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Full Length Research Paper

Antioxidant activity of extracts from *Schinus molle* L. and *Gleditsia triacanthos* L.

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Methanolic and chloroform extracts obtained from various parts of *Schinus molle* and *Gleditsia triacanthos* were evaluated by DPPH radical scavenging assay. The methanolic extracts from *S. molle* showed scavenging activity ranging from 35.97±1.02 to 83.38±2.74%, while the chloroform seed extract showed relatively weak scavenging activity ranging from 8.20±1.02 to 68.82±3.17%. The IC_{50} values of *S. molle* methanolic leaves extract, *S. molle* methanolic stem-bark extract and *S. molle* chloroform seed extract (SMMELS, SMMESB and SMCHSD) were found to be 476.43, <250 and ~3000 µg mL^{-1}, respectively. The methanolic extracts from *G. triacanthos* showed scavenging activity ranging from 35.97±1.02 to 92.36±0.11%, while the chloroform seed extract showed relatively very weak scavenging activity ranging from 3.74±1.04 to 15.47±4.57%. The IC_{50} values for *G. triacanthos* methanolic leaves extract, *G. triacanthos* methanolic stem-bark extract, *G. triacanthos* methanolic thorns extract and *G. triacanthos* chloroform seed extract (GTMELS, GTMESB, GTMETS and GTCHSD) were found to be 452.32, 720.56, <250 and >3000 µg mL^{-1}, respectively. The positive controls, GAMEOH and GAETAC, showed an IC_{50} value <250 µg mL^{-1} each. From this study, we concluded that the extracts from these two medicinal plants, *S. molle* and *G. triacanthos*, showed promising antioxidant activity. Therefore, further investigations, such as bioactive guided isolation of pure compounds, antioxidant activity of pure compounds, application of these extracts or pure compounds in culinary, etc., are required.

Key words: Antioxidant, chloroform extract, gallic acid, *Schinus molle*, *Gleditsia triacanthos*, radical scavenging assay, methanolic extract.

INTRODUCTION

The species *Schinus molle* L. also known as American pepper, pervian pepper, pepper tree, aguaribay, peppercorn tree, etc., belongs to the Anarcardiaceae family (Mehani and Segni, 2013; Pedro et al., 2012; Trevor et al., 2013). *S. molle* is a medicinal plant used in traditional medicine (Abderrahim et al., 2018). *S molle* is

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a tree that grows to 7 to 10 m height; it is native to South and Central America and has been cultivated in Southern African countries. The fruits (seeds) of *S*. *molle* are edible and they are about 5 mm diameter (Trevor et al., 2013). The seeds of *S*. *molle* are reddish pink and have a taste similar to pepper. It has been reported that *S*. *molle* has antibacterial, analgesic, cytotoxic, anti-inflammatory, antifungal, antiseptic, insecticidal, and antioxidant activities (Deveci et al., 2010; Diaz et al., 2008; Ferrero et al., 2006; Ruffa et al., 2002; Yueqin et al., 2003; Abir et al., 2016; Abderrahim et al., 2018; Bendaoud et al., 2010; Mohamed et al., 2016).

The species of *Gleditsia triacanthos* L. is a deciduous tree belonging to the Fabaceae family. *G*. *triacanthos* is also known by other names such as honey locust and thorny locust. *G*. *triacanthos* is native to Asia and North America (Benhamiche et al., 2016; Mohammed et al., 2014). *G*. *triacanthos* grows to 15 to 30 m height (Stubbendiek and Conard, 1989). The yellow flowers of *G*. *triacanthos* have strong pleasant smell. *G*. *triacanthos* has thorns which are single or branched and grow to 3 to 10 cm. The edible fruits of *G*. *triacanthos* are about 15 to 40 cm long and about 2.5 to 3.5 cm wide (Blair, 1990). GreenTech S.A. uses extract from seeds of *G. triacanthos* and has been sold in the name of *Gleditschia* as cosmetic product (Miguel et al., 2010).

Gleditsia species have been used for personal care and medicinal applications that include hair protection, local medicine for smallpox, skin diseases, whooping, measles, asthma and difficult labour in the Native American (Miyase et al., 2010). It has been reported that *G*. *triacanthos* has anti-inflammatory, analgesic, hepatoprotective, antimicrobial and antioxidant activities (Tahia et al., 2013; Mohammed et al., 2014; Miguel, 2010).

The antioxidant study of essential oils and extracts from *S*. *molle* and *G*. *triacanthos* were reported previously (Abir et al., 2016; Abderrahim et al., 2018; Bendaoud et al., 2010; Mohamed et al., 2016; Mohammed et al., 2014; Miguel, 2010). However, the scavenging activity of methanolic and chloroform extracts of various parts of *S*. *molle* and *G. triacanthos* has not been reported previously, particularly the plant species gathered from the Kingdom of Lesotho. Therefore, the aforementioned plant extracts were screened for their DPPH radical scavenging assay and the results thus obtained are reported.

MATERIALS AND METHODS

Plant materials

The plant materials, *S*. *molle* and *G*. *triacanthos*, were collected from Botanical Garden, Roma Campus, National University of Lesotho. Both plant materials were collected in August 2017 and were identified by Mr. Moretloa Polaki, Lecturer, Department of Biology, Faculty of Science and Technology, National University of Lesotho. From *S*. *molle*, the following parts of plant materials were used for this study: leaves (596.744 g), stem-bark (241.246 g) and seeds (115.126 g). From *G*. *triacanthos*, the following parts were used for this study: leaves (337.000 g), stem-bark (247.271 g), thorns (165.169 g) and seeds (217.705 g). A voucher specimen for each part of the plants is kept at Organic Chemistry Laboratory, Department of Chemistry and Chemical Technology, Faculty of Science and Technology, National University of Lesotho. The following labelling was used to represent various parts of plant materials: KMSMLS, KMSMSB and KMSMSD for leaves, stem-bark and seeds of *S*. *molle*, respectively; KMGTLS, KMGTSB, KMGTTS and KMGTSD for leaves, stem-bark, thorns and seeds of *G*. *triacanthos*, respectively.

Processing of materials

The plant materials were allowed to air dry at room temperature for two weeks. The air dried leaves and seeds of *S*. *molle* were ground into powder using a commercial blender (Waring Blender, Blender 80119, Model HGB2WT93, 240V AC, 50-80 Hz, 3.6 AMPs, Laboratory and Analytical Supplier). The air dried stem-bark of *S*. *molle* was chopped into small pieces and then crushed using a Woodworking Table Saw 250 mm machine (Serial Number: JFD1412109-13, Model Number: SAWLD001, Motor, 1500W, 220 V, 50 Hz, Blade Rising Range: 0-80 mm, Motor Speed: 4500 rpm, Max. Depth of Cutting (90° and 45°): 80 mm and 5 mm). The crushed materials were further ground into powder using the aforementioned Waring Blender. The same procedures mentioned were repeated to get powder from the air-dried leaves, seeds, thorns and stem-bark of *G*. *triacanthos*.

Preparation of plant extracts

The powdered leaves of *S*. *molle* were extracted first with methanol at room temperature for two days by shaking manually and occasionally. The solution was filtered using Whatman No.1 filter paper and the solvent methanol was removed using water bath and/or Buchi rota-vapour. The same procedure was repeated once again. Finally, the material was extracted with methanol at reflux condition for 5 h. All three filtrates were combined and 63.00 g of methanolic extract was obtained. The same procedure was followed for the powdered stem-bark of *S*. *molle* and 7.19 g of methanolic extract was obtained. The powdered seeds of *S*. *molle* was extracted first with chloroform with at room temperature by shaking manually and occasionally followed by at reflux condition for 5 h. The extracts were combined and 12.91 g of chloroform extract was obtained after removal of solvent using water bath and/or Buchi rota-vapour. The same methanolic extraction procedure was followed for leaves, stem-bark and thorns of *G*. *triacanthos*, respectively, 47.51, 8.44 and 7.51 g of methanolic extracts were obtained. Similarly, the same chloroform procedure was followed for seeds of *G*. *triacanthos* and 8.94 g of resinous chloroform extract was obtained after removal of solvent using water bath and/or Buchi rota-vapour.

Chemicals and solvents used

Gallic acid, DPPH, DMSO (AR grade, 99.5%), methanol (AR grade, 99.5%), ethyl acetate (AR grade, 99.5%), and chloroform (AR grade, 99.5%) were all purchased from Sigma-Aldrich.

DPPH radical scavenging assay and determination of IC_{50} values

DPPH radical scavenging activity of various extracts of *S*. *molle* and

Table 1. The percentage radical scavenging activity of various extracts from *S. molle* and *G. triacanthos* at various concentrations.

Extract	Concentrations (µg mL^{-1})				
	250	500	1000	2000	3000
SMMELS	39.41±3.19	71.62±1.41	77.96±5.10	82.53±5.13	83.38±2.74
SMMESB	51.04±2.74	51.81±0.39	54.22±4.57	54.86±3.19	56.68±5.13
SMCHSD	8.20±1.02	21.37±4.57	22.23±2.29	63.40±2.69	68.82±3.17
GTMELS	39.50±3.49	62.47±5.18	66.43±5.14	84.04±0.61	86.29±2.27
GTMESB	35.97±1.02	44.87±3.29	59.94±2.72	60.05±4.40	63.40±2.69
GTMETS	67.10±7.06	89.31±0.88	90.15±0.81	92.00±0.35	92.36±0.11
GTCHSD	3.74±1.04	6.14±1.39	8.26±0.99	8.34±0.11	15.47±4.57
GAMEOH	52.53±4.64	54.30±0.82	56.29±2.64	64.44±2.04	69.42±7.25
GAETAC	76.96±1.50	92.49±5.18	93.12±0.39	93.67±4.06	94.57±1.02

SMMELS: *S. molle* methanolic leaves extract; SMMESB: *S. molle* methanolic stem-bark extract; SMCHSD: *S. molle* chloroform seed extract; GTMELS: *G. triacanthos* methanolic leaves extract; GTMESB: *G. triacanthos* methanolic stem-bark extract; GTMETS: *G. triacanthos* methanolic thorns extract; GTCHSD: *G. triacanthos* chloroform seed extract; GAMEOH: gallic acid in 50% methanol served as positive control for GTMESB, GTMESB, GTMETS, SMMELS and SMMESB; GAETAC: gallic acid in ethyl acetate served as positive control for GTCHSD and SMCHSD. All experiments were conducted in triplicate (n = 3) and reported as mean of three values together with standard deviation, ±SD.

G. triacanthos was conducted according to the method described in the literature (Sasidharan et al., 2007) with slight modification. Briefly, stock solutions of methanolic extracts were prepared at a concentration of 3.0 mg of extract in 1 mL of 50% methanol (v/v). Further dilutions were made from these stock solutions such that solution was obtained with concentrations of 3000, 2000, 1000, 500 and 250 µL for each extract. 50 µL of each one of them was mixed with 1 mL of 0.1 mM solution of DPPH in 50% methanol (v/v). The mixture without extract sample was used as blank and just spiked with 50 µL of 50% methanol (v/v). A stock solution of commercial antioxidant, gallic acid, of the same concentration in 50% methanol (v/v) was prepared and further dilutions were made as previously and served as positive control for methanolic extracts. Similarly, stock solutions of chloroform extracts were prepared at a concentration of 3.0 mg of extract in 1 mL of ethyl acetate.

Further dilutions were made from these stock solutions such that extract solution was obtained with concentrations of 3000, 2000, 1000, 500 and 250 µL for each extract. 50 µL of each one of them was mixed with 1 mL of 0.1 mM solution of DPPH in ethyl acetate. The mixture without extract sample was used as blank and just spiked with 50 µL of ethyl acetate. A stock solution of gallic acid of the same concentration in ethyl acetate was prepared and further dilutions were made as previously and served as positive control for chloroform extracts. The mixtures were incubated for 30 min and their optical density was measured at 517 nm. The IC_{50} values were calculated from graphs by plotting extract concentrations versus percentage inhibition of DPPH radical using Microsoft Excel.

The extract concentration that causes 50% reduction in the initial concentration of DPPH is defined as the IC_{50} value of extract which is important measure of potency for a given extract. Each experiment was carried out in triplicate and the averages of the three values were used to calculate IC_{50} values. Standard deviation was calculated for each concentration from the three values of the experiment. The ability to scavenge DPPH radical was calculated by Equation 1:

$$\text{DPPH radical scavenging activity (\%)} = ((A_0 - A_1) / A_0) \times 100 \quad (1)$$

Where:

A_0 = optical density of solution of DPPH radical and A_1 = optical density of solution of DPPH radical + solution of extract (or optical density of solution of DPPH radical + solution of Gallic acid).

Statistical analysis

Results were expressed as means of three determinations. One way analysis of variance (ANOVA) was used to compare means at the significance level $p < 0.05$. All analysis were performed by Microsoft Excel software.

RESULTS AND DISCUSSION

Table 1 shows the DPPH radical scavenging activity of various extracts of *S. molle* and *G. triacanthos*. *S. molle* methanolic leaves extract (SMMELS) showed 39.41±3.19, 71.62±1.41, 77.96±5.10, 82.53±5.13 and 83.38±2.74% of scavenging activity at concentrations of 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. While the positive control (GAMEOH), showed 52.53±4.64, 54.30±0.82, 56.29±2.64, 64.44±2.04 and 69.42±7.25% of scavenging activity at concentrations of 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. Thus, SMMELS exhibited higher radical scavenging activity than positive control at all concentrations except at concentration 250 µg mL^{-1}. At concentration 250 µg mL^{-1}, SMMELS showed only 39.41±3.19% of scavenging activity while GAMEOH showed 52.53±4.64% of scavenging activity. *S. molle* methanolic stem-bark extract (SMMESB) showed 51.04±2.74, 51.81±0.39, 54.22±4.57, 54.86±3.19 and 56.68±5.13% of scavenging activity at concentrations 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. This result showed that SMMESB has comparable activity as that of positive control at low concentrations and at high concentrations; the scavenging

Table 2. The IC_{50} values of various extracts of *S. molle* and *G. triacanthos* based on DPPH radical scavenging assay.

S/N	Extracts	IC_{50} (µg mL^{-1})
1	SMMELS	476.43
2	SMMESB	<250
3	SMCHSD	~3000
4	GTMELS	452. 32
5	GTMESB	720.56
6	GTMETS	<250
7	GTCHSD	>3000
8	GAMEOH	<250
9	GAETAC	<250

SMMELS: *S. molle* methanolic leaves extract; SMMESB: *S. molle* methanolic stem-bark extract; SMCHSD: *S. molle* chloroform seed extract; GTMELS: *G. triacanthos* methanolic leaves extract; GTMESB: *G. triacanthos* methanolic stem-bark extract; GTMETS: *G. triacanthos* methanolic thorns extract; GTCHSD: *G. triacanthos* chloroform seed extract; GAMEOH: gallic acid in 50% methanol served as positive control for GTMESB, GTMESB, GTMETS, SMMELS and SMMESB; GAETAC: gallic acid in ethyl acetate served as positive control for GTCHSD and SMCHSD. All experiments were conducted in triplicate (n = 3) and reported as mean of three values together with standard deviation, ±SD.

