	l, r	X		X	X		0.095
73.		Talinaceae	*Talinum triangular* (Jacq.) Willd. (FHI 109932)	Water leaf	Egbure	ae	X	X				0.057
74.		Ulmaceae	*Trema orientalis* (L.) Blume (FHI 107813)	Pigeon wood	Afefe	l, s	X		X			0.057
75.		Xanthorrhoeaceae	*Aloe vera* (L.) Burm. f. (FHI 108024)	Aloe	Ahon-erin	l	X	X				0.113
76.		Zingiberaceae	*Aframomum melegueta* K. Schum. (FHI 109986)	Alligator pepper	Atare	f	X		X			0.075
77.		Zingiberaceae	*Zingiber officinale* Roscoe (FHI 107935)	Ginger	Atale	rhi	X	X		X	X	0.113
Key: ae = aerial part; bu = bulb, f = fruits; l = leaves; rhi = rhizome; r = root; s = stem bark; t = tuber												
D = Diabetes; HTN = Hypertension; S = Stroke; HD = Hyperlipidemia; O = Obesity												

Of the plant species encountered in the study for the treatment of various ailments, trees constituted 45% of the plant population, while shrubs, herbs and climbers contributed 33%, 18% and 4%, respectively. The analysis of the plant parts used in this study revealed that the predominant plant part was dominated by leaves (43%), followed by stem (27%) and fruit (10%) (Figure 2). Similar occurrences were recorded in previous ethnobotanical studies in several parts of Nigeria (3, 24, 32-34). This could be connected to the relative availability of leaves for most part of the year and its collection posing the least threat to biodiversity conservation. The most frequently cited plant family was Leguminosae (12%), followed by Euphorbiaceae (8%), Apocynaceae (6%), Compositae (5%) and Anacardiaceae (4%), with the remaining plant families having percentage occurrence less than 3% (Table 2).

The recipes obtained from the respondents were found to be poly-herbals as they believe it is a more holistic method of managing the illness and they claimed it is more potent than the use of individual plant species. Previous studies have revealed that the combination of several plant species in traditional medicine offers synergistic approach to the management of the ailment as each plant will contribute different quota to the therapeutic efficacy of the recipes (35, 36). In this study, twenty-three, nineteen, eleven, ten and seven herbal remedies were mentioned for the treatment of diabetes, hypertension, stroke, heart diseases and obesity, respectively (Supplementary material). Various methods employed for the preparation of the herbal recipes were encountered in this study including decoction (43%), juice (22%), infusion (20%), powder (9%) and paste (6%). The powdered preparations were used when mixed with hot pap, while decoctions and infusions were usually made with water or pap water. The pap water and hot pap were obtained by soaking dried corn in water for three to four days to soften it after which it was ground to form a smooth paste. To get rid of corn shaft that may be contained in the paste, it is sieved and made to stand for three days. The supernatant is called pap water, whereas hot pap was obtained by boiling the sediment in hot water. The liquid preparations were administered using a cup or table spoon, whereas the pastes were applied externally on the affected part.

Data obtained from this study revealed that *Vernonia amygdalina*Delile was the most frequently used plant with a user mention index (UMi) of 0.208. Other commonly used medicinal plants included *Citrus aurantifolia*(Christm.) Swingle (UMi 0.170), *Viscum album* L. (UMi 0.151), *Carica papaya* L. (UMi 0.151), *Allium sativum* L. (UMi 0.132), *Bryophyllumpinnatum*(Lam.) Oken. (UMi 0.113), *Xylopia aethiopica* (Dunal) A. Rich. (UMi 0.113), *Ocimumgratissimum* L. (UMi 0.113), *Naucleadiderrichii*(De Wild.) Merr. (UMi 0.113), *Aloe vera*(L.) Burm. f. (UMi 0.113) and *Zingiber officinale*Roscoe (UMi 0.113). Amongst the plant species, *Citrus aurantifolia*was the only plant mentioned by several respondents for the management of the five ailments. *Allium sativum,Xylopia aethiopica* and *Zingiber officinale*were used for the treatment of all the ailments with the exception of stroke, while *Carica papaya*, *Vernonia amygdalina* and *Kigeliaafricana*(Lam.) Benth were used for the management of DM, hypertension, stroke and obesity (Table 2). With the exception of *Anacardium occidentale*L., *Spondiasmombin* L., *Brideliaferruginea* Benth, *Macaranga barteri*Müll. Arg., *Senna alata*(L.) Roxb., *Calyptrochilumchristyanum* (Rchb. f.) and *Morinda lucida* Benth., all the plant species that were used for the management of DM were also used in the treatment of one or more of its co-morbidities. This finding may suggest that those recipes used for the management of diabetes can as well manage any of its co-morbidities if administered to individuals suffering from any of the ailment. This can also provide relief from the adverse effects of polypharmacy associated with the use of synthetic drugs that is often experienced by sufferers of DM with accompanying comorbidities.

Brief literature review of some of the identified plants used for the management of diabetes and its comorbidities

Many of the plant species encountered in this research have been investigated for their use in the management of DM and related medical ailments and this may provide support for their use in the study area. A brief description of the antidiabetic potentials and usage in the management of other cardiovascular diseases of some of the frequently mentioned plants is provided below.

Aframomummelegueta(family: Zingiberaceae), commonly referred to as Alligator pepper or grain of paradise, is a tropical plant widely cultivated in many African nations for its edible spicy fruits (37). 6-gingerol and oleanolic acid isolated from the fruits of *A. melegueta* showed strong inhibition of the activity of α-amylase and α-glucosidase, when compared to the standard antidiabetic drug, acarbose, and the antidiabetic effect of the fruits of *A. melegueta*could be attributed to these compounds (38). The administration of the seeds of *A. melegueta*produced significant reduction in several cardiovascular parameters including the systolic blood pressure and mean arterial pressure (MAP) in normotensive and hypertensive human population (39). Adefegha et al reported that the inclusion of *A. melegueta*seeds in the diet of hypercholesterolemic rats for 30 days significantly reduced the MAP, attenuated hepatotoxicity and elicited antihypercholesterolemic effect suggesting the plant may have therapeutic usefulness in the management of hypertension and obesity (40). In a similar research, the seeds of *A. melegueta*ameliorated the increment in serum triacylglycerol, low-density lipoprotein (LDL) cholesterol and total cholesterol as well as the decrease in the activities of superoxide dismutase, glutathione peroxidase and glutathione reductase caused by the administration of Triton X-100 in hyperlipidemic rats (41).

Allium sativum (garlic) is an important functional food and dietary supplement in many parts of the world.. In particular, there is a wide assumption that they confer protective effect on the heart and prevent several cardiovascular diseases and this has been validated scientifically in several literature (42-45). Garlic significantly reduced the blood glucose levels of STZ-induced diabetic rats as well as attenuated the progression of diabetic structural nephropathy that was observed in non-treated diabetic rats (43), while another similar research reported that the extract markedly reduces the serum levels of triglycerides, creatinine, total cholesterol and LDL-cholesterol (46).

Bryophyllumpinnatum(family: Crassulaceae), commonly referred to as resurrection plant, is a herbaceous plant native to Madagascar but with widespread use in many parts of the world. Several researches have shown that the chronic administration of the aqueous extract of *B. pinnatum* produced hypoglycemic effect in STZ-induced diabetic rats as well as elicited a significant reduction in the serum cholesterol and triglyceride levels (47-49). In a recent study, *B. pinnatum*reduced lipid peroxidation in heart and liver and exerted antihypercholesterolemia in rabbits(50).

Decoctions and infusions obtained from the morphological parts of *Carica papaya*have been used traditionally in the management of several ailments including cancer, DTN, diarrhea, inflammation and infectious diseases (51). In an early human study, there was an increase in the serum insulin levels of type 2 diabetic patients that took 602 g of *C. papaya* fruit; a nutritional dose that is equivalent to 50 g of carbohydrate (52). The administration of the methanol extract of *C. papaya* leaves to Wistar rats at a twice daily dose of 100 mg/kg bw displayed remarkable antihypertensive effect as it reduced the plasma angiotensin converting enzyme (ACE) activity and cardiac hypertrophy at levels similar to the positive control, enalapril (53). Other studies showed that the root extract of the plant reduces the MAP of rats in a renovascular model of hypertension (54).

Citrus aurantifolia is a small tree used in African traditional medicine for the management of anorexia, obesity, malaria, DTN and cancer and cough (3, 55). Administration of the *C. aurantifolia*juice in rats with high cholesterol diet intake significantly reduced the levels of LDL and total cholesterol, while causing an increment in the plasma HDL cholesterol levels. In the same study, the juice of the plant inhibited the activity of ACE in a dose dependent manner and also exerted potent antioxidant potential in various *in vitro* antioxidant assays including DPPH and nitric oxide scavenging assays (56). In a 45-day study, the simultaneous administration of the essential oils of *C. aurantifolia*with ketotifen significantly reduced the consumption of food and caused drastic weight loss in experimental mice (57).

Persea americana, a tree of about 20 m and indigenous to South Central Mexico, is used in traditional medicine for the treatment of hypertension (58), DTN (59), renal diseases (60) and obesity (61). Phenolic compounds including protocatechuic acid, kaempferide and vanillic acid present in the methanol extract of the seeds of *P. americana* were thought to be responsible for the significant reduction in the LDL and total cholesterol levels of mice on high hyperlipidemic diet (62). An earlier study revealed that methanol extract of the leaves of *P. americana* induced a transient reduction in MAP in anaesthetized normotensive rats (63), while another *in vivo* study demonstrated that the extract displayed significant vasorelaxant effect on isolated thoracic rat aorta (64). The chronic administration (28 days) of the hydroethanolic extract of *P. americana* in STZ-induced diabetic rats decreased the blood glucose levels and enhanced the metabolic activity of the experimental animals; an effect probably due to the activation of the protein kinase B enzymatic pathway (65).

Vernonia amygdalina (Asteraceae), a shrub indigenous to tropical Africa, is probably the most widely used member of the *Vernonia* genus for medicinal purpose. Several researches have documented the use of *V. amygdalina*in the management of DTN and vascular diseases. The aqueous extract (80 mg/kg) of the leaves of *V. amygdalina*was shown to induce a dose-dependent blood sugar lowering effects in alloxan-induced diabetic rabbits (66), while the chronic administration of its ethanolic extract (400 mg/kg) was reported to elicit a hypoglycemic effect as well as induce the expression of Glut 4 receptors in STZ-induced diabetic rats. In a study demonstrating the lipid lowering effects of the methanolic extract of *V. amygdalina*conducted in rats fed with high cholesterol diet, *V. amygdalina*at a dose of 200 mg/kg induced 49% dose-dependent decrease in LDL cholesterol, while it increased the levels of HDL by 59%. In addition, the extract significantly decreased the levels of plasma and post mitochondrial fraction lipid peroxidation by 42% and 45%, respectively (67).

Viscum album (Loranthaceae), commonly referred to as African mistletoe, is used for the management of abdominal discomfort, anxiety, DTN, epilepsy, hypertension and stroke (68). Nkanuand co-workers reported that the crude extract of *V. album* at a dose of 150 mg/kg bw significantly reduced the blood glucose and MAP of diabetic and hypertensive rats by about 84.2% and 34.5%, respectively (69). The methanol extract of *V. album* exerted anti-diabetic and anti-hyperlipidemic effects in STZ-induced diabetic rats by decreasing the fasting blood glucose level by 34% and significantly reducing the levels of serum triglycerides, lactate dehydrogenase and LDL cholesterol, following a chronic administration (21 days) of the extract at a dose of 100 mg/kg bw(70).

Xylopiaaethiopica'sfruits and seeds are used for culinary purposes in many regions of Africa (71). In a recent study, dietary supplementation of hypercholesterolemic rats with Ethiopian pepper fruits significantly reduced the plasma ACE and total cholesterol levels, as well as reversed the elevated serum levels of alanine aminotransferase and aspartate transaminase caused by the high cholesterol diet. Phenolic compounds including rutin, quercetin and ellagic acid were accounted to be responsible for the observed antihypertensive and hypolipidemic properties (72). Administration of a 50:50 mixture of *Alstoniacongensis*bark and *Xylopia aethiopica* fruits had a significant hypoglycemic effect in normoglycemic rats (73), while the chronic administration of a herbal mixture (Okudiabet®), which contains *X. aethiopica* as one of its principal constituents, markedly reduced the blood glucose levels in alloxan-induced diabetic rats (74).

Zingiber officinale (ginger) has a long historical use in traditional medicine in various culture and has been scientifically validated for the treatment of several diseases including DTN, hypertension and other cardiovascular ailments (75). The ethanolic extract of ginger significantly lowered the several serum lipid parameters such as total cholesterol, triglycerides and LDL-cholesterol and also protected the pancreas and liver from lipid peroxidation in STZ-induced diabetic rats (76, 77). Administration of the ethanolic extract of *Z. officinale*rhizomes produced a dose-dependent reduction in blood glucose levels in normoglycemic and STZ-induced diabetic rats (75), while another study revealed that a single administration of ginger juice attenuated 5-hydroxytryptamine induced hyperglycaemia in diabetic rats (78). Several *in vitro* studies have reported the inhibitory activity of *Z. officinale*on AA-induced platelet aggregation, COX-derived thromboxanes and prostaglandin synthesis (79-81).

