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ORIGINAL RESEARCH ARTICLE

Ethnobotanical Survey and Phytochemical Profiling of Medicinal Plants Used for Traditional Bone-Setting in Katsina State, Nigeria

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ABSTRACT
The study investigates the ethnobotanical uses and phytochemical analysis of medicinal plants employed in traditional bone setting in Katsina State, Nigeria. An ethnobotanical survey was conducted in six local government areas: Katsina, Kaita, Malumfashi, Funtua, Daura, and Sandamu using a structured questionnaire to gather data from traditional bone setters, herbalists, farmers, and others. The survey identified several medicinal plants, with *Calotropis procera* having the highest citation frequency and *Faidherbia albida* the least. The phytochemical composition of the selected plants was evaluated using standard methods, revealing the presence of alkaloids, flavonoids, saponins, tannins, terpenoids, and carbohydrates in all samples. The ethanolic extracts of the plants were analyzed using Gas Chromatography-Mass Spectrometry (GC-MS), identifying 32 bioactive compounds in *Calotropis procera* with four major bioactive compounds and 22 bioactive compounds in *Faidherbia albida*, having Hexadecanoic acid, methyl ester ($C_{17}H_{34}O_2$), 9,17-Octadecadienal, (Z)- ($C_{18}H_{32}O$), 9,11-Octadecadienoic acid, methyl ester, (E,E)- ($C_{19}H_{34}O_2$), and 4-Nonyne (C_9H_{16}) as major bioactive compounds. This study has contributed to the preservation of indigenous knowledge used for traditional bone setting in Katsina State.

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INTRODUCTION
Since ancient times, medicinal plants have been integral to healthcare. Natural products derived from these plants have demonstrated their vital role in treating diseases, underscoring the symbiotic relationship between humans and the environment (Sofowora *et al.*, 2013). Medicinal plants are defined as those commonly used for treating and preventing specific ailments and diseases, and they are generally considered to pose no harm to humans. These plants can be categorized into 'wild plant species,' which grow naturally in self-sustaining populations within natural or semi-natural ecosystems without human intervention, and 'domesticated plant species,' which have been cultivated through human activities such as selection or breeding and require management to thrive (Tuttolomondo *et al.*, 2014).

World Health Organization (WHO, 2002) describes traditional bone setting as a health practice, approach, knowledge, and beliefs incorporating plant, animal, and mineral-based medicines, spiritual therapies, manual techniques and exercises, applied singularly or in combination to diagnose and treat fractures in the human body.

Dada *et al.* (2011) established some of the reasons contributing to the continued use of traditional bone setting in African countries. They include cheaper fees, easy accessibility, quick service, cultural beliefs, utilization of incantations and concoction, and pressure from friends and families. In a further explanation, Ekere (2003) states that traditional medicine is based on the belief that the natural resources have active therapeutic principles that heal occult supernatural forces, power to change active principles which can be manipulated by those who know how to produce marvellous results. This implies that Africans believe in using the natural way to treat illnesses rather than the orthodox medicine brought from Western societies (Omololu, 2008).

In an earlier study in Nigeria, superstition, ignorance, and poverty are the basis for continued patronage despite complications (Udosen *et al.*, 2005). The fact that the patrons of this service cut across every stratum of society, including the educated and the rich (Thanni, 2000) indicates that it is not only poverty and ignorance that take them there. Mostly, Africans believe that diseases and accidents have spiritual components that must be tackled along with treatment. The major and commonest problems they treat are fractures and dislocations (Thanni, 2000). There are however many complications attributed to the TBS.

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Nigerians have a deep belief and reliance on the services of the traditional practitioners for their health care needs. An estimated 75 percent of the population still prefers to solve their health problems by consulting the traditional healers (Adam, 2009), Nigerian Tribune (March 2008). Documenting Traditional Medicine Knowledge helps in preserving the knowledge. Today, the cultural survival of many indigenous communities is threatened, and some traditional systems of disseminating information may be lost. Modern lifestyles and the disruption of traditional ways of life cause younger generations to lose interest in learning traditional medicine practices. Traditional languages used to pass information are no longer widely used and understood. Therefore, documenting Traditional Medicine Knowledge may help preserve this knowledge for future generations (Abbott, 2014).

A significant number of herbal medications are recognized for their substantial medicinal properties and are utilized in the treatment of various health conditions. In folk medicine, various indigenous drugs are used in single or combination forms to treat different inflammatory and arthritic conditions with considerable success **(**Daniel and Norman, 2001). Furthermore, the process of finding new therapeutic chemical compounds begins by conducting an ethnomedical survey of plants (Khalid *et al*., 2016).

There is no previous study done on plants used for bone setting in Katsina State; therefore, this research aims to document and preserve the traditional knowledge of medicinal plants used for bone setting in Katsina State, safeguarding cultural heritage for future generations.

METHODOLOGY

Study area

This research work was conducted in Katsina State, one of the northern states of Nigeria. Katsina State has a land area which covers 23,938 sq km. The state is located between latitudes of 11°08'N and 13°22'N and longitudes 6°52'E and 9°20'E with an elevation of 465 m above sea level. The state is bounded by Niger Republic to the north, to the east by Jigawa and Kano States, Kaduna State to the south and Zamfara State to the west (Figure 1). The state has 34 local government areas which are categorized into three Senatorial Zones, namely the Katsina South, Katsina North, and the Katsina Central Senatorial Zones. From each Senatorial Zones, two local governments where selected for the purpose of this research.

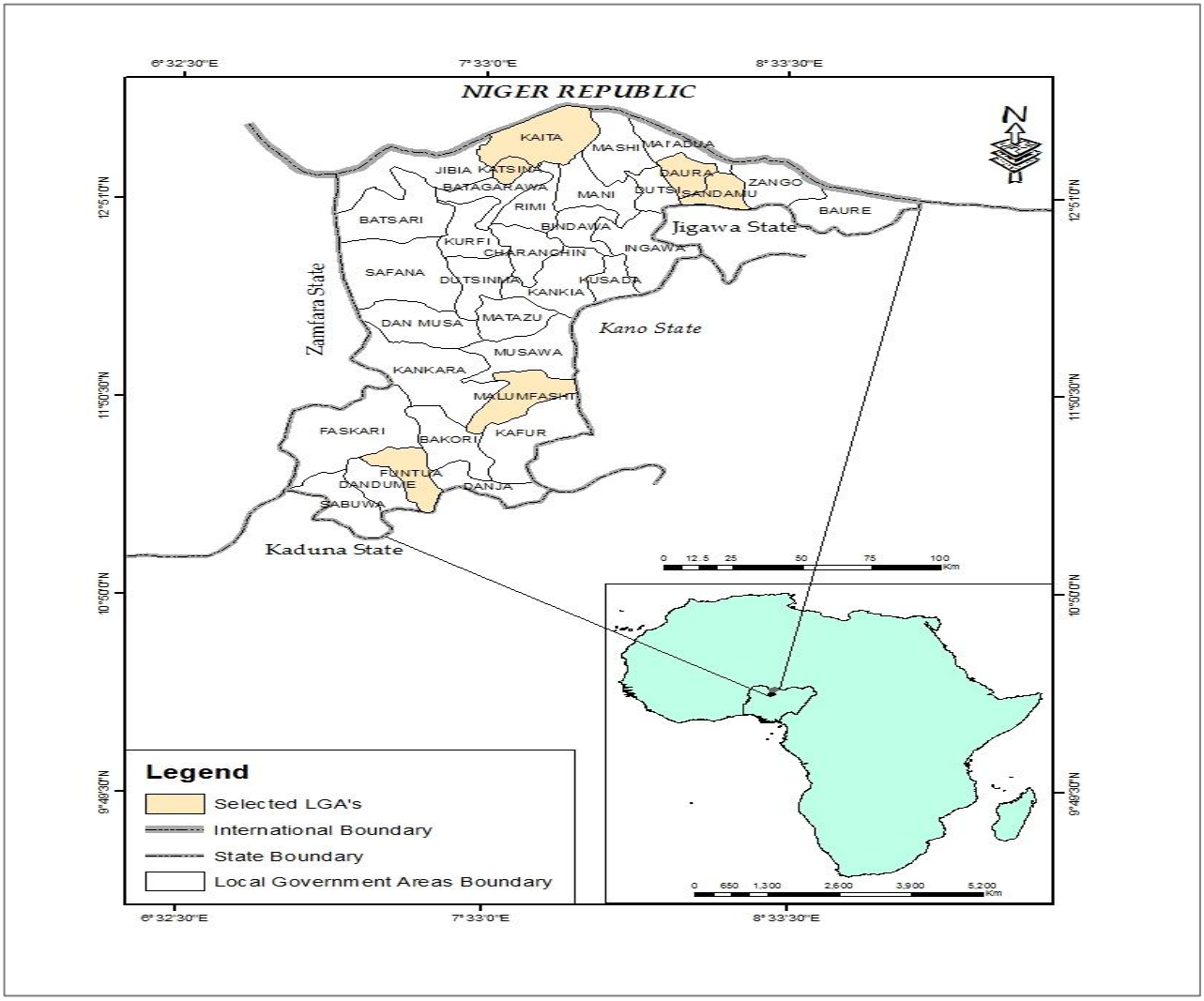

Figure 1: Map of Katsina State Showing the Study Areas (prepared by GIS lab UMYU)