activity was slightly higher. *S. molle* chloroform seed extract (SMCHSD) showed 8.20±1.02, 21.37±4.57, 22.23±2.29, 63.40±2.69 and 68.82±3.17% of scavenging activity at concentrations 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. In this case, the positive control (GAETAC) showed 76.96±1.50, 92.49±5.18, 93.12±0.39, 93.67±4.06 and 94.57±1.02% of scavenging activity at concentrations of 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. This result showed that SMCHSD exhibited very weak activity at low concentrations relative to positive control, GAETAC. However, at high concentrations such as 2000 and 3000 µg mL^{-1}, it showed higher scavenging activity of 63.40±2.69 and 68.82±3.17%, respectively. Among the three extracts (SMMELS, SMMESB and SMCHSD) from *S. molle*, SMMELS showed highest scavenging activity (refer to Table 1).

G. triacanthos methanolic leaves extract (GTMELS) showed 39.50±3.49, 62.47±5.18, 66.43±5.14, 84.04±0.61 and 86.29±2.27% of scavenging activity at concentrations 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. Thus, GTMELS exhibited higher radical scavenging activity than positive control (GAMEOH) at all concentrations except at concentration 250 µg mL^{-1}. At concentration 250 µg mL^{-1}, GTMELS showed only 39.50±3.49% of scavenging activity while GAMEOH showed higher scavenging activity of 52.53±4.64%. *G. triacanthos* methanolic stem-bark extract (GTMESB) showed 35.97±1.02, 44.87±3.29, 59.94±2.72, 60.05±4.40 and 63.40±2.69% of radical scavenging activity at concentrations 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. Therefore, GTMESB showed low scavenging activity of 35.97±1.02 and 44.87±3.29% at concentrations 250 and 500 µg mL^{-1}, respectively, while GAMEOH showed scavenging activity of 52.53±4.64 and 54.30±0.82%, respectively. However, at concentrations 1000, 2000 and 3000 µg mL^{-1}, both GTMESB and GAMEOH showed comparable scavenging activity (Table 1). *G. triacanthos* methanolic thorns extract (GTMETS) showed scavenging activity of 67.10±7.06, 89.31±0.88, 90.15±0.81, 92.00±0.35 and 92.36±0.11% at concentrations 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. This result showed that GTMETS showed remarkably high scavenging activity at all concentrations compared to positive control, GAMEOH. *G. triacanthos* chloroform seed extract (GTCHSD) showed very weak activity of 3.74±1.04, 6.14±1.39, 8.26±0.99, 8.34±0.11 and 15.47±4.57% of scavenging activity at concentrations 250, 500, 1000, 2000 and 3000 µg mL^{-1}, respectively. Among the four extracts (GTMELS, GTMESB, GTMETS and GTCHSD) from *G. triacanthos*, GTMETS showed highest scavenging activity (Table 1).

The IC_{50} values of various extracts of *S. molle,* and *G. triacanthos* are shown in Table 2. SMMELS, SMMESB and SMCHSD exhibited IC_{50} values of 476.43, <250 and ~3000 µg mL^{-1}, respectively. SMMESB is the most potent with IC_{50} value <250 µg mL^{-1}. GTMELS, GTMESB, GTMETS and GTCHSD exhibited IC_{50} values of 452. 32, 720.56, <250 and >3000 µg mL^{-1}, respectively. Of the four extracts from *G. triacanthos*, GTMETS was found to be the most potent with IC_{50} value <250 µg mL^{-1}. The positive controls, GAMEOH and GAETAC both showed IC_{50} value <250 µg mL^{-1}.

The radical scavenging activity of hexane, ethyl acetate, ethanol and methanol extracts from fruits of *S. molle* have previously been evaluated and their IC_{50}

values were found to be 539.4±13.3, 30.7±0.9, 12.5±0.4 and 4.4±0.2 µg mL^{-1}, respectively (Abir et al., 2016). The essential oils from leaves, stems and fruits of *S*. *molle* showed IC_{50} values 3586±119.0, 3559.2±122.0 and >10000 µg mL^{-1}, respectively (Abir et al., 2016). However, methanolic extracts were obtained from leaves and stem-bark (SMMELS and SMMESB) and their IC_{50} values were found to be 476.43 and <250 µg mL^{-1}, respectively. This means that these two extracts exhibited much higher scavenging activity than essential oils from leaves and stems. The essential oils from leaves and fruits of *S*. *molle* collected from two different regions in Algeria showed IC_{50} values ranging from 6900 to 8600 µg mL^{-1} (Abderrahim et al., 2018). However, in the present study, SMMELS and SMCHSD showed lower IC_{50} values of 476.43 and 3000 µg mL^{-1}, respectively.

The essential oil from fruits of *S*. *molle* collected from Sfax, Tunisia showed IC_{50} values 3607.6±104.0 µg mL^{-1} in the DPPH assay and 257±10.3 µg mL^{-1} in the ABTS assay (Bendaoud et al., 2010). However, the chloroform seed extract (SMCHSD) from the present study showed slightly lower IC_{50} value of about 3000 µg mL^{-1} in the DPPH assay. The essential oils from fruits of *S*. *molle* collected from Mograne, Tunisia showed scavenging activity ranging from ~3 to ~28% in the DPPH assay (Hosni et al., 2011). The essential oil from a branch of *S*. *molle* collected from Alexandria, Egypt and its methanol, methylene chloride and water extracts showed IC_{50} values 13.11±3.00, 228.66±1.12, 334.11±1.53 and 12.66±2.15 µg mL^{-1}, respectively (Mohamed et al., 2016). The methanolic stem-bark extract (SMMESB) from the present study also showed a comparable IC_{50} value of <250 µg mL^{-1}.

The ethanolic extract from leaves of *G. triacanthos* exhibited 97.89% antioxidant activity in the *in-vivo* assay (Mohammed et al., 2014). Luteolin-7-O-β-glucopyranoside, a pure compound, isolated from aqueous ethanol fraction exhibited 91.80% scavenging activity (Mohammed et al., 2014). The ethanolic extract from seeds of *G. triacanthos* collected from Porto, Portugal showed 18.77% scavenging activity and showed IC_{50} value of 13310±0.67 µg mL^{-1} (Miguel, 2010). Some fractions from this ethanolic extract showed scavenging activity ranging from 61.88 to 71.59% and showed IC_{50} values ranging from 1400±0.37 to 4170±0.32 µg mL^{-1} (Miguel, 2010).

Conclusion

DPPH radical scavenging activity of methanolic and chloroform extracts obtained from various parts of two medicinal plants *viz*. *S.molle* and *G. triacanthos* collected from the Kingdom of Lesotho have been evaluated. The methanolic extracts from *S*. *molle* showed scavenging activity ranging from 35.97±1.02 to 83.38±2.74%, while the chloroform seed extract showed scavenging activity ranging from 8.20±1.02 to 68.82±3.17%. The methanolic extracts from *G*. *triacanthos* showed scavenging activity ranging from 35.97±1.02 to 92.36±0.11%, while the chloroform seed extract showed scavenging activity ranging from 3.74±1.04 to 15.47±4.57%. From this study, it was concluded that the extracts from these two medicinal plants, *S*. *molle* and *G*. *triacanthos*, showed promising antioxidant activity. The IC_{50} values of these extracts were also determined and found to be between <250 and 3000 µg mL^{-1}.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria

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People in Katsina State, Nigeria have been using medicinal plants to cure several ailments associated with liver since time immemorial; however the use of such plants was never documented. In this study, an ethnobotanical survey was conducted to document the medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria. A semi-structured questionnaire method was adopted to interview 150 respondents (50 respondents from 1 Local Government Area of each of the three Senatorial Zones of the State) comprising herbalist, farmers, house wives, and others. A total of 62 plant species belonging to 57 genera distributed among 34 families were documented. Most of the reported plants belong to the Fabaceae (24.19%), Moraceae (6.45%), followed by Anacardiaceae, Euphorbiaceae and Asteraceae (each with 4.84%). *Senna occidentalis* L., *Ficus thonningii* Bl., and *Moringa oleifera* Lam. had the highest relative frequency of citation (RFC) of 0.75, 0.64, and 0.53 respectively. Majority (38.71%) of the reported plants were trees and about 79.03% of the surveyed plants are sourced from wild. Leaves were the most frequently used (45.16%) plants part. Most of the herbal medicines (80.65%) were prepared in form of decoction and all the medicines were administered orally. This is the first ethnobotanical study on hepatic ailments in the study area. Results of the study could serve as baseline data based on which further ethnopharmacological investigations would be carried out. Further researches aimed at conserving as well as validating the folkloric use of the surveyed plants would be ideal.

Key words: Ethnobotany, hepatic ailments, Katsina State, medicinal plants, Nigeria.

INTRODUCTION

Liver, the second-largest organ in the human body, plays a key role in the metabolism of various substances. Besides that, liver also performs vascular, immunological, secretory as well as excretory functions in the human body system (Mitra and Metcalf, 2009). Liver is involved in almost all the biochemical pathways to growth, fight against disease, nutrient supply, energy provision and reproduction (Ward and Daly, 1999). Unfortunately

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however, liver is being affected by both infectious and non-infectious diseases. Liver diseases pose a serious challenge to international public health (Ahsan et al., 2009). One of the most common causes of liver disease is inflammation, which often results from abuse of alcohol, poor diet or even malnutrition. Nigeria is one of the countries with largest burden of hepatitis B virus (one of the leading causative agents of hepatic ailments) with 10-15% prevalence (Owolabi and Ojo, 2008).

Unfortunately, conventional or synthetic drugs used in the treatment of liver diseases are inadequate and sometimes can have serious side effects (Rao et al., 2006). Moreover, there are still no specific treatments in modern medicine that give protection to the liver against damage or help to regenerate hepatic cells (Chatterjee, 2000; Chattopadhyay, 2003).

The scientific study of the relationship that exists between people and plants is called ethnobotany (Ijaz et al., 2017). Since the beginning of human civilization, medicinal plants have been used by mankind for its therapeutic value. Today about 80% of the world's population rely predominantly on plants and plant extracts for healthcare (Setzer et al., 2006). Nature has been a source of medicinal agents for thousands of years and an impressive number of modern drugs have been isolated from natural sources. Many of these isolations were based on the uses of the agents in traditional medicine. In Nigeria, many rural communities have been using medicinal plants to cure various forms of ailments (Sani and Aliyu, 2011).

Recently, the use of medicinal plants to cure various forms of liver diseases and dysfunctions is becoming increasingly popular and has received wide acceptance (Oyagbemi and Odetola, 2010). Moreover, a large number of medicinal plants and compounds derived from them have been found to have some hepatoprotective ability (Kalaskar and Surana, 2014; Mishra et al., 2014; Arka et al., 2015; Xu et al., 2018).

The use of medicinal plants as traditional medicine is well known in rural areas of many developing countries. Traditional healers claim that their medicine is cheaper and more effective than modern medicine. Indigenous knowledge on the use of medicinal plants is transmitted orally in various communities of the world. This lead to fast disappearing of the knowledge due to the advent of modern technology and transformation of traditional culture and the younger generations are not interested in carrying on this tradition.

There is therefore, a great danger that this knowledge of traditional medicine could be lost. Katsina is one of the poor states of Nigeria. Most people in the area depend on medicinal plants for their healthcare because of poverty as well as affordability and accessibility of the medicinal plants (Kankara et al., 2015). Despite the intense use of the plants, no attempt was made to document their usage for hepatic ailments. It is against this background this research was designed with the aim of documenting medicinal plants used for the management of hepatic ailments in the study area.

MATERIALS AND METHODS

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 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. 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, one local government was selected for the purpose of this research.

Data collection

This research work was conducted during the period of August 2016 to October 2016 in three Senatorial Zones of Katsina State, Nigeria. One local government area was randomly selected from each Senatorial Zone; the Local Government Areas were Batagarawa, Kankia, and Malumfashi. The ethnomedicinal plants data were gathered using a semi-structured questionnaire by interviewing 150 respondents (50 respondents from 1 Local Government Area of each of the Senatorial Zones of the State). The questionnaire was validated using Cronbach's alpha with $0.5 < \alpha \geq 0.8$ degree of consistency. During the interview, questions asked according to the questionnaire were divided into two parts, A and B. In part A, socio-demographic information of the respondents was recorded, and information of the plants used for the management of hepatic ailments was recorded in B part.

Collection and identification of plants specimens

Six field trips were carried out to collect the specimens of the reported plants from their natural habitat and cultivated lands with the help of some medicinal plants collectors, traditional healers and farmers. Flora collection permit was obtained from Local Authorities before embarking on the trips. Photographs of the plants were taken using a Sony (14.0) digital camera to aid in the botanical authentication of the plants. Identification of the reported plants was achieved by the aid of herbarium specimens deposited at Umaru Musa Yar'adua University Herbarium and literature on medicinal plants found in Nigeria. Further identifications of the surveyed plants were obtained using catalogue of life (2016) plants databases available online. Herbarium specimens were prepared and deposited in the Herbarium of Umaru Musa Yar'adua University, Katsina State.

Data analysis

A descriptive statistical method using percentages and frequencies was used to analyze the socio-demographic data of the respondents, and the results of this study were analyzed using the Relative Frequency of Citation (RFC). RFC is used to determine the relative importance of a particular species. It is determined using the relation: $RFC = Fc/N$, where Fc is the number of respondents

Table 1. Socio-demographic information of the respondents of ethnobanical survey of medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria.

Biodata	Frequency	Percentage (%)
Gender		
Male	57	38
Female	93	62
Age		
25-35	7	4.67
36-45	16	10.67
46-55	23	15.33
56-65	78	52
> 65	26	17.33
Educational status		
None	117	78
Primary	22	14.67
Secondary	9	6
Tertiary	2	1.33
Occupation		
Herbalists	69	46
Farmers	37	24.67
House wives	28	18.67
Others	16	10.67

who cited a particular species and N is the total number of the respondents (Tardio and Pardo-de-Santayana, 2008).

RESULTS AND DISCUSSION

Socio-demographic information

Table 1 shows the socio-demographic information of the respondents. As shown in the table, 57 respondents were males (38%) and 93 respondents were females (62%)among the total number of 150 respondents interviewed during the survey. Majority of the respondents (52%) are 56 to 65 years of age among the different age groups interviewed. Most of the respondents (78%) had no formal education, and 46% were herbalists. The research revealed that most of the respondents to the indigenous knowledge with regard to their age show that majority were of old age (Figure 1). This reveals that, the passage of ethnomedicinal knowledge is probably more from the elders to the younger ones as similarly reported by Adekunle (1992), and also knowledge transferred to the younger generation was very poor; they seem to keep the knowledge with them either for the sake of secrecy or due to apathy of the younger generation to traditional knowledge. This, however, poses a serious threat to the indigenous knowledge because it may eventually be lost forever following the demise of the older generation (Kankara et al., 2015).

Plant species used for liver diseases

Information on the medicinal plants used for the management of liver diseases in the study area is presented in Table 2. The table contains all the surveyed plants, their common names, scientific names, family names, parts of the plant used, growth habit, domestications, frequency of citation as well as modes of preparation and the routes of administration. A total of 62 plant species belonging to 57 genera, distributed among 34 families are used to treat various liver diseases in Katsina State, Nigeria. Senna occidentalis appeared to be the most popular specie in this study. Phytochemicals present in this plant (including but not limited to flavonoids, alkaloids, lignins, tannins and phenols) may be responsible for its curative power (Manikandaselvi et al., 2016). Several biological activities of S. occidentalis (formerly known as Cassia occidentalis) such as antimicrobial (Hussaini and Deeni, 1991), antimalarial

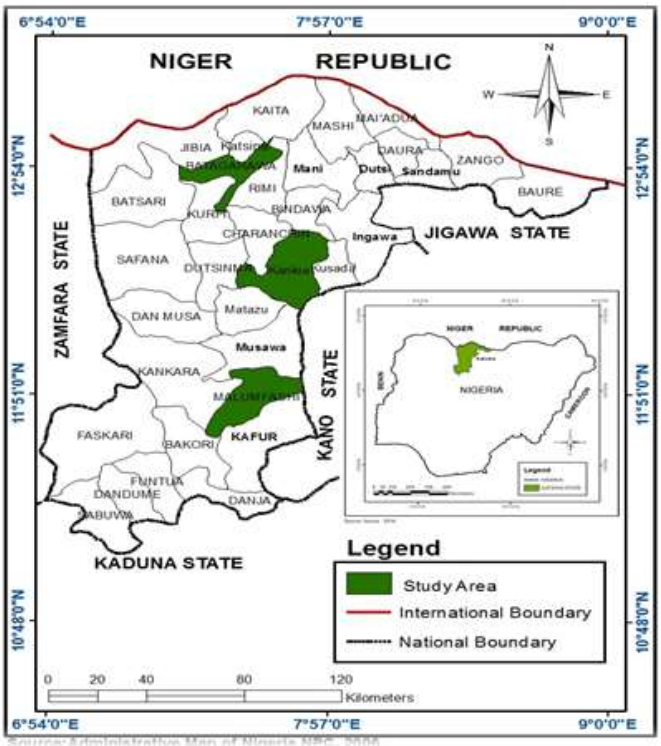

Figure 1. Map of Katsina State, Nigeria showing the study area.

(Tona et al., 2001), anti-inflammatory (Sadique et al., 1987) and anticarcinogenic (sharma et al., 1999) are reported. It is also interesting to note that hepatorotective effect of S. occidentalis has been proven scientifically (Jafri et al., 1991; Usha et al., 2007). It is also worth noting that some of the species reported in this study such as Hibiscus sabdariffa, Moringa oleifera and Zingiber officinale are also used for the same purpose elsewhere (Panday, 2011). The highest recorded family is Fabaceae with 15 species, followed by Moraceae with 4 species, and Anacardiaceae, Asteraceae, and Euphorbiaceae with 3 species each. Connaraceae, Convolvulaceae, Malvaceae, Meliaceae, and Myrtaceae are represented by 2 species each, whereas 24 families contributed 1 species each (Figure 2). The high occurrence of the family Fabaceae could be explained by the fact that most species belonging to the family Fabaceae are mostly found throughout the seasons because they are adapted to withstand the adverse effects of Sahel regions as reported by Kankara et al. (2015). This is however, contrary to the findings of Kalaskar and Surana (2004) who reported that majority of plants used against liver diseases by different tribes of India belong to the Malvaceae family. While majority of plants used to treat liver problems in Maritime region of Togo belong to Caesalpiniaceae (Kpodar et al., 2015).

Majority of the plants used to treat liver diseases in the study area (38.71%) were reported as trees (Figure 3), followed by shrubs (37.10%), and herbs (24.19%). This may be due to the fact that this growth form is available in almost all seasons and in addition are not affected by seasonal variations as reported by Albuquerque (2006). Majority (79.03%) of the plants reported in this study are sourced from the wild (Figure 4). This may not be unconnected to the belief that wild plants have more healing power than their cultivated counterparts. Similar findings were also reported from Togo and India (Haile and Delenasaw, 2007; Kpodar et al., 2015). This has a negative consequence on the plants' diversity of the area as the area is already being faced by other ecological problems. Leaves are the main used plant part in this study (45.16%), followed by the bark (35.48%), and the whole plant (24.19%), whereas the fruit, flower, rhizome, root, stem, and seed account only for 16.11% all together. This corresponds with the findings of other ethnomedicine studies in Africa like Uganda, Ethiopia and Mali where it was reported that most of the plant parts used in different preparations for remedy were the leaves (Tagola, and Diallo 2005). Most of the medications (80.65%) are prepared as decoction (Figure 5), then powder (16.13%), and maceration (3.23%). This also agrees with the findings of Kpodar et al. (2016) who found that medicinal plants used for liver diseases in the Maritime Region of Togo are mostly prepared as decoctions.

White potassium is added in most cases to the

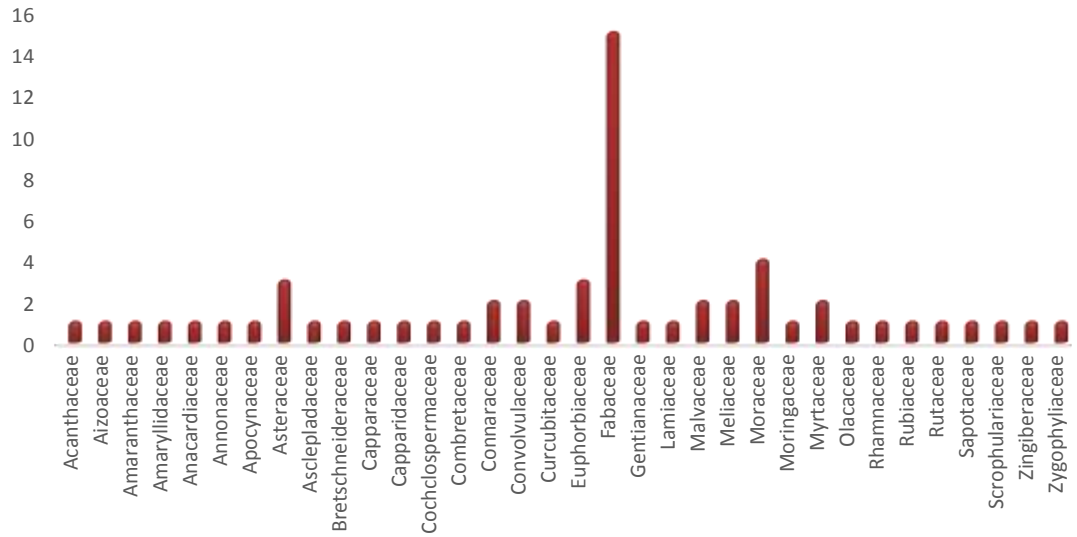

Figure 2. Distribution of plant families used for the management of hepatic ailments in Katsina State, Nigeria.

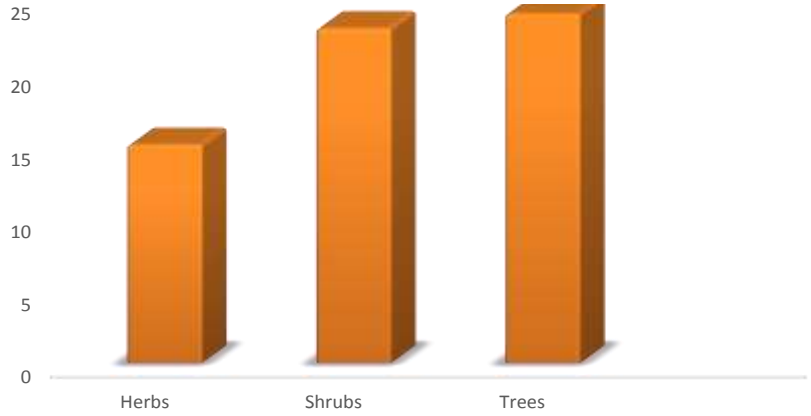

Figure 3. Habit status of medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria.

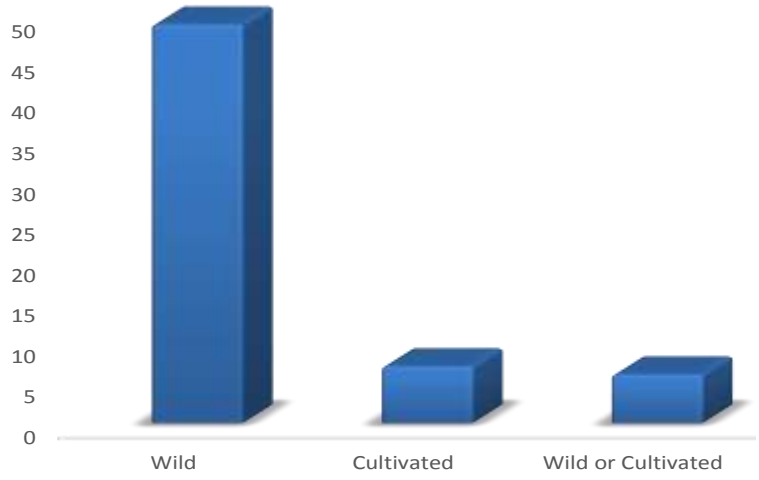

Figure 4. Habitat status of the medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria.

Table 2. Medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria.

Botanical name (Family)	Local name	Common name (Voucher No.)	Part used	Habit/Habitat	RFC	Mode of preparation	Route of administration
Acacia nilotica (L.) Delile (Fabaceae)	Bagaruwa	Black piquant (SSK156)	B, Sd	T/W	0.28	Decoction	Oral
Acanthospernum hispidum DC. (Asteracaae)	Yawo	Bristle star bur (SSK181)	WP	H/W	0.22	Decoction	Oral
Adansonia digitata L. (Malvaceae)	Kuka	Baobab (SSK184)	B	T/W	0.15	Decoction	Oral
Allium sativum L. (Amaryllidaceae)	Tafarnuwa	Garlic	Rh	H/C	0.19	Decoction	Oral
Amaranthus spinosus L. (Amaranthaceae)	Alayyahu	Spiny pigweed (SSK161)	WP	H/C	0.13	Decoction	Oral
Anogeