Journal of Medicinal Herbs
journal homepage:**www.jhd.iaushk.ac.ir**

Ethno-medicinal practices in the treatment of diabetic foot ulcers in Kano state, north-western Nigeria

Sakina Buhari Sani[*1], Bala Sidi Aliyu[2], Muhammad Hayatu[2], Musa Aliyu[3], Abdullahi Balarabe Nazifi[3], Yusuf Nuhu[2]

[1]*Department of Biology, Kano University of Science and Technology, Wudil, Kano, Nigeria;*
Email:** ***sakinasanibuhari@yahoo.com

[2]*Department of Plant Biology, Bayero University, Kano, Nigeria;*
[3]*Department of Pharmacology and Therapeutics, Bayero University, Kano, Nigeria;*

ARTICLE INFO

Type: *Original Research*
Topic: *Medicinal Plants*
Received *February 20th2021*
Accepted *June 23th2021*

Key words:
- ✓ *Diabetic foot ulcer*
- ✓ *Ethno-medicine*
- ✓ *Herbalists*
- ✓ *Medicinal plants*
- ✓ *Kano state*

ABSTRACT

Background & Aim: Diabetic foot ulceration is a severe complication of diabetes mellitus that results in considerable ill health, financial burden and mortality. Many people in Nigeria utilize medicinal plants to treat diabetic foot ulcer and related complications, nonetheless, the utilization of such plants has not been acknowledged. This study was done to validate and document the medicinal plants used in the remedy of diabetic foot ulcer in Kano State, Nigeria.

Experimental: The target group of the study were herbalists and diabetic foot ulcer patients. The ethnobotanical information was obtained from willing respondents through an oral interview and a semi-structured questionnaire.

Results: A total of 300 respondents were consulted in this study, and they exposed the utilization of 36 medicinal plants against diabetic foot ulcer. The frequently used plant families were Fabaceae and Rhamnaceae. Stem bark and leaves were the commonly reported plant parts used. The methods of preparation are usually by decoction or pounding the plant parts into powder; and the preparations are administered via topical (51%), oral (27%) and topical/oral (19%) routes. Moringa oleifera, Anisopus manni and Cadaba farinosa were the first three frequently cited species, while *Ficus glumosa*, *Anogeissus leiocarpus*, *Guiera senegalensis* were among the most preferred medicinal plants. Approximately 92% have been reported to be pharmacologically active, while 36% have similar ethno-medical claims in certain regions of the world.

Recommended applications/industries: This study revealed the ethno-medicinal practices against diabetic foot ulcer in Kano State. Scientific validation of the efficacy and safety of these plants would assist towards development of better drugs and integrating some of the species into orthodox medicine.

1. Introduction

Diabetes mellitus (DM) is an assembly of metabolic disorders depicted by hyperglycaemia and a key reason of morbidity and mortality worldwide (Everett and Mathioudakis, 2018). According to the International Diabetes Federation (IDF), 19 million individuals aged between 20 and 79 years are diabetic, with approximately 3.7 million death from the disease in 2019, and about 2.7 million cases identified in Nigeria (IDF, 2019). The persistent hyperglycemia associated with unregulated DM causes widespread vascular damage targeting the kidneys, nerves, heart and eyes; thus making DM one of the global chief cause of cardiovascular disease, renal failure, lower limb amputation and blindness (Gezawa *et al.*, 2019; IDF, 2019).

Diabetic foot ulceration is a serious and life threatening complication of DM and accounts for significant ill health, mortality and healthcare expenses (Nongmaithem *et al*., 2016; Everett and Mathioudakis, 2018; Alosaimi *et al*., 2019). It is estimated that 25% of people living with DM are likely to be affected with foot ulcer in their lifetimes (IDF, 2019). Nigeria has the highest burden of DM in the sub-Saharan Africa and is reported to have 10% prevalence of diabetic foot ulceration (Gezawa *et al*., 2019), with a lower limb amputation rate of 35.4% (Ugwu *et al*., 2019). Diabetic patients with foot abscess are at high risk for major complications such as slow wound healing, infection and gangrene which may lead to amputation (Walsh *et al*., 2016; Everett and Mathioudakis, 2018). Furthermore, the cost of handling diabetic foot ulcers is enormous; studies have shown that it accounts for one-third of diabetes-associated expenses, thus making it one of the expensive diabetes complications to manage (Alosaimi *et al*., 2019). Due to some of these related problems, many people in developing countries resort to alternative source of remedy especially herbal medicines. The availability of medicinal plants and ample experience on wound healing is another reason for many people in Nigeria and other developing countries to utilize medicinal plants in the remedy of diabetic foot ulcers and related problems (Abubakar *et al*., 2018; Oguntibeju, 2019).

Ethno-medicine (also referred to as traditional, alternative or complementary medicine) is the oldest form of healthcare system worldwide and is used in the prevention and treatment of physical and mental illnesses within local and regional healing practices (Yuan *et al*., 2016). It incorporates the use of substances (animals, plants and mineral elements), dosages and practices based on socio-cultural customs, beliefs, skills and observation of specific group largely herbalists and traditional therapists (WHO, 2013). The practice of ethno-medicine in Nigeria is also well established (Kankara *et al*., 2015; Shinkafi *et al*., 2015). Available data have shown that natural products including medicinal plants are highly effective against diabetic foot ulcers and associated problems (Lau *et al*., 2009; Delshad *et al*., 2017; Oguntibeju, 2019). Indeed, medicinal plants were shown to have immense capacity for facilitating wound healing, controlling of infection, reducing the period of hospitalization as well as the number of lower limb amputations associated with diabetic foot ulcers (Tiwary *et al*., 2011; Lakshmi *et al*., 2016; Oguntibeju, 2019). Even though individuals have been using medicinal plants to cure diabetic foot ulcers in Kano state for a long time, their application has not been documented. The knowledge and practice of ethno-medicine is mostly passed down from peers to peers verbally (Inngjerdinge *et al*., 2004; Kankara *et al*., 2015); this may pose a negative effect on native knowledge because it may vanish over time. Thus, documentation of the ethno-medical practices will provide not only significant data on the plants used against diabetic foot ulcers but also relevant reference point information that may facilitate their conservation. Furthermore, such information are starting points for drug discovery and pharmacological studies of new drug leads. This study therefore, aimed to explore the ethno-medical practices in the treatment of diabetic foot ulcers in Kano state, Nigeria.