Data collection

This research work was conducted in three Senatorial Zones of Katsina State, Nigeria. Two local government areas were randomly selected from each Senatorial Zone. The survey was carried out from August 2023 to January 2024. The ethnomedicinal plants data were gathered using a semi-structured questionnaire by interviewing 120 respondents, where 20 respondents were selected from each Local Government Area (LGA) and 2 (two) LGAs were randomly selected across the 3 (three) Senatorial Zones of the State. The target groups for this study were herbalists, traditional bone setters, farmers, and other people of old age who have practiced and used medicinal plants. Before the questionnaire administration, the traditional rulers in each Local Government Area organized and facilitated conversation sessions with the potential respondents. The questionnaire was divided into two parts, namely parts A and B. In part A, the socio-demographic information of the respondents was recorded, and information on plants that are used for traditional bone setting will be recorded in part B. The interview was conducted in the Hausa language, and each respondent was interviewed alone to ensure confidentiality.

Collection and identification of plant specimens

Alongside traditional herbalists and field assistants, the authors collected traditional plants reported to have bone-setting usage in the field. The specimens of the supposed bone-setting plants were gathered. The gathered voucher specimens were identified, dried, numbered, pressed, and placed at the Biology Department Herbarium, Umaru Musa Yar'adua University Katsina, Nigeria.

Data analysis

A descriptive statistical method using frequencies and percentages was used to analyze the socio-demographic data of the respondents, and the results of the ethnobotanical survey were analyzed using the Relative Frequency of Citation (RFC)

Relative Frequency of Citation (RFC)

This measure was calculated to determine the relative importance of a particular species. This value was determined using the relation RFC = F_c / N (Tardio and Pardo-de-Santayana, 2008), where F_c is the number of respondents who cited a particular species and N is the total number of respondents.

Extraction of the plant materials

Ethanolic extracts of the powdered plant samples, Leaves of (*Calotropis procera and Faidherbia albida*) were prepared by soaking 50g of the dry powdered plant samples in 350ml of absolute ethanol at room temperature for 48 hours. The extract was thereafter filtered first through a Whatmann filter paper No. 42 (125mm) and then through cotton wool. The extract was then concentrated using a rotary evaporator with a water bath set at 40^0C.

Phytochemical analysis

Phytochemical analysis and gas chromatography-mass spectrometry (GC-MS) were carried out for the most cited and least cited plant

Methods of phytochemical analysis

Phytochemical tests were carried out using standard procedures described by Evans and Trease (2002) and Ayoola *et al.* (2008).

Gas Chromatography Mass Spectrometry

The GC-MS analysis of the leaf extract of *Faidherbia albida* and *Calotropis procera* was done at the Central Laboratory, Usmanu Danfodio University, Sokoto, Nigeria. The prepared leaf extracts were analyzed using GCMS-QP2010 plus Shimadzu Japan, equipped with a VF-5 ms fused silica capillary column of 30 m length, 0.25 mm diameter, and 0.25 mm film thickness. For GC-MS recognition, it was achieved by an electron ionization system with an ionization energy of 70 eV was used. Helium gas was used as a carrier gas at a constant flow rate of 1.58 ml/min. The injector and mass transfer line temperature was set at 230 and 250 °C, respectively. The oven temperature was programmed from 80 to 200 °C at 10 °C/min, held isothermal for 1 minute, and finally raised to 280°C. Identification of the constituent was achieved by comparison of the mass spectra and the reviewed literature.

RESULTS

Socio-demographic information

Table 1 shows the socio-demographic information of the respondents; it indicates that a total of one hundred and twenty (120) people were interviewed for medicinal plants used for traditional bone setting in Katsina state. As shown in Table 1, most respondents (85.0%) were male and 15.0% female. The table also revealed that the majority of the respondents, 26.7%, are within the age range of 41 and 50. Most of the respondents had no formal education, followed by 27.5% with only basic education, then 9.2% with Secondary education, and 4.1% with Tertiary education

Plant species used for traditional bone setting

Table 2a and b shows information on the medicinal plants used for bone healing in the study area. The table shows the plant species, their common names, the parts used, their modes of preparation, and the routes of administration. According to this research's findings, 48 plant species belonging to 26 families are used for bone setting in Katsina State, Nigeria. The family Fabaceae was the dominant family with 8 species, followed by the

Moraceae family with 4 species. The families Anarcadiaceae, Combretaceae, and Leguminosae each had three (3) species, while the families Cucubitaceae, Euphorbiaceae, Rubiaceae and Zingiberaceae were represented by 2 species each. The remaining 14 families were represented by one species each (Figure 2)

Dosage, mode of preparation, and route of administration

In this study, there was no specific dosage used. Figure 3 shows the mode of preparation of the surveyed plants. Some of the plants 6.0% are used in powdered form, applied on the wound. Another 40% are used as an ointment, by mixing the powder with hen fat, cow butter, goat fat, or shea butter. Also, 17.0% are used as maceration, while decoction accounts for 37.0%.

Some of the plants, 47.5% are administered via the oral route, 50.0% are administered topically on the affected area, while the remaining 2.5% are administered by massaging the affected area (Figure 4).

Relative Frequency of Citation (RFC)

Calotropis procera, *Vitellaria paradoxa, Acacia nilotica, Tamarindus indica,* and *Zingiber officinale* exhibited the highest Relative Frequency of Citation (RFC) values of 0.11, 0.067, 0.042, 0.042, and 0.042 respectively. Although many plants were reportedly used for bone setting, *Calotropis procera* appeared to be the most important plant species as identified in this study. *Adansonia digitata, Prosopi safricana*, *Faidherbia albida Parkia biglobosa, Momordica balsamina, Sclerocarya birrea, Ziziphus mauritiana, Crinum jagus, Sterospermum kunthianum,* exhibited the lowest Relative Frequency of Citation (RFC) values of 0.017.

Qualitative phytochemical analysis

The phytochemical analyses of ethanolic extracts of the highest cited and least cited plants are presented in Table 3. Shows that *Calotropis procera* and *Faidherbia albida* test negative for anthraquinones and cardiac glycosides. Both test plants test positive for alkaloids, saponins, carbohydrates, flavonoids, terpenoids, and tannins. *Calotropis procera* tests positive for steroids while negative for *Faidherbia. albida.*

Gas Chromatography –Mass Spectrometer analysis of *Calotropis procera and Faidherbia albida* leaf

The GC-MS analysis of the ethanolic leaf extract of *Calotropis procera* showed 32 peaks (Figure 5), indicating the presence of 32 bioactive compounds in the leaf. The Peak No., Retention Time (Min), Compound name, Molecular formula, Molecular weight (g/mol), and Area percentage are shown in Table 4. The result showed some major bioactive compounds appearing in the dominant peaks of the chromatogram. The major bioactive compounds found in the ethanolic extract of *Calotropis procera* include: Glycerin ($C_3H_8O_3$), Dodecanoic acid, methyl ester ($C_{13}H_{26}O_2$), Tetradecanoic acid, ethyl ester ($C_{16}H_{32}O_2$), and Decanoic acid, ethyl ester ($C_{12}H_{24}O_2$). Glycerin is the most abundant compound detected, appearing multiple times with a high area percentage. Several fatty acid esters, such as Tetradecanoic acid, methyl ester, Decanoic acid, methyl ester, and Dodecanoic acid, methyl ester, are present in significant amounts.

The GC-MS analysis of the ethanolic leaf extract of *Faidherbia albida* showed 22 peaks (Figure 6) indicating the presence of 22 bioactive compounds in the leaf. The Peak No., Retention Time (Min), Compound name, Molecular formula, Molecular weight (g/mol), and Area percentage are shown in the table. The result showed some major bioactive compounds appearing in the dominant peaks of the chromatogram. The major bioactive compounds found in the ethanolic extract of *Faidherbia albida* include: Hexadecanoic acid, methyl ester ($C_{17}H_{34}O_2$), 9,17-Octadecadienal, (Z)- ($C_{18}H_{32}O$), 9,11-Octadecadienoic acid, methyl ester, (E,E)- ($C_{19}H_{34}O_2$), and 4-Nonyne (C_9H_{16}).