Conclusion

To summarize our findings, we present in this report the inventory of medicinal plants in four local government areas of southwestern Nigeria used for the management of DTN and its comorbidities. A total of 77 medicinal plants belonging to 76 genera in 44 plant families were mentioned by the respondents. In particular, 53 medicinal plants were used for the management of DTN, 35 for hypertension, 28 for stroke, 17 for heart diseases and 25 for obesity. The most frequently cited plant family was Leguminosae (12%), followed by Euphorbiaceae (8%), Apocynaceae (6%), Compositae (5%) and Anacardiaceae (4%) with the remaining plant families having percentage occurrence less than 3%.. While only *Citrus aurantifolia*was mentioned by several respondents for the management of the five ailments, review of literature has confirmed the multiple effect of some of the key plants on diabetes and it's commorbidities. As most of the respondents encountered in this study belong to the elderly population, this documentation will serve a great deal in preserving the indigenous traditional knowledge of the local communities.Since most diabetic patients often have one or more accompanying comorbidities, a safe and efficacious herbal preparation that can manage both diabetes and its comorbidities may provide scientific breakthrough especially for the local communities.

Declarations

Ethics approval and consent to participate.

Informed consent was obtained from each participant according to the guideline of Research Ethics Committee of the University of Ibadan. A copy of the form used is available upon request.

Consent for publication

Not applicable in this study

Availability of data and materials

All data generated or analysed during this study are included in this published article (and its supplementary information files).

Competing interests

The authors declare that they have no competing interests

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Authors Contribution

OOO and LOS conceived and designed the work. The interview was conducted by LOS under the supervision and guidance of OOO. Literature search and data analysis were done by LOS and PAS. The first draft of the manuscript was written by LOS and carefully revised by PAS. All authors agreed on the final draft of the manuscript.

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Abbreviations

ACE, angiotensin-I converting enzyme; ADL, adenosine diphosphate; BW, body weight; DM, diabetes mellitus; FHI, forest herbarium Ibadan; HDL, high-density lipoprotein; IK, indigenous knowledge; LDL, low-density lipoprotein; LGAs, local government areas; MAP, mean arterial pressure; STZ, streptozotocin; TMPs, traditional medical practitioners; UMi, use-mentions index; WHO, world health organization

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Figures

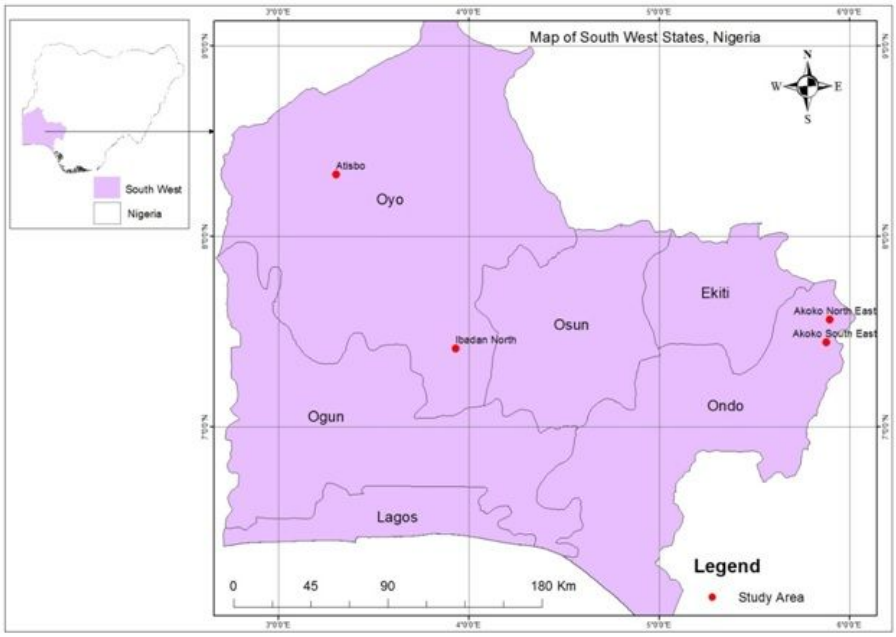

Figure 1

Map of southwestern Nigeria showing the study area

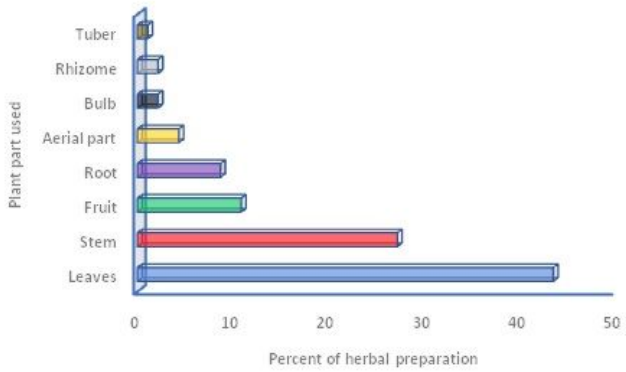

Figure 2

Medicinal plant parts used in the preparation of various remedies for the treatment of diabetes and its co-morbidities in four local government areas in southwestern Nigeria.

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