2. Materials and Methods

2.1. Study area

The study was carried out in Kano State metropolis which is located between latitudes 11°52′0′N and 12°7′0′N and longitudes 8°23′30′E and 8°38′0′E. It is the largest urban area in north-western Nigeria (Figure 1). The metropolitan area consists of eight Local Government Areas (Dala, Fagge, Gwale, Kumbotso, Municipal, Nassarawa, Tarauni and Ungogo) out of the 44 Local Governments that make up Kano State. Most of the people living in this area belong to the Hausa ethnic group.

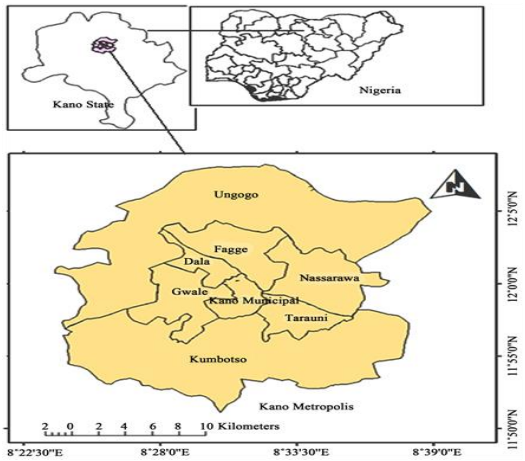

Figure 1: Study area; Dala, Fagge, Gwale, Kumbotso, Municipal, Nassarawa, Tarauni and Ungogo Local Governments of Kano State, Nigeria (Source: www.scirp.org).

2.2. Study groups

Kano metropolis has a high number of traditional herbalists who provide health care services. The herbalists and the diabetic foot ulcer patients form the target groups of the population for the ethnobotanical survey. A cross-sectional suvey and systematic random sampling was used to select the target groups.

2.3. Identification of target groups

Locations of knowledgeable herbalists from the study area were identified by local administrators. Murtala Muhammed Specialists Hospital was selected as the study area for the identification of diabetic foot ulcer patients.

2.4. Informed consent/ ethical approval

Unwritten informed consent was gotten from the respondents to participate in the research prior to the interview (Tugume *et al*., 2016). The permission to conduct this research at Murtala Muhammed Specialists Hospital in order to get information from diabetic foot ulcer patients was acquired from Ministry of Health/Hospital Management Board of Kano State with a reference number MMSHZ/0324/III/167.

2.5. Ethnobotanical survey

The survey was conducted out between July and December, 2017 through semi-structured interviews in Hausa language. Semi-structured questionnaire which was written both in English and the state native language was also administered to document the data given by the respondents. The questionnaire consisted of demographic data, knowledge of diabetes and information of the plants used which includes local plant names, plant part use, methods of preparation and mode of administration. Certain incentives were given to some of the traditional herbalists to stimulate their participation in the research. Indeed, studies in Africa have turned to rewarding the respondents for their information and time (Gbolade, 2009).

2.6. Plant identification and validation

Samples of plants identified in the course of the survey were collected along the line. The specimens were identified and validated by a taxonomist in the Herbarium section of Department of Biological Sciences, Bayero University, Kano, and Department of Botany, Ahmadu Bello University, Zaria, where voucher specimens were deposited. The plant names were further validated in the plant list (www.theplantlist.org).

2.7. Literature survey

Additional information on medicinal plants used in the treatment of diabetic foot ulcer was acquired from available journal articles. The authenticity of data obtained from the respondents was assessed based on related ethno-medical claims or proof of phytochemical or pharmacological studies in the literature.

2.8. Data analysis

The socio-demographic data of the respondents were subjected to descriptive statistical analysis such as frequencies and percentages. Data on the ethno-botanical survey were analyzed using the Relative Frequency of Citation (RFC) and preference ranking.

2.8.1. Relative frequency of citation

The RFC reveals the relative significance of the species. For each species, the RFC was determined using the relationship: RFC=NC/TI×100 (Tardıo and Pardo-de-Santayana, 2008), where NC is the number of citation of the plant and TI is the total number of informants

2.8.2. Preference ranking

Fifteen (15) most frequently used plants for the treatment of diabetic foot ulcer in this study based on RFC were subjected to preference ranking using the method described by Martin, (1995) and Tugume *et al.* (2016). The plants were mentioned to ten key informants (knowledgeable herbalists) for ranking according to effectiveness of the species. The values allocated for each species by the informants were aggregated to get the whole rank value. The plant species were positioned in descending order with the species that had the highest total number ranked first.

3. Results and discussion

Traditional form of medicine forms an integral part of peoples' culture since time immemorial and has played a significant role in the treatment of human diseases (Burton *et al*., 2015). This encompasses the entire knowledge, expertise and tradition that are based on the philosophies and experiences native to diverse cultures which are used to preserve health as well as to prevent, diagnose, improve, or treat physical and

mental illness (WHO, 2013). A good knowledge of traditional medicine that involves the use of medicinal plants is known among the people of northern Nigeria (Shinkafi *et al*., 2015). Certainly, various studies have also reported the use of medicinal plants in the treatment of various human ailments including DM by the inhabitants of Kano State (Danbatta and Aliyu, 2011; Abubakar *et al*., 2017; Ali *et al*., 2017; Negbenebor *et al*., 2017). Diabetic foot ulceration, a common and severe complication of DM is also managed by herbal medical practitioners in Kano using different forms of herbal remedies; and the efficacy of such remedies are widely acclaimed by people in the community. This study reported the ethno-medical practices used in the treatment of diabetic foot ulcers in Kano metropolis. It also highlighted the important medicinal plants most cited and preferred for the treatment of the disease. This may possibly promote conservation of the important indigenous medicinal plants and also serve as a step forward towards discovering new lead drugs against the disease.