DISCUSSION

The findings of the socio-demographic characteristics of the respondents (Table 1) reveal a strong gender imbalance, with 85.0% of the participants being male. Similar results have been reported by Abdullahi (2011) in his review of traditional medicine in Africa, where male practitioners dominate traditional healing practices, particularly in rural areas, due to cultural and societal norms.

Table 1. Socio-demographic information of the respondents

Biodata	Frequency	Percentage (%)
Sex		
Male	102	85.0
Female	18	15.0
Age		
20–30	12	10.0
31–40	22	18.3
41–50	32	26.7
51–60	27	22.5
61–70	19	15.8
>70	8	6.7
Education		
None	71	59.2
Basic	33	27.5
Secondary	11	9.2
Tertiary	5	4.1
Occupation		
TBS	65	54.2
Herbalists	27	22.5
Farmers	10	8.3
Others	18	15.0

TBS– Traditional bone setters

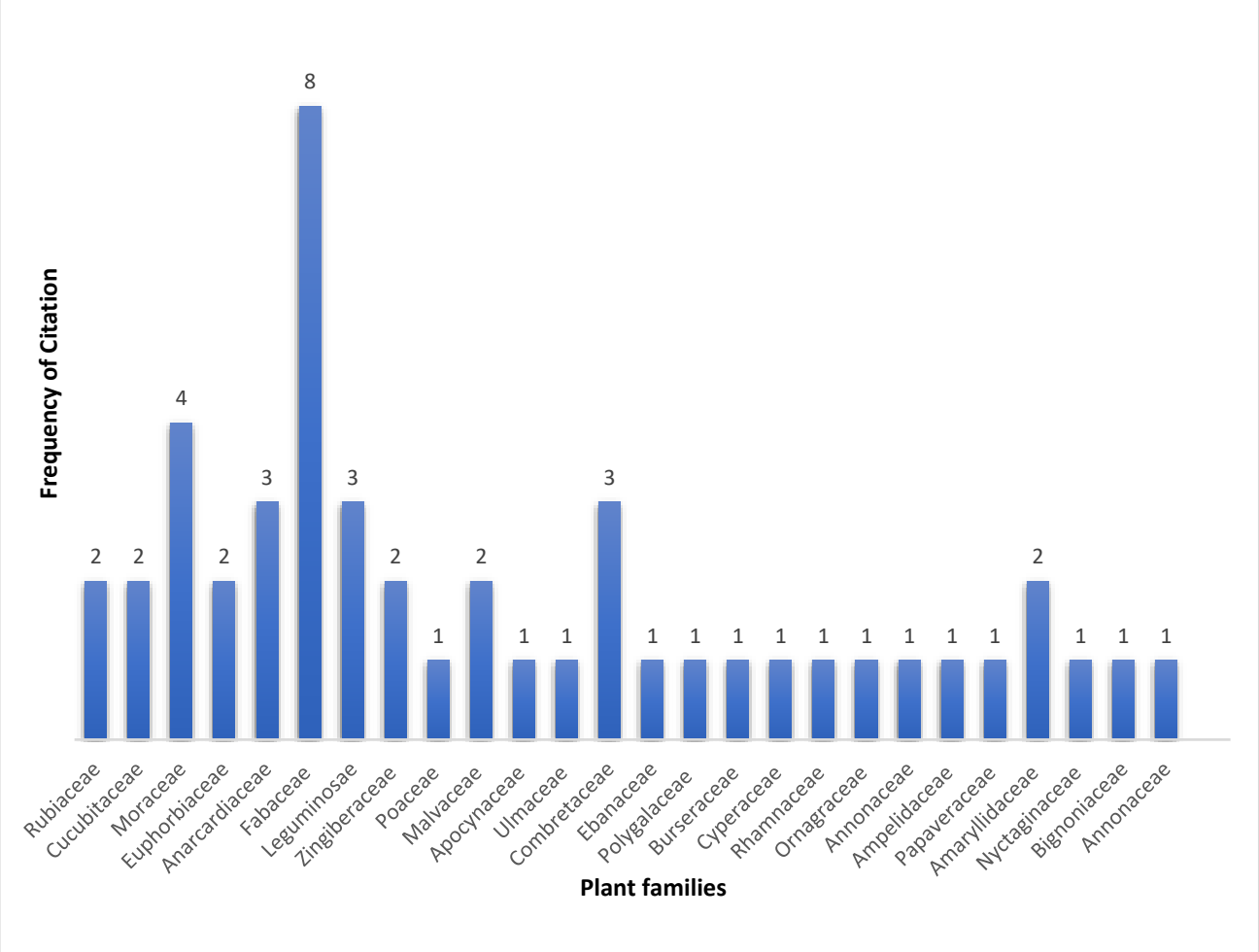

Figure 2 Distribution of plant families used for Traditional bone setting in Katsina State, Nigeria

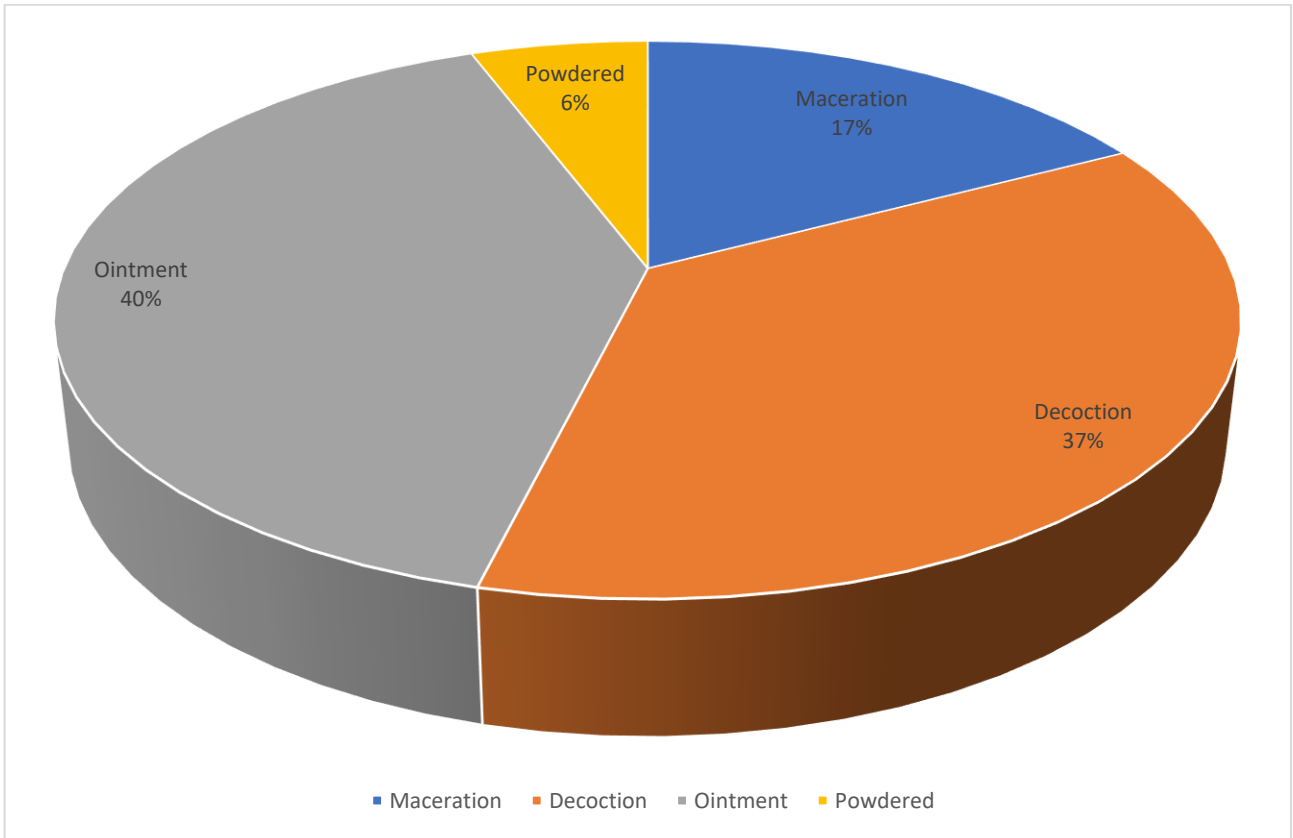

Figure 3: Mode of preparation of medicinal plants used for Traditional bone setting in Katsina State, Nigeria.