A total of 300 respondents were interviewed across the Local Government Areas of Kano metropolis. These include herbalists (67%) and diabetic foot ulcer patients (33%). The herbalists constituted of males (44%) and females (22%). Most of the herbalists (25%) were between the age of 41-50 years followed by ages between 51 years and above (22%) (Table 1).

Table 1. Socio-demographic information of the respondents

Parameter	Respondents	Specification	N (%)
Size	Herbalist	-	200 (67)
	DFUP	-	100 (33)
Category	Herbalist	Divulge information	142 (47)
		Refused to divulge	58 (19)
	DFUP	Used known herb	62 (21)
		Used unknown herb	20 (7)
		Don't use	18 (6)
Gender	Herbalist	Males	133 (44)
		Females	67 (22)
	DFUP	Males	56 (19)
		Females	44 (15)
Age (years)	Herbalist	20-30	8 (3)
		31-40	50 (17)
		41-50	74 (25)
		51-above	68 (22)
	DFUP	20-30	0(0)
		31-40	10 (3)
		41-50	35 (12)
		51- above	55 (18)

N = number of respondent, DFUP = diabetic foot ulcer patient

Of the diabetic foot ulcer patients interviewed, 15% were females and 19% were males. Also, 18% of the foot ulcers were found in diabetic patients aged between 51 years and above while 12% in age range of 41-50 years (Table 1). During the interview, 68% of the respondents (47% herbalists that divulge information plus 21% diabetic foot ulcer patients that use known herbs) gave clear knowledge about the plants used in the remedy of diabetic foot ulcer. Respondents that did not give clear information about the medicinal plants were excluded from further studies and only their demographic data was obtained. The socio-demographic information of the respondents showed that majority of the herbalists in Kano metropolis are above 40 years of age and some of them did not divulge information on their ethno-medical practices even with a reward. This shows that as time passes by, important information on their ethno-medical practices may be lost following the departure of the older age groups. The herbalists that divulged information about the medicinal plants used against diabetic foot ulcers were able to give clinical presentation of diabetes mellitus and diabetic foot ulcers from their responses. They considered that increased urination, increased thirst, fatigue and slow wound healing are the major indications for the treatment of the disease .

A total of thirty six plant species were identified and their RFCs ranged from 0.5 to 14.7%. The highest RFC was that of Moringa oleifera (14.7%), followed by Anisopus mannii (12.3%) and Cadaba farinosa (10.3%) (Table 2). The RFC is applied to pick out potential species requiring further studies and recommendation in drug development. The index also validates the rate of recurrence of citation of a medicinal plant species

used for different ailments. In this study, Moringa oleifera had the highest RFC followed by Anisopus mannii, Cadaba farinosa, Guiera senegalensis and Leptadenia hastata. The antidiabetic potentials of Moringa oleifera has been widely reported (Muhammad *et al.*, 2016) and it has been shown to accelerate wound healing through augmentation of cell proliferation and repositioning of normal dermal fibroblast cells (Gothai *et al.*, 2016). In addition, Moringa oleifera inhibits bacterial infections associated with diabetic foot ulcers (Fouad *et al.*, 2019). Similarly, the wound healing activities of Anisopus mannii and Cadaba farinosa have been reported (Telrandhe and Uplanchiwar, 2013).

Table 2. Plant species used in the treatment of diabetic foot ulcers in Kano state and their frequency of citation.

Botanical name	NC	RFC
Acacia nilotica (L.) Delile	14	6.9
Albizzia chevalieri Harms	10	4.9
Allium cepa L.	2	1.0
Allium sativum L.	1	0.5
Anisopus mannii N.E.Br.	25	12.3
Anogeissus leiocarpus (DC.) Guill. & Perr.	19	9.3
Artemisia annua L.	17	8.3
Balanites aegyptiaca (L.) Delile	10	4.9
Borassus aethiopum Mart.	5	2.5
Boswellia dalzielii Hutch.	16	7.8
Byrsocarpus coccineus Schum. & Thonn.	2	1.0
Cadaba farinosa Forssk.	21	10.3
Cassia singueana Oliv.	17	8.3
Cassia tora L.	4	2.0
Chamaecrista mimosoides (L.) Greene	6	2.9
Dichrostachys cinerea (L.) Wight & Arn.	5	2.5
Eucalyptus camaldulensis Dehnh.	2	1.0
Ficus glumosa Delile	14	6.9
Guiera senegalensis J.F. Gmel.	20	9.8
Ipomoea asarifolia (Desr.) Roem.& Schult	1	0.5
Jatropha curcas L.	4	2.0
Lamium purpureum L.	1	0.5
Lannea microcarpa Engl. & K. Krause	16	7.8
Leptadenia hastata (Pers.) Decne	20	9.8
Momordica balsamina L.	1	0.5
Moringa oleifera Lam.	30	14.7
Nymphaea lotus L.	1	0.5
Parkia biglobosa (Jacq.) G. Don	5	2.5
Piliostigma reticulatum (DC.) Hochst	11	5.4
Prosopis africana (Guil & Perr) Taub.	8	3.9
Senna occidentalis (L.) Link	2	1
Strychnos spinosa Lam.	2	1
Syzygium aromaticum (L.) Merr. & L.M. Perry	3	1.5
Ziziphus mauritiana Var.	12	5.9
Ziziphus mucronata Willd.	1	0.5
Ziziphus spina-christi (L.) Desf.	6	2.9

NC = Number of citation, RFC = Relative frequency of citation

Detailed report on the plants used for diabetic foot ulcers in the study area is presented in Table 3. The table displayed the plant species, their families, local names, parts used, methods of preparation and administration. A sum of 36 medicinal plant species representing 21 families and 32 genera were reported to be used in the treatment of diabetic foot ulcer in Kano metropolis (Table 3).

The family Fabaceae had the highest number of species (10) followed by Rhamnaceae (3). Alliaceae, Combretaceae, Asclepiadaceae and Myrtaceae had two species each (Figure 2). The Fabaceae (Leguminosae) family is the third-largest land plant family with 751 genera and approximately 19,000 species. This was followed by the Rhamnaceae family which has 55 genera and about 950 species (Christenhusz and Byng, 2016). These families contain important secondary metabolites (like alkaloids, flavonoids, saponins and tannins) which act individually or synergistically to facilitate blood clotting, combat infections and promote wound healing processes (Thakur *et al.*, 2011). Alkaloids and their congeners are used for their analgesic, anti-inflammatory and antibacterial properties (Mahibalan *et al.*, 2016). Flavonoids are important compounds with biological actions including antimicrobial, anti-inflammatory, antioxidant, anti-proliferative, antiviral and wound healing activity (de Albuquerque *et al.*, 2016). Tannins possess astringent properties which facilitate the healing of inflamed tissues and wounds (Su *et al.*, 2017; Salihu *et al.*, 2018).

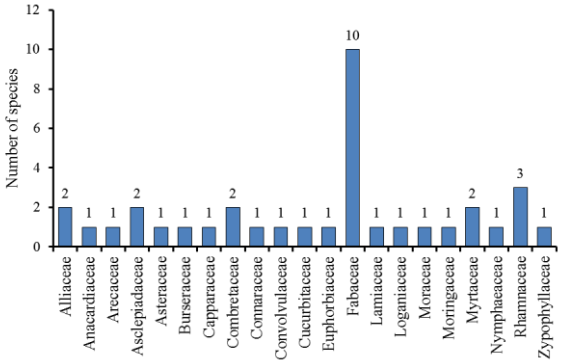

Figure 2. Distribution of plant families used for the treatment diabetic foot ulcer in Kano state, Nigeria.

Among the plant parts used, the leaves account for the highest proportion (47%) followed by stem bark (25%), roots (12%), fruits (6%), bulbs (4%), seeds (4%) and pods (2%) (Figure 3).

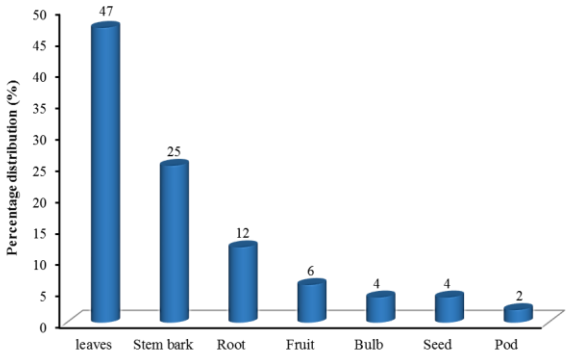

Figure 3: Plant parts used for the treatment diabetic foot ulcer in Kano state, Nigeria.

Various plant parts have values in the preparation of remedies for diabetic foot ulcers, and the leaves account for the highest proportion of the parts used followed by stem bark. This is in line with other reports that revealed the leaves as the most frequently used plant material for wound healing and treatment of leg ulcers (Inngjerdinge *et al*., 2004; Nwafor *et al*., 2018). Various ethnobotanical studies in Kano state and other parts of Nigeria also showed that leaves and stem bark were the frequently used plant parts in traditional medicine (Abubakar *et al*., 2017; Ali *et al*., 2017; Fingesi *et al*., 2018). The use of leaves and stems may be attributed to their accessibility and abundance of bioactive compounds which are known to be accountable for the activity of medicinal plants.

The plants investigated are used either freshly or after shade drying. The recipes for diabetic foot ulcers include decoctions, macerates, powders, ashes and oils. The survey showed that decoction (44.7%) was the commonly used method of preparation followed by powder (31.6%), maceration (10.5%), pounding (8%), ashing (2.6%) and oil (2.6%) (Figure 4).

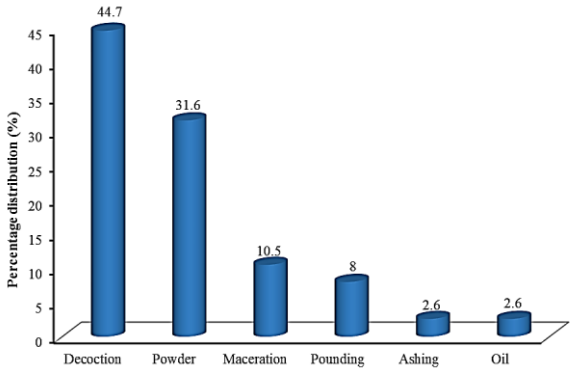

Figure 4: Methods of preparation of the plants used for the treatment diabetic foot ulcer in Kano state, Nigeria.

Decoctions and powders were the most common methods because the medicaments are easily prepared by mixing with tea, pap or soup. These two methods have also been reported to be popular amongst herbal medical practitioners (Umair *et al*., 2017). In some cases, two or more plant species are used along with other ingredients such as onions, milk, honey and cock fats. These preparation are similar to those reported in other studies (Inngjerdinge *et al*., 2004; Delshad *et al*., 2017; Oguntibeju, 2019).

Table 3. Medicinal plants used for the treatment of diabetic foot ulcers in Kano state, Nigeria.

Botanical name	Family	Local name	Habit	Voucher number	Parts used	For m	Preparation	Route of administration	Other ailments used for	Reference
***Acacia nilotica* (L.) Delile**	Fabaceae	Bagaruwa	Tree	BUKHAN186	P	Dried	Powder	Topical	Wounds, Pile	Kankara *et al*., 2015; Ali *et al*., 2017
***Albizzia chevalieri* Harms**	Fabaceae	Katsari	Tree	BUKHAN378	SB, L	Dried	Powder	Topical	Diabetes, HTN, cancer	Noté *et al*., 2017
***Allium cepa* L.**	Alliaceae	Albasa	Herb	BUKHAN370	B, R	Fresh	Pounded with cock fat	Topical	Cancer, liver disease, snake bite	Ali *et al*., 2017; Marrelli *et al*., 2018
***Allium sativum* L.**	Alliaceae	Tafarnuwa	Herb	BUKHAN297	B	Dried	Maceration	Oral	Catarrh, cold, cough, diabetes	Danbatta and Aliyu, 2011; Abubakar *et al*., 2017
***Anisopus mannii* N.E.Br.**	Asclepiadaceae	Kashe zaki	Herb	BUKHAN211	L, SB, R	Dried	Powder	Oral with milk	Diabetes	Sani *et al*., 2019
Anogeissus	Combretaceae	Marke	Tree	BUKHAN29	SB	Fresh	Decoction	Oral and	Skin diseases,	Inngjerdingen

***leiocarpus* (DC.) Guill. & Perr.**								topical	fever, malaria, diarrhoea, stomach ache, wounds	*et al*., 2004; Chaabi *et al*., 2008
***Artemisia annua* L.**	Asteraceae	Tazargade	Herb	BUKHAN652	L	Dried	Maceration	Oral	Fever and vomiting	Ali *et al*., 2017
***Balanites aegyptiaca* (L.) Delile**	Zygophyllaceae	Aduwa	Tree	BUKHAN359	SB, F	Dried	Decoction	Oral and topical	Malaria, wounds, jaundice, intestinal worms, syphilis, epilepsy, skin disease, diabetes, dysentery	Anani *et al*., 2015; Chothani and Vaghasiya, 2011; Abou Khalil *et al*., 2016
Borassus aethiopum Mart.	Arecaceae	Giginya	Palm	BUKHAN276	S	Dried	Ash	Topical	STI, cutaneous fungal infections, and measles	Sakande *et al*., 2011
Boswellia dalzielii Hutch.	Burseraceae	Hanu	Tree	BUKHAN362	SB	Dried	Maceration	Oral	Rheumatism, fever, pile,convulsions, GI troubles, diabetes	Nazifi *et al*.,2017; Mbiantcha *et al*., 2020
Byrsocarpus coccineus Schum. & Thonn	Connaraceae	Tsamiyar-kasa	Herb	ABU 864	L, SB	Fresh	Maceration	Topical	Pile, cancer, gonorrhea, leg ulcer,	Christian *et al*., 2015; Nwafor *et al*., 2018; Ukwade *et al*., 2020
Cadaba farinosa Forssk.	Capparaceae	Bagayi	Shrub	BUKHAN491	L	Dried	Powder	Topical	Skin and breast cancer, diabetes	Ezekiel and Tadzabia 2015; Sani *et al*., 2019
Cassia singueana Oliv.	Fabaceae	Runhu	Shrub	BUKHAN316	L	Dried	Powder	Topical	Fever, malaria, conjunctivitis, impotence, stomach upset, diabetes	Stephen *et al*., 2017
Cassia tora L.	Fabaceae	Tafasa	Shrub	BUKHAN307	L	Dried	Decoction	Topical	Diabetes, constipation, skin infection	Ogunkunle and Ladejobi, 2006; Sani *et al*., 2020
Chamaecrista mimosoides (L.) Greene	Fabaceae	Bagaruwar kasa	Herb	–	L, SB	Dried	Decoction	Oral and topical	diarrhea and dysentery	Ajaib and Khan, 2015
Dichrostachys cinerea (L.) Wight & Arn.	Fabaceae	Dundu	Shrub	BUKHAN383	L	Dried	Powder	Topical	Dysentery, toothache, headache, elephantiasis, gonorrhea, boils, leprosy, syphilis, cough, snake bites	Ayeni and Kayoed, 2019
Eucalyptus camaldulensis Dehnh.	Myrtaceae	Bishiyar turare	Tree	BUKHAN347	L	Fresh	Oil or leaf decoction	Topical	Respiratory disease, bleeding, wounds, pain	Sabo and Knezevic, 2019
Ficus glumosa Delile	Moraceae	Kawuri	Tree	BUKHAN607	SB	Dried	Decoction	Oral	Edema, HTN, hemorrhoid, skin diseases, diabetes	Ntchapda, *et al*., 2014
Guiera senegalensis J.F. Gmel.	Combretaceae	Sabara	Shrub	BUKHAN32	L	Dried	Decoction	Oral and topical	Diarrhoea, chicken pox, diabetes	Ohemu *et al*., 2014; Kankara *et al*., 2015; Shinkafi *et al*.,

										2015
Ipomoea asarifolia (Desr.) Roem. & Schult	Convolvulaceae	Duman rafi	Herb	BUKHAN152	L	Dried	Decoction	Oral	Dermatitis, scabies, syphilis, skin ulcers, wounds	de Albuquerque *et al.*, 2007; Agra *et al.*, 2007
Jatropha curcas L.	Euphorbiaceae	Bini/cini da zugu	Shrub	BUKHAN60	SB	Dried	Decoction	Topical	Jaundice, sores, wounds, renal infection, Gonorrhoea, hair lice	Patil *et al.*, 2013
Lamium purpureum L.	Lamiaceae	Bunsurun fage	Herb	BUKHAN257	L	Dried	Powder	Inhalation	Diarrhoea	Vergun *et al.*, 2019
Lannea microcarpa Engl. & K. Krause	Anacardiaceae	Faru	Tree	BUKHAN280	L	Dried	Decoction	Oral	Conjunctivitis, stomatitis and gingivitis, ulcers, wounds	Picerno *et al.*, 2006
Leptadenia hastata (Pers.) Decne	Asclepiadaceae	Yadiya	Herb	BUKHAN248	L, SB, R	Fresh	Decoction with onions	Oral	Diabetes, HTN, catarrh, skin diseases	Sani *et al.*, 2019; Danbatta and Aliyu, 2011
Momordica balsamina L.	Cucurbitaceae	Garahuni	Shrub	BUKHAN311	L	Dried	Decoction	Topical	Navel pain,	Kankara *et al.*, 2015
Moringa oleifera Lam.	Moringaceae	Zogale	Tree	BUKHAN11	L	Fresh	Decoction	Oral and topical	Muscle cramps, oedema, cough, diabetes	Nadkarni, 2009; Shinkafi *et al.*, 2015
Nymphaea lotus L.	Nymphaeaceae	Bado	Herb	BUKHAN356	R	Dried	Decoction	Oral and topical	Guinea worm infection and rheumatism	Kameni *et al.*, 2017
Parkia biglobosa (Jacq.) G. Don	Fabaceae	Dorawa	Tree	BUKHAN262	F, SB	Dried	Powder	Topical	Dysentery, diabetes, malaria, tonic	Musara *et al.*, 2020
Piliostigma reticulatum (DC.) Hochst	Fabaceae	Kalgo	Shrub	BUKHAN72	S	Fresh	Pounding	Topical	Dysentery, diarrhoea, inflammation, infections, pain, smallpox	Zerbo *et al.*, 2010
Prosopis africana (Guil & Perr) Taub.	Fabaceae	Kirya	Tree	BUKHAN193	SB, L, R	Dried	Powder	Topical	skin infections, intestinal worms, diabetes	Ayanwuyi *et al.*, 2010
Senna occidentalis (L.) Link	Fabaceae	Rai dore	Shrub	BUKHAN73	L	Fresh	Pounding	Topical	Skin disorders, wounds, fever, typhoid, oedema, diabetes, constipation	Gadanya and Muhammad, 2018
Strychnos spinosa Lam.	Loganiaceae	Kokiya	Tree	BUKHAN127	L	Dried	Powder	Oral with milk	snakebite, ulcers, fever, wounds, headache, GI problems, venereal diseases, leprosy, diarrhea	Neuwinger, 1996
Syzygium aromaticum (L.) Merr. & L.M. Perry	Myrtaceae	Kanumfari	Herb	BUKHAN342	F	Dried	Decoction	Oral	toothache, burns, mouth infection, cough and catarrh	Aiyeloja and Bello, 2006; Prashar *et al.*, 2006; Ali *et al.*,

										2017
Ziziphus mauritiana Var.	Rhamnaceae	Magarya	Tree	BUKHAN233	L	Dried	Powder	Topical	Jaundice, diabetes	Kankara *et al.*, 2015; Shinkafi *et al.*, 2015
Ziziphus mucronata Willd.	Rhamnasae	Magaryar kura	Tree	BUKHAN112	R	Dried	Decoction	Topical	Depression, diabetes	Mongalo *et al.*, 2020
Ziziphus spina-christi (L.) Desf.	Rhamnaceae	Kurna	Shrub	BUKHAN269	L	Dried	Powder	Topical	Pulmonary ailments, fever, wounds, dysentery	Abalaka *et al.*, 2010

Parts used (P = Pod, SB = Stem bark, L = Leaves, B = Bulb, R = Roots, F = Fruits, S = Seeds); GI = Gastrointestinal, HTN = Hypertension

Considering the mode of administration of the preparations, most of the preparations are administered via the topical route (51%). This include those used to wash the wounds and those applied as poultices. Other routes of administration are oral (27%), a combination of oral and topical (19%) and inhalation (3%) (Figure 5). In some situations, a single plant extract is administered through both oral and topical route and the least is inhalational route. Some of the topical preparations are used to either wash the wounds or are applied as poultices; while the powders are either taken orally with milk or yoghurt, or applied as ointment with cock fat. These forms of administration were also described in previous reports (Delshad *et al*. 2017; Oguntibeju, 2019).

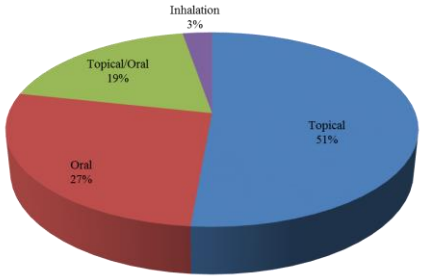

Figure 5. Methods of administration of the preparations used for the treatment diabetic foot ulcer in Kano state, Nigeria.

Table 4. Some reported pharmacological activities and isolated compounds present in the identified plants.

Plant species	Pharmacological activity	Isolated compounds	References
Albizzia chevalieri Harms	Antibacterial, antioxidant, hypoglycaemic, anticonvulsant	Chevalierosides A–C (1–3)	Noté et al., 2017; Ahmed *et al.*, 2019
Allium cepa L.	Antioxidant, antigenotoxic, antiproliferative	Quercetins, anthocyanins	Fredotovic *et al.*, 2017
Allium sativum L.	Antibacterial, antioxidant, anti-inflammatory, antidiabetic, anticancer	Alliin, Allicin, E-Ajoene,Z-Ajoene	Batiha *et al.*, 2020a
Anisopus mannii N.E.Br.	Antidiabetic, anti-inflammatory, antimicrobial, anti-carcinogenic, anti-lipideamic, wound healing	Monososrin, Pentacyclic triterpene esters, Longispinogenin 3-O-β-D-glucopyranoside	Aliyu *et al.*, 2011; Zaruwa *et al.*, 2013, 2018
Anogeissus leiocarpus (DC.) Guill. & Perr.	Antioxidant, anti-inflammatory, anticancer	Quinic acid, Hexahydroxydiphenoylhexos, Gallic acid, Catechin,Epicatechin	Orlando *et al.*, 2019
Artemisia annua L.	Antimicrobial, antioxidant, antidiabetic, anti-inflammatory	Artimisin, coumarins, Quercetins	Mesa *et al.*, 2015
Balanites aegyptiaca (L.) Delile	Antitumor, antioxidant, antibacterial, antidiabetic, antimalarial	flavonoides, furanocoumarins, Diosgenin, N-trans-feruloyltyramine, N-cis-feruloyltyramine, trigonelline, balanitol, fatty acid	Al-Thobaiti and Abu Zeid, 2018
Borassus aethiopum Mart.	Antimicrobial, antioxidant, anti-inflammatory	Galacturonic acid	Assoi *et al.*, 2017; Assoi and Wicker, 2020
Boswellia dalzielii Hutch.	Antibacterial, antifungal	Incensole, gallic acid, protocatechuic acid, 4′-methoxy-(*E*)-resveratrol-3-orutinoside and β-sitosterol	Alemika *et al.*, 2004
Byrsocarpus coccineus Schum. & Thonn.	Hypoglycemic, antioxidant, Anti-proliferative,	Quercetin 3-O-alpha-arabinoside (I), quercetin (II), quercetin 3-	Ahmadu *et al.*, 2007; Dada *et al.*, 2013

	Hepatoprotective	beta-D-glucoside	
Cadaba farinosa Forssk.	Antidiabetic, antibacterial, wound healing and anticancer	Cadabecine, quercetin, isoorientin, hydroxybenzoic acid, syringic acid, vanillic acid and 2-hydroxy- 4-methoxy benzoic acid	Telrandhe and Uplanchiwar, 2013
Cassia singueana Oliv.	Hepatoprotective, antioxidants,	Proanthocyanidins, mallic acid, catechin	Sobeh *et al*., 2017
Cassia tora L.	Anti-tumor, anti-inflammatory, antioxidant antibacterial and hypotensive	Emodin, palmitic, stearic, succinic acid, uridin and tricontan-1-ol, stigmasterol	Jain and Patil, 2010
Chamaecrista mimosoides (L.) Greene	Antioxidant	-	Adewusi *et al*., 2011
Dichrostachys cinerea (L.) Wight & Arn.	Antibacterial, antiviral, antiplasmodial	Quercetin-3-O-rhamnopyranoside, myricetin-3-O-rhamnopyranoside, kaempferol, apigenin	El-sharawy *et al*., 2017
Eucalyptus camaldulensis Dehnh.	Antimicrobial, anti-diabetic, anti-inflammatory, antiviral effect	1,8-cineole, cuminal, phellandrene, aromadendren	Sabo and Knezevic, 2019
Ficus glumosa Delile	Antibacterial activity	Esters,isothujol, terbutylazine	Kwazo *et al*., 2015
Guiera senegalensis J.F. Gmel.	Antioxidant, antidiabetic	Myricitrin,quercetin,1,3,4,5-tetra-O-galloylquinic acid, gallic acid	Dirar *et al*., 2019; Miaffo *et al*., 2020
Ipomoea asarifolia (Desr.) Roem.& Schult	Antioxidant, anti-inflammatory,	Chlorogenic acid, caffeic acid, rutin	Furtado *et al*., 2016
Jatropha curcas L.	Antibacterial, anti-inflammatory, anticancer	Jatrophin, palmarumycin JC1,-Hydroxy-4-methoxybenzaldehyd, curcain	Abdelgadir and Staden, 2013
Lamium purpureum L.	Antioxidant	Acteoside, shanzhiside methyl ester, caryoptoside and lamalbide	Ito *et al*., 2006
Lannea microcarpa Engl. & K. Krause	Anti-inflammatory	4-methoxy-myricetin 3-O-α-L-rhamnopyranoside, gallic acid, epicatechin	Picerno *et al*., 2006.
Leptadenia hastata (Pers.) Decne	Antioxidant, antibacterial, anti-inflammatory, anticancer, anti-trypanosomal, antidiabetic	acetic acid, hexadecane, hexadecanoic acid, 11-octadecanoic acid, 4,5-2H-oxazole-5-one and cyclodocosane	Sanda *et al*., 2013; Haruna *et al*., 2017
Momordica balsamina L.	Antimicrobial, hypoglycemic	–	van de Venter *et al*., 2008
Moringa oleifera Lam.	Antibacterial, anti-inflammatory, hypoglycemic, antidiabetic, wound healing	Hexadecanoic acid, ethyl ester, Palmitic acid ethyl ester, 2,6-Dimethyl-1, 7-octadiene-3-ol	Nepolean *et al*., 2009; Gothai *et al*., 2016
Nymphaea lotus L.	Antibacterial, antidiabetic, antioxidant	Myricitrin, Nympholides A and B	Kameni *et al*., 2017; Fajemiroye *et al*., 2018
Parkia biglobosa (Jacq.) G.Don	Antibacterial, antidiabetic, antioxidant	Ferulic acid, lupeol, epi-catechin 3-O-gallate	Tringali *et al*., 2000; Musara *et al*., 2020
Piliostigma reticulatum (DC.) Hochst	Antioxidant	Quercetin 3, isoquercetin, 1, 6-c-methylkaempferol-3-methyl ether 2	Aderogba *et al*., 2005
Prosopis africana (Guil & Perr) Taub.	Antibacterial, wound healing	Hexacosanol, β-sitosterol, quercetin, β-sitosterol 3-O-β-D-glucopyranoside	Ezike *et al*., 2010; Oscar *et al*., 2018
Senna occidentalis (L.) Link	Antibacterial , anti-inflammatory, antioxidant, hypolipidaemic	Achrosin, aloe-emodin, emodin, oleic acid, physcion, quercetin	Gadanya and Muhammad, 2018; Mahanthesh *et al*., 2019
Strychnos spinosa Lam.	Antibacterial	Sarracenin	Tor-Anyiin *et al*., 2015
Syzygium aromaticum (L.) Merr.& L.M. Perry	Antioxidant, antibacterial, antiviral, anti-inflammatory	Eugenyl acetate, eugenol, and β-caryophyllene	Batiha *et al*., 2020b
Ziziphus mauritiana Var.	Antidiabetic, antibacterial, anti-tumor	including alphitolic, betulinic, maslinic, oleanolic, ursolic, 3-O-trans-alphitolic, 3-O-cis-p-alphitolic	Palejkar *et al*, 2012
Ziziphus mucronata Willd.	Antibacterial , antioxidant	zizyberanalinic acid,affeic acid, gallic acid, rutin, epicatechin, mucronin, abyssenine	Mongalo *et al*., 2020
Ziziphus spina-christi (L.) Desf.	Antimicrobial	Betulin, stigmasterol, sitosterol, ethyl oleate quercetin	Ads *et al*., 2018

Furthermore, approximately 36% were observed to have comparable ethno-medical claims in certain regions of the world (Picerno *et al*., 2006; Rajan *et al*., 2013).

Preference ranking of the 15 most used medicinal plants for the remedy of diabetic foot ulcer in Kano state metropolis are presented in Table 5.

Table 5. Preference ranking of the 15 most used medicinal plant for the treatment of diabetic foot ulcer in Kano state metropolis

Plant used	Plant part	Key informants (n=10)										Total (100)	Rank
		A	B	C	D	E	F	G	H	I	J		
Ficus glumosa	Stem bark	10	10	10	10	10	9	9	5	9	9	91	1st
Anogeissus leiocarpus	Stem bark	9	9	5	8	9	10	10	8	10	8	86	2nd
Guiera senegalensis	Leaves	8	8	8	9	8	8	8	9	8	10	81	3rd
Acacia nilotica	Leaves	8	6	8	7	10	8	8	9	5	10	79	4th
Ziziphus mauritiana	Leaves	10	7	8	10	8	9	9	5	4	7	77	5th
Lannea microcarpa	Leaves	9	10	7	5	8	10	7	6	5	9	76	6th
Balanites aegyptiaca	Stem bark	7	9	10	6	9	7	6	5	5	8	70	7th
Boswellia delzielli	Stem bark	7	7	4	6	5	7	7	10	7	7	67	8th
Moringa oleifera	Leaves	4	8	7	7	8	9	5	6	5	4	63	9th
Cassia singueana	Leaves	4	5	6	9	3	9	10	7	5	4	62	10th
Leptadenia hastata	Leaves	3	10	6	4	10	4	6	5	3	6	57	11th
Anisopus mannii	Leaves	5	9	4	4	7	4	6	5	5	4	53	12th
Albizia chevalieri	Leaves	10	4	5	7	6	5	3	2	4	5	51	13th
Piliostigma reticulatum	Stem bark	7	5	4	8	3	3	4	6	2	5	47	14th
Cadaba farinose	Leaves	5	3	4	6	5	8	3	5	4	2	45	15th

The scores indicate rank values assigned to the plants based on their efficacy by the respondents. Highest score (10) was assigned for medicinal plants which the respondents thought were most effective against diabetic foot ulcer and the lowest score (1) for the least effective plant. A-J indicates the key informants.

Ficus glumosa, *Moringa oleifera*, *Guiera senegalensis*, *Anogeissus leiocarpus*, *Acacia nilotica*, *Lannea microcarpa*, *Ziziphus mauritiana*, *Balanites aegyptiaca*, *Boswellia dalzielii* and *Cassia singueana* appeared to be the first ten (10) most preferred medicinal plants for the treatment of diabetic foot ulcers. When different plant species are approved for a specific ailment, preference ranking aids categorization of the species in terms of preference of the respondents (Teman and Dillo, 2016). Interestingly, literature review of the first ten most preferred medicinal plants by the informants revealed that most of the plants exhibited antibacterial effect against some pathogenic bacteria. These include *Boswellia delzielii* (Dandashire *et al*., 2019), *Balanites aegyptiaca* (Tula *et al*., 2014), *Anogeissus leiocarpus* (Mann *et al*., 2008), Ziziphus mauritiana (Tanvir *et al.*, 2015), *Ficus glumosa* (Umar *et al*., 2013), *Acacia nilotica* (Shekar *et al*., 2015) and *Guiera senegalensis* (Mamman and Isa, 2013). The wound healing properties of some of these plants (*Lannea microcarpa*, *Zizipus mauritiana*, *Acacia nilotica* and *Anogeissus leiocarpus* (Picerno *et al*., 2006; Rajan *et al*., 2013; Victor *et al*., 2013; Kankara *et al*., 2017) have also been reported.

4. Conclusion

The use of medicinal plants to treat diabetic foot ulcers is common in Kano state, north-western Nigeria. This study reported 36 medicinal plant species used to treat diabetic foot ulcers in Kano metropolis. There is need to validate such claims with the view of characterizing potential lead compounds that could be useful against diabetic foot ulcers. This report can also be of significant value to policy makers and safe-guarding managers for viable management of the plant species.

5. Acknowledgement

The authors appreciate Sangarif Herbal Medicine Center, for assisting in the identification of knowledgeable herbalists for the ethnobotanical survey, as well as the respondents that participated in this research.

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