Table 2a Medicinal plants used for traditional bone setting and their applications in Katsina State

Family	Scientific name	Common name	Local name	Frequency of citation
Amaryllaceae	*Allium sativum*	Garlic	Tafarnuwa	0.025
Amaryllidaceae	*Crinum jagus*	Harmattan lilly	Gadali	0.017
Ampelidaceae	*Cissus quadrangularis*	Climbing cactus	Daddori	0.033
Anacardiaceae	*Ozoroa mucronate*	Estern cape resin tree	Kasheshe	0.025
Anarcardiaceae	*Lannaea macrocarpa*	African grape	Faaru	0.033
Ancardiaceae	*Sclerocarya birrea*	Marula	Danya	0.017
Annonaceae	*Xylopia aethiopica*	Bullocks heart	Kimba	0.025
Apocynaceae	*Calotropis procera*	Sodom apple	Tumfafiya	0.11
Bignoniaceae	*Sterospermum kunthianum*	Pink jacaranda	Sansami	0.017
Burseraceae	*Boswellia dalzielii*	Frankincense tree	Hano	0.033
Combretaceae	*Anogeissus leiocarpa*	African birch	Marke	0.033
Combretaceae	*Guiera senegalensis*	Moshi medicine	Sabara	0.025
Combretaceae	*Terminalis avicennioides*		Baushe	0.025
Cucubitaceae	*Luffa aegyptica*	Sponge guard	Soso	0.025
Cucurbitaceae	*Momordica balsamina*	Balsam apple	Garahuni	0.017
Cyperaceae	*Cyperus articulatus*	Jointed flat sedge	Kajiji	0.033
Ebanaceae	*Diospyros mespiliformi*	African ebony	Kanya	0.033
Euphorbiaceae	*Jatropha curcus*	Barbados nut	Bini da zugu	0.033
Fabaceae	*Piliostigma thonningii*	Mountain ebony	Kalgo	0.025
Fabaceae	*Prosopis Africana*	African mesquite	Kirya	0.017
Fabaceae	*Dichrostachys glomerata*	Sickle bush	Dundu	0.025
Fabaceae	*Faidherbia aibida*	Winter thorn	Gawo	0.017
Fabaceae	*Entada Africana*	African dream herb	Tawatsa	0.033
Fabaceae	*Tamarindus indica*	Tamarind	Tsamiya	0.042
Fabaceae	*Parkia biglobosa*	African locust bean	Dorowa	0.017
Fabaceae	*Acacia nilotica*	Black piquant	Bagaruwa	0.042
Leguminosae	*Cassia occidentalis*	Coffee senna	Rai dore	0.025
Leguminosae	*Cassia sieberiana*		Malga	0.025
Leguminosae	*Bahaunia rufescens*	silver butterfly tree	Sisi/tsattsagi	0.025
Malvaceae	*Adansonia digitate*	Baobaba	Kuka	0.017
Moraceae	*Ficus citrifolia*	Giant bearded fig	Durumi	0.025
Moraceae	*Ficus congensis*	Fig	Baure	0.033
Moraceae	*Ficus thonningii*	Bladder fig	Cediya	0.025
Moraceae	*Ficus valli choudae*	False cape fig	Kamasagi	0.025
Nyctaginaceae	*Boerhavia diffusa*	Common hogweed	Jibji	0.025
Papaveraceae	*Argemone Mexicana*	Mexican poppy	Qanqamarka ta bika	0.025
Poaceae	*Cynodon dactylon*		Tsakiyar zomo	0.025
Polygalaceae	*Securidaca longipedunculata*	Violet tree	Sanya	0.025
Rhamnaceae	*Ziziphus mauritiana*	Indian jujube	Magarya	0.017
Rubiaceae	*Mitracarpus hirtus*	Tropical girdlepod	Wawa kaji magori	0.025
Rubiaceae	*Crossopteryx febrifuga*	Crystal bark/ ordeal tree	Kashin awaki	0.025
Sapotaceae.	*Vitellaria paradoxa*	Sheabutter tree	Kadanya	0.067
Ulmaceae	*Celtis integrifolia*	Nettle tree	Zuwo	0.033
Zingiberaceae	*Zingiber officinale*	Ginger	Citta	0.042
Zingiberaceae	*Curcuma longa*	Turmeric	Kurkum	0.033

Table 2b Medicinal Used For Traditional Bone Setting In Katsina State

Scientific name	Plant Parts Used	Mode of Preparation	Mode of Administration	Illness
Mitracarpus hirtus	Leaves	Powdered leaves mix with hen fat	Topical	Fracture/ dislocation
Luffa aegyptica	Leaves	Decoction of fresh leaves with red potash	Oral	Sprain/fracture/dislocation
Ficus citrifolia	Bark/ Roots	Grinded bark and roots to powder and mix with goat fat	Topical	Fracture/dislocation
Ficus congensis	Bark	Maceration of dried or fresh bark	Oral	Fraction/dislocation/joint pain
Ficus thonningii	root/bark/leaves	Powdered bark of the roots of *Argemone Mexicana* and *Ficus thonningii* mix with cow or goat fat	Topical	Fracture
		Infusion of leaves for massage	Dermal	Joint pain
Jatropha curcus	Leaves	Infusion of leaves for massage	Dermal	Joint pain
Lannaea macrocarpa	Bark	Maceration of dried or fresh bark	Oral	Fracture/dislocation
	Leaves	powdered leaves + leaves of *Cissus quadrangularis* mix with ghee butter or hen fat to make ointment	Topical	
Piliostigma thonningii	Leaves	Decoction of leaves with red potash	Oral	Fracture/dislocation
		Mix powdered leaves and stem bark for wound dressing	Topical	
Cassia occidentalis	Leaves, root	Decoction of leaves/root	Oral	Fracture/dislocation
		Grind leaves with potash and apply on affected area	Topical	

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Table 2b continued

Scientific name	Plant Parts Used	Mode of Preparation	Mode of Administration	Illness
Prosopis Africana	Bark	Maceration	Oral	Fracture/dislocation/joint pain
Zingiber officinale	Rhizome	Grind fresh and apply on affected area	Topical	Sprain/joint pain
		Mix fresh ginger with fresh turmeric and sheabutter		
Cynodon dactylon	Leaves	Mix dried powder with cow fat	Topical	Fracture
Adansonia digitate	Bark	Decoction of the fresh bark for massage	Dermal	Sprain/dislocation
Calotropis procera	Leaves	Decoction of leaves with red potash	Oral	Fracture/sprain/dislocation/join t pain
		Mix dried grinded leaves with goat fat and apply on affected area	Topical	
		Infusion of fresh leaves for massage	Dermal	
Dichrostachys glomerata	Root,bark	Decoction of fresh or dried parts	Oral	Fracture/dislocation
Faidherbia aibida	Leaves, bark	Mix powdered with red potash and apply	Topical	Fracture/sprain/dislocation
Entada Africana	Leaves	Grind fresh leaves together with salt and dry, then mix with sheabutter or cow fat	Topical	Fracture//sprain/ dislocation/joint pain
		Infusion of fresh/dried leaves for massage	Dermal	
Tamarindus indica	Leaves, bark	Decoction of leaves	Oral	Fracture/ dislocation
		Grind the bark and mix with cow fat or sheabutter	Topical	
Parkia biglobosa	Bark	Grind to powder and apply on affected part	Topical	Fracture

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Table 2b continued

Scientific name	Plant Parts Used	Mode of Preparation	Mode of Administration	Illness
Celtis integrifolia	Leaves	Grind dried leaves and mix with sheabutter or cow fat or hen fat as ointment	Topical	Fracture//sprain/ dislocation/joint pain
Anogeissus leiocarpa	Root	Decoction of plant root with *Sterospermum kunthianum* and red potash	Oral	Joint pain
Momordica balsamina	Root	Grind to powder and add cow fat or sheabutter and apply	Topical	Fracture//sprain
Diospyros mespiliformi	Bark	Grind to powder and add cow fat or sheabutter and apply	Topical	Fracture//sprain/ dislocation/joint pain
Sclerocarya birrea	bark	Grind bark to powder and add cow fat	Topical	Fracture//sprain/ dislocation/joint pain
	leaves	Boil leaves with red potash and take	Oral	
Securidaca longipedunculata	Root	Decoction of dried or fresh root	Oral	Joint pain
Ozoroa mucronate	Root	Decoction of dried or fresh root with red potash	Oral	Fracture//sprain/ dislocation/joint pain
Boswellia dalzielii	Bark	Maceration of dried or fresh bark	Oral	Fracture//sprain/ dislocation/joint pain
Guiera senegalensis	Leaves	Decoction of fresh or dried leaves with red potash	Oral	Fracture//sprain/ dislocation/joint pain
Cyperus articulatus	Root	Decoction with red potash	Oral	Joint pain
Acacia nilotica	Root	Maceration or decoction of fresh or dried root	Oral	Fracture//sprain/ dislocation/joint pain
Ziziphus mauritiana	Leaves, root	Grind dry leaves/root to powder and apply on affected area	Topical	Fracture/sprain/ dislocation/joint pain
		Decoction of root or leaves	oral	

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Table 2b continued

Scientific name	Plant Parts Used	Mode of Preparation	Mode of Administration	Illness
Cassia sieberiana	bark	Maceration of bark	Oral	Fracture/dislocation/Sprain/joi nt pain
Terminalis avicennioides	Leaves	Powdered leaves mixed with cow fat applied powdered leaves applied on wound dressing	Topical	Fracture/wounds/dislocation
Cissus quadrangularis	Leaves, stem	Decoction of leaves and stem	Oral	Fracture/sprain/ dislocation
		Powdered leaves of *Cissus quadrangularis* + leaves of *Lannaea microcarpa* applied on affected area	Topical	
Argemone Mexicana	Leaves	Dried leaves are grinded with dried leaves of *Ficus sur* mix with cow fat	Topical	Fracture/dislocation
Allium sativum	Bulb	Decoction with ginger and turmeric	Oral	Joint pain
Curcuma longa	Rhizome	Blend with ginger to paste and apply on area affected	Topical	Joint pain/arthrites
Ficus valli choudae	Bark	Maceration of with red potash	Oral	Fracture/dislocation/sprain
		Powdered bark with creeper yaada kwarya mix with cow fat or sheabutter	Topical	
Boerhavia diffusa	Leaves	Grind dried leaves to powder and mix with goat fat or hen fat	Topical	Sprain/dislocation
Sterospermum kunthianum	Leaves/bark	Decoction of fresh/dried leaves with red potash	Oral	Joint pain/arthritis
		Maceration of bark		
Crossopteryx febrifuga	Leaves/ Root	Decoction of leaves for massage	Oral	Fracture/disloacation/sprain
		Powdered bark mix with sheabutter as ointment	Topical	

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Table 2b continued

Scientific name	Plant Parts Used	Mode of Preparation	Mode of Administration	Illness
Xylopia aethiopica	Seeds	Decoction with garlic and ginger	Oral	Arthritis/joint pain
Vitellaria paradoxa	Leaves	Decoction of dried/fresh leaves for massage	Oral	Fracture/sprain/dislocation/arthritis
	Seeds	Extracted butter is mixed with powdered plants applied as ointment	Topical	
Crinum jagus	Bulb	Decoction of bulb	Oral	Joint pain
Bahaunia rufescens	Leaves	Powdered leaves mix with cow fat as ointment	Topical	Sprain/dislocation/fracture
	Bark	Decoction with red potash	Oral	

Table 3 Phytochemical constituents of medicinal plants used for Bone setting in Katsina State

Phytochemical Parameters	*Faidherbia albida*	*Calotropis procera*
Alkaloids	+	+
Carbohydrates	+	+
Cardiac glycosides	–	–
Anthraquinones	–	–
Flavonoids	+	+
Saponins	+	+
Steroids	–	+
Terpenoids	+	+
Tannis	+	+

Keys: **- Absent** **+ Present**

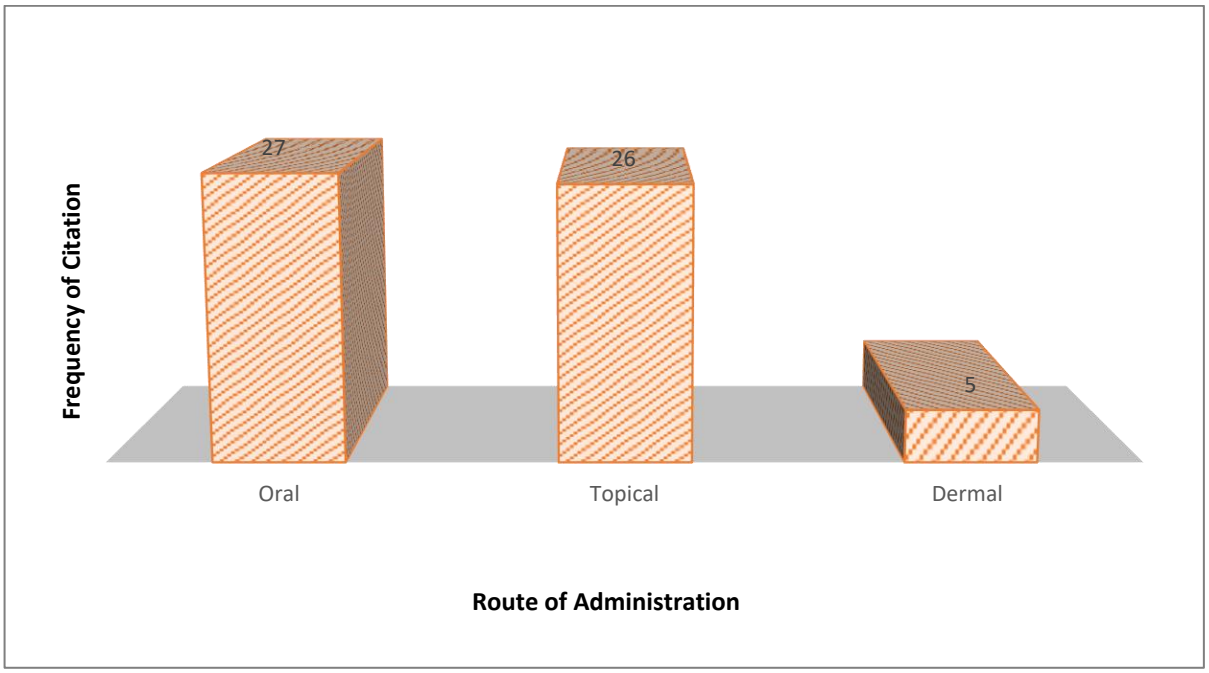

Figure 4 Route of administration of plants used for Traditional bone setting in Katsina State, Nigeria.

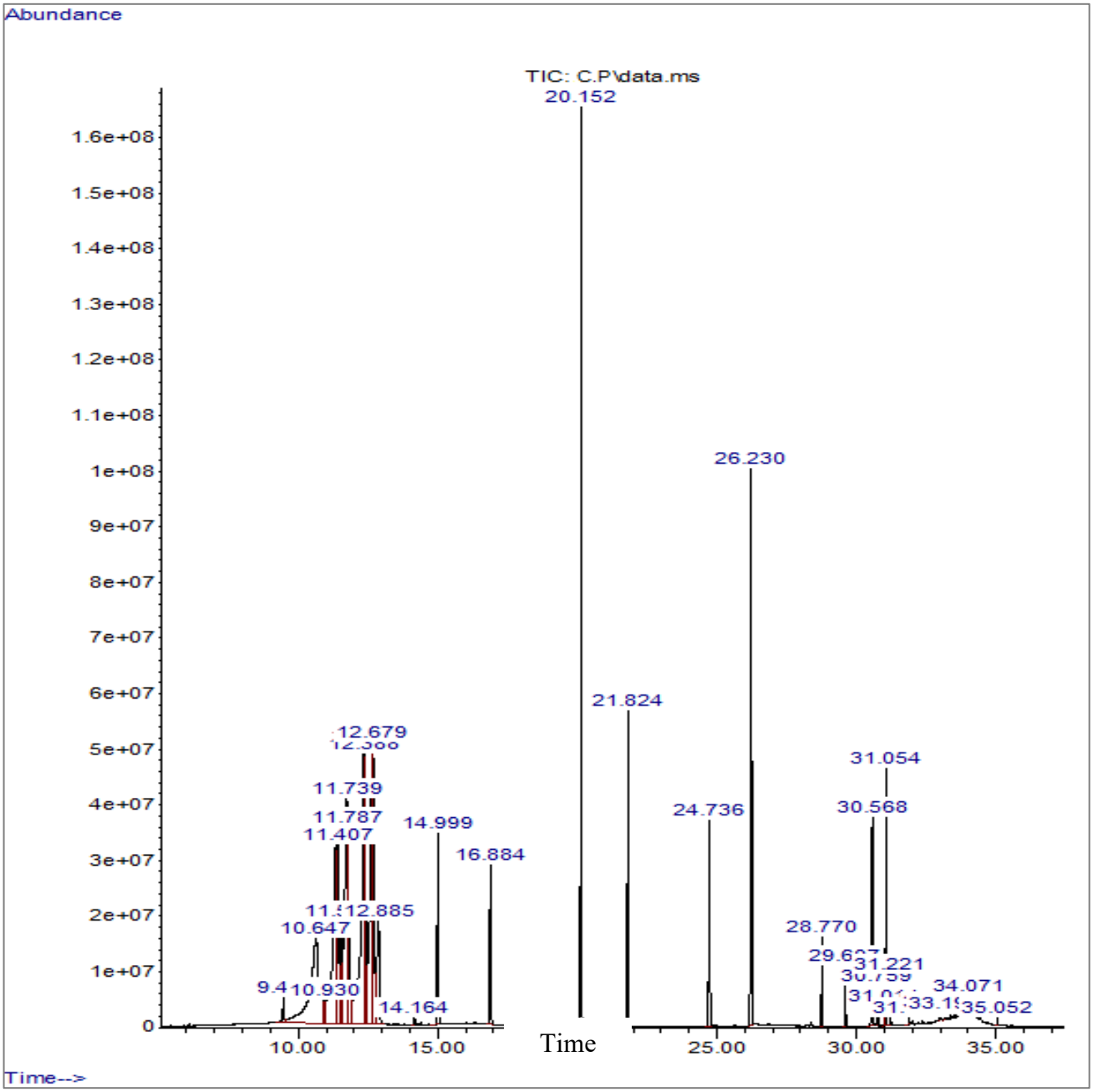

Figure 5: GC-MS chromatogram ethanolic extract of *Calotropis procera* leaf

Table 4 Chemical components of ethanolic extract of *Calotropis procera* leaf

Peak No.	Retention Time (Min)	Compound Name	Molecular Formula	Molecular Weight (g/mol)	Area
1	9.4635	Octanoic acid, methyl ester	$C_9H_{18}O_2$	158.24	0.3641
2	**10.647**	**Glycerin**	**$C_3H_8O_3$**	**92.09**	**9.6026**
3	10.9302	Glycerin	$C_3H_8O_8$	92.09	0.1574
4	**11.3536**	**Glycerin**	**$C_3H_8O_3$**	**92.09**	**8.5**
5	11.4068	Glycerin	$C_3H_8O_8$	92.09	3.8162
6	11.5245	Pentanoic acid, ethyl ester	$C_7H_{14}O_2$	130.18	2.0074
7	**11.7389**	**Glycerin**	**$C_3H_8O_3$**	**92.09**	**8.4665**
8	11.7866	Glycerin	$C_3H_8O_3$	92.09	3.0674
9	**12.357**	**Glycerin**	**$C_3H_8O_3$**	**92.09**	**11.2037**
10	12.3876	Glycerin	$C_3H_8O_3$	92.09	3.6341
11	**12.6522**	**Glycerin**	**$C_3H_8O_3$**	**92.09**	**8.9004**
12	12.6785	Glycerin	$C_3H_8O_3$	92.09	3.4088
13	12.8848	Glycerin	$C_3H_8O_3$	92.09	3.3251

To be continued next page

Table 4 continued

Peak No.	Retention Time (Min)	Compound Name	Molecular Formula	Molecular Weight (g/mol)	Area
14	14.1637	2-Undecanone	$C_{11}H_{22}O_{22}$	170.29	0.0894
15	14.9991	Decanoic acid, methyl ester	$C_{11}H_{22}O_2$	186.29	2.5303
16	16.884	Decanoic acid, ethyl ester	$C_{12}H_{24}O_2$	200.32	2.1765
17	**20.1521**	**Dodecanoic acid, methyl ester**	**$C_{13}H_{26}O_2$**	**214.35**	**8.8189**
18	**21.8243**	**Decanoic acid, ethyl ester**	**$C_{12}H_{24}O_2$**	**200.32**	**4.5257**
19	24.7357	Methyl tetradecanoate	$C_{15}H_{30}O_2$	242.40	2.849
20	**26.2305**	**Tetradecanoic acid, ethyl ester**	**$C_{16}H_{32}O_2$**	**256.43**	**6.7103**
21	28.7702	Pentadecanoic acid, 14-methyl-, methyl ester	$C_{17}H_{34}O_2$	270.45	1.0483
22	29.6073	Hexadecanoic acid, ethyl ester	$C_{18}H_{36}O_2$	284.48	0.4866
23	30.5685	9-Octadecenoic acid, methyl ester, (E)-	$C_{19}H_{36}O_2$	296.49	1.5934
24	30.7587	Methyl stearate	$C_{19}H_{38}O_2$	298.50	0.2591
25	31.0111	Linoleic acid ethyl ester	$C_{20}H_{36}O_2$	308.50	0.1165
26	31.0536	(E)-9-Octadecenoic acid ethyl ester	$C_{20}H_{38}O_2$	310.51	1.6207
27	31.2212	Octadecanoic acid, ethyl ester	$C_{20}H_{40}O_2$	312.53	0.3156
28	31.8995	Cyclohexanone,4-(1,1-dimethylethyl)-	$C_{10}H_{18}O$	154.25	0.0562
29	32.9706	*	$C_{19}H_{38}O_4$	330.50	0.0534
30	33.1896	Bis(2-ethylhexyl) phthalate	$C_{24}H_{38}O_4$	390.56	0.0531
31	34.0707	9-Octadecenoic acid (Z)-, 2,3-dihydroxypropyl ester	$C_{21}H_{40}O_4$	356.54	0.1681
32	35.0517	Supraene	$C_{30}H_{62}$	422.81	0.0753

***** = Hexadecanoic acid, 2-hydroxy-1 (hydroxymethyl)ethyl ester

Table 5 Chemical components of ethanolic extract of *Faidherbia albida* leaf

Peak No.	Retention Time (Min)	Compound Name	Molecular Formula	Molecular Weight (g/mol)	Area Pct
1	5.4618	Bicyclo[2.2.1]heptan-2-one, 1,7,7-trimethyl-, (1S)-	$C_{10}H_{16}O$	152.23	0.295
2	6.3074	5-Hexyn-1-ol	$C_6H_{10}O$	98.15	0.579
3	9.6255	Decanoic acid, methyl ester	$C_{11}H_{22}O_2$	186.29	0.5646
4	**14.6826**	**Dodecanoic acid, methyl ester**	**$C_{13}H_{26}O_2$**	**214.34**	**3.1203**
5	15.4093	O,N-Dimethyl-dehydrococcinine	$C_{16}H_{23}NO_2$	261.36	0.0856
6	19.1336	9,17-Octadecadienal, (Z)-	$C_{18}H_{32}O$	264.45	0.5656
7	19.4597	Nonanoic acid, 9-oxo-, methyl ester	$C_{10}H_{18}0_3$	186.25	1.2775
8	23.4221	7,11-Hexadecadienal	$C_{16}H_{28}O$	236.39	0.9467
9	**23.8724**	**Hexadecanoic acid, methyl ester**	**$C_{17}H_{34}O_2$**	**270.45**	**7.1809**
10	**27.3635**	**9,17-Octadecadienal, (Z)-**	**$C_{18}H_{32}O$**	**264.45**	**73.4853**
11	**29.2576**	**9,11-Octadecadienoic acid, methyl ester, (E,E)-**	**$C_{19}H_{34}O_2$**	**294.48**	**2.5752**
12	**30.5752**	**4-Nonyne**	**C_9H_{16}**	**124.22**	**2.1228**
13	30.7236	9,12-Octadecadienal	$C_{18}H_{32}O$	264.45	0.3879
14	31.1148	1,5,9,13-Tetradecatetraene	$C_{14}H_{22}$	190.32	0.8299
15	31.2635	7,10-Hexadecadienoic acid, methyl ester	$C_{17}H_{30}O_2$	266.42	0.4664
16	31.5694	Cyclododecyne	$C_{12}H_{20}$	164.29	1.5248
17	32.4937	Cyclopentaneundecanoic acid	$C_{16}H_{30}O_2$	254.41	0.2485
18	32.8505	Cyclopentaneundecanoic acid	$C_{16}H_{30}O_2$	254.41	0.2064
19	33.0633	1,3-Oxathiane, 2-ethyl-6-methyl-	$C_7H_{14}OS$	146.25	0.1488
20	33.9854	7,10-Hexadecadienoic acid, methyl ester	$C_{17}H_{30}O_2$	266.42	0.2137
21	35.4994	1,5,9,13-Tetradecatetraene	$C_{14}H_{22}$	190.32	1.6074
22	36.0627	7,10-Hexadecadienoic acid, methyl ester	$C_{17}H_{30}O_2$	266.42	1.5677

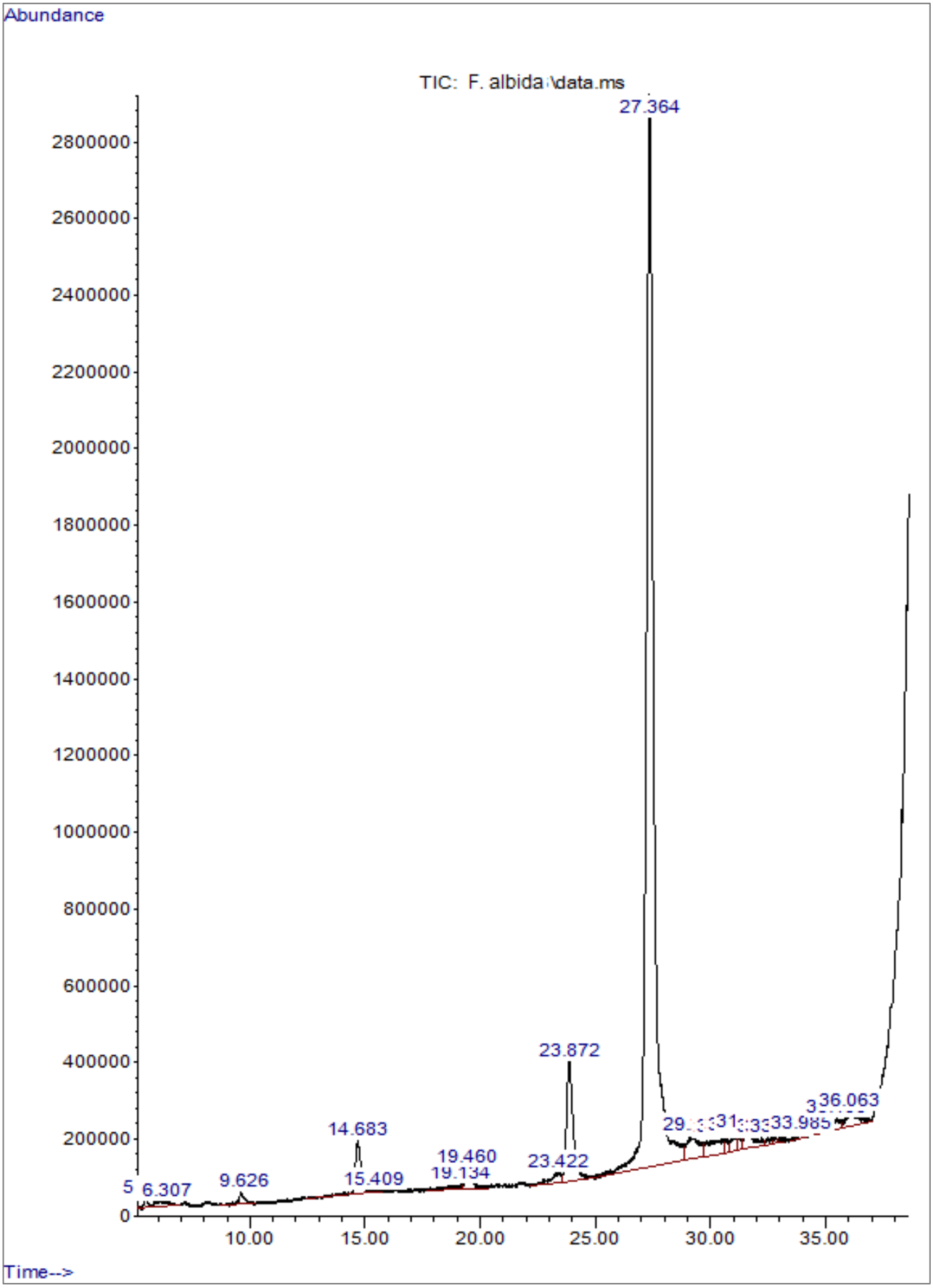

Figure 6: GC-MS chromatogram ethanolic extract of *Faidherbia albida* leaf

This male dominance in bone setting practices can be attributed to the physical demands of the craft, as well as societal expectations that associate masculinity with manual, hands-on work such as bone setting and surgery. Mukherjee et al. (2006) also highlighted the dominance of older, more experienced practitioners in traditional

medicine, which corresponds with the findings of this study, where (26.7%) of practitioners were aged between 41 and 50. Older practitioners are typically seen as custodians of traditional knowledge, having acquired skills through years of apprenticeship and experience. The finding that a significant portion of respondents (59.2%) had no formal education aligns with Bodeker (2001), who emphasized that many traditional healers rely on practical knowledge rather than formal academic training.

The study's identification of 48 medicinal plant species belonging to 26 families echoes the extensive biodiversity often documented in ethnobotanical studies. Giday et al. (2009) found that African traditional medicine, especially in bone setting and fracture healing, frequently involves a wide range of plant species from various families, each selected for its specific therapeutic properties. The predominant use of the *Fabaceae* family (8 species) in this study is consistent with findings from Ekor et al. (2010), who reported that *Fabaceae* plants are frequently utilized for their analgesic, anti-inflammatory, and healing properties in Nigeria.

Sofowora (2008) also reported that the Moraceae family is well-represented in traditional medicine, which correlates with the presence of Ficus species, widely used in many parts of Africa for the treatment of bone fractures and injuries. The extensive use of diverse plant families in this study supports the argument made by Sofowora (2008) about the importance of preserving and cataloging the knowledge of medicinal plants, especially in rapidly changing ecological and cultural landscapes. The finding that 14 families had only one species each suggests the application of a wide range of plants in a context-specific manner, as seen in Rubi *et al.* (2015), who reported that traditional healers often use a variety of species for personalized treatment plans, depending on the specifics of the injury or the patient's health condition.

The use of Relative Frequency of Citation (RFC) as an indicator of the popularity of certain plant species is in line with standard ethnobotanical research practices. The prominence of *Calotropis procera* (RFC = 0.11) in this study is corroborated by Olajide et al. (2000), who found *Calotropis procera* to be one of the most commonly used plants in traditional Nigerian medicine, particularly for treating ailments such as inflammation, pain, and fractures. Their study identified the plant as effective in bone regeneration and soft tissue healing, which is consistent with the results found here. Other studies, such as Glew et al. (2010), similarly document the use of *Vitellaria paradoxa*, *Acacia nilotica*, and *Zingiber officinale* for their anti-inflammatory, analgesic, and wound-healing properties. These plants have been validated in various ethnopharmacological studies and contribute to understanding why practitioners frequently cite them. The lower RFC of *Adansonia digitata*, *Prosopis africana*, and *Faidherbia albida* (0.017) suggests they are less commonly used for bone setting, but this does not rule out their efficacy in other areas of health, such as gastrointestinal or skin disorders, which have been documented in other studies (Albuquerque et al., 2010).

The lack of standardized dosages and preparation methods for medicinal plants in traditional medicine is a common finding in the literature. Bussmann et al. (2006) observed that in most ethnopharmacological studies, there is no uniformity in the way medicinal plants are prepared or dosed, reflecting the highly individualized nature of traditional healing practices. The use of ointments (40.0%), decoctions (37.0%), and macerations (17.0%) in this study supports the idea that these preparations are tailored based on the severity and type of injury. Giday et al. (2009) noted that topical ointments are often preferred for musculoskeletal issues, as they provide localized relief and can be easily applied to the affected area.

The fact that a significant portion of plant species (47.5%) are taken orally suggests that traditional healers also target internal healing mechanisms. This aligns with findings by Moyo et al. (2017), who highlighted that many plants used for bone setting have systemic effects that aid in tissue regeneration and immune system stimulation. The combined use of topical and oral treatments indicates a holistic approach to bone setting that addresses external injury and internal healing processes.

Phytochemical screening of *Calotropis procera* and *Faidherbia albida* revealed the presence of bioactive compounds such as alkaloids, flavonoids, saponins, and terpenoids, which are known for their analgesic, anti-inflammatory, and wound-healing properties. These findings are consistent with those by Maupeu et al. (2014) and Olajide et al. (2000), who reported that *Calotropis procera* contains compounds that possess anti-inflammatory and analgesic activities. These phytochemical compounds are known to inhibit inflammatory mediators like cyclooxygenase (COX) and prostaglandins, which directly contribute to the anti-inflammatory effects observed in traditional bone setting. Mbaya et al. (2018) also identified terpenoids, alkaloids, and flavonoids in *Faidherbia albida*, supporting its anti-inflammatory and pain-relieving plant role. The absence of cardiac glycosides and anthraquinones in the plants studied here further confirms their safety for consumption and topical use, as these compounds are often associated with toxicological effects on the heart and digestive system. The presence of steroids in *Calotropis procera* reveal its anti-inflammatory activity as steroids are often associated with reducing inflammation and promoting tissue healing, which may explain its effectiveness in treating bone fractures and sprains.

In this study, *Calotropis procera* has a higher citation, indicating its widespread recognition and use in traditional bone setting, *Faidherbia albida* remains highly relevant despite having the least citation. The low citation may not necessarily reflect its medicinal potential but rather a lack of awareness among traditional healers about its full therapeutic benefits. Scientific evidence suggests that *Faidherbia albida* contains potent bioactive compounds with strong anti-inflammatory properties essential for reducing pain, swelling, and accelerating bone healing. Only the leaves of *Faidherbia albida* were evaluated in the study, but other parts of the plant, such as the bark, roots, pods, and seeds, may contain even higher concentrations

of active constituents with greater anti-inflammatory and bone-healing properties. Therefore, further research should focus on these parts to fully explore the plant's medicinal potential. By expanding its use beyond just the leaves, *Faidherbia albida* could become a more valuable and widely accepted remedy in traditional bone setting. Raising awareness and conducting pharmacological studies on different plant parts will help optimize its application while preserving indigenous healing knowledge.

The GC-MS analysis of the ethanolic leaf extract of *Calotropis procera* showed 32 peaks, indicating the presence of 32 bioactive compounds in the leaf. The Peak no., Retention Time (Min), Compound name, Molecular formula, Molecular weight (g/mol), and Area percentage constituted the parameters by which each compound was identified. The result showed some major bioactive compounds appearing in the dominant peaks of the chromatogram. The major bioactive compounds found in the ethanolic extract of *Calotropis procera* include: Glycerin ($C_3H_8O_3$), Dodecanoic acid, methyl ester ($C_{13}H_{26}{}_{O2}$), Tetradecanoic acid, ethyl ester ($C_{16}H_{32}O_2$), and Decanoic acid, ethyl ester ($C_{12}H_{24}O_2$). Glycerin is the most abundant compound detected, appearing multiple times with a high area percentage. Several fatty acid esters, such as Tetradecanoic acid, methyl ester, Decanoic acid, methyl ester, and Dodecanoic acid, methyl ester, are present in significant amounts. Glycerin is a simple polyol compound. It is a colorless, odorless, viscous liquid that is sweet-tasting and non-toxic. It is widely used in pharmaceutical formulations, food products, and cosmetics due to its moisturizing properties. Glycerin is also an important intermediate in the synthesis of various chemicals. Glycerin is widely recognized for its moisturizing properties and has anti-inflammatory effects. It can help soothe irritation and reduce inflammation, particularly in skin applications (Loden 2001). Glycerin is a powerful humectant and has similar hygroscopicity to natural moisturizing factors. After topical application, it increases the moisture content inside and outside the keratinocytes, preventing the intercellular lipids' lamellar structure from being transformed from plate to crystal. (It also helps to protect the skin barrier by regulating the expression of aquaporin-3, the primary aquaporin in the epidermis (Nair 2003). This effect is somewhat maintained even after the glycerin is removed from the skin surface. Dodecanoic acid, methyl ester, or methyl laurate, has demonstrated anti-inflammatory effects by inhibiting pro-inflammatory cytokine production. Tetradecanoic acid, ethyl ester, as an ester of myristic acid, can exhibit anti-inflammatory properties by affecting lipid signaling and reducing inflammatory mediators. Decanoic acid, methyl ester, exhibits anti-inflammatory properties by modulating fatty acid metabolism and reducing pro-inflammatory cytokines. The presence of these major bioactive compounds agrees with the findings of (Olu *et al.*, 2022)

The GC-MS analysis of the ethanolic leaf extract of *Faidherbia albida* showed 22 peaks, indicating the presence of 22 bioactive compounds in the leaf. The Peak No., Retention Time (Min), Compound name, Molecular formula, Molecular weight (g/mol), and Area percentage are shown in the table. The result showed some major bioactive compounds appearing in the dominant peaks of the chromatogram. The major bioactive compounds found in the ethanolic extract of *Faidherbia albida* include; Hexadecanoic acid, methyl ester ($C_{17}H_{34}O_2$), 9,17-Octadecadienal, (Z)- ($C_{18}H_{32}O$), 9,11-Octadecadienoic acid, methyl ester, (E,E)- ($C_{19}H_{34}O_2$), and 4-Nonyne (C_9H_{16}) 9,17-Octadecadienal, (Z)- is an unsaturated aldehyde that may have anti-inflammatory effects through modulation of lipid signaling pathways. 9,11-Octadecadienoic acid, methyl ester, (E,E)- a linoleic acid ester, has been associated with anti-inflammatory activities by modulating fatty acid pathways and reducing inflammation markers. 4-Nonyne is an alkyne derivative that can sometimes modulate inflammation by interacting with cellular enzymes. These major compounds identified have common bioactive properties, which include antioxidant and anti-inflammatory properties (Aparna *et al.*, 2012)

CONCLUSION

In conclusion, this study has contributed knowledge of the medicinal plants used by traditional bonesetters in Katsina State, Nigeria. Their families, usage patterns, and mode of preparation were identified as well. The phytochemical composition of these plants was evaluated using standard methods, revealing the presence of alkaloids, flavonoids, saponins, tannins, terpenoids, and carbohydrates in all samples. Gas Chromatography-Mass Spectrometry (GC-MS) identified 32 bioactive compounds in *Calotropis procera* and 22 in *Faidherbia albida*, with several major compounds in both plants possessing anti-inflammatory properties.

RECOMMENDATIONS

Based on the findings of this study, it is recommended that;

1. Establishing a digital database or herbarium by researchers and the government can aid in archiving the plant species, ensuring the preservation of this valuable indigenous knowledge for future generations
2. Other parts of the plants should be evaluated and incorporated into further research to fully explore their therapeutic potential and expand the understanding of their medicinal properties and traditional use.
3. Collaboration between researchers, healthcare providers, and traditional healers is essential for integrating traditional and modern practices.
4. Establishing standardized dosage guidelines for the medicinal plants used in traditional bone setting is also essential to ensure both safety and efficacy. Proper dosage recommendations would help mitigate the risks associated with excessive or insufficient intake of herbal remedies, reducing the likelihood of toxicity or ineffectiveness.

DATA AVAILABILITY

The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

FUNDING

No funding

DECLARATIONS

Ethics approval and consent to participate

Ethical considerations were duly observed during data collection. All the respondents were briefed about the purposes of the work during the data collection exercise. Ethical approval was obtained from the Department of Biology, Umaru Musa Yar'adua University, and the various ethical committees of the Local Government Authority involved in the study. The procedures used in this study adhered to the tenets of the Declaration of Helsinki. Informed consent was obtained from all individual participants included in the study.

Conflict of interest

None to declare.

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APPENDIX 1

QUESTIONNAIRE

ETHNOBOTANICAL STUDIES AND ANTI-INFLAMMATORY ACTIVITY OF MEDICINAL PLANTS USED FOR TRADITIONAL BONE SETTING USED IN KATSINA STATE, NIGERIA

SECTION 1: PARTICIPANT'S DEMOGRAPHIC PROFILE

Please tick the appropriate answer where necessary.

1. SEX: Male ☐ Female ☐

2. AGE: 20-30 ☐ 31-40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ >70 ☐

3. L.G.A: Malumfashi ☐ Funtua ☐ Daura ☐ Sandamu ☐ Katsina ☐ Kaita ☐

4. EDUCATIONAL STATUS: No Formal Education ☐ Primary ☐ Secondary ☐ Tertiary ☐

5. OCCUPATION: Traditional healers ☐ TBS ☐ Farmers ☐ Other ☐

TBS: Traditional bone setters

SECTION B

1. Scientific name of plant …….
2. Common names/Local names of plant …….
3. Disease/Illness for which the plant is used .....
4. Parts of the plant used …….
5. How are these parts used? Fresh ☐ Dried ☐
6. How do you prepare for it for medicinal use? (Powder ☐ Ointment ☐ Maceration ☐ Decoction ☐
7. What is the mode of Administration? Oral ☐ Topical ☐ Dermal ☐

APPENDIX II

Plate 1 ***Calotropis procera*** **source:(katsina state institute of technology and management)**

Plate 2 ***Faidherbia albida*** **tree (plants on the world online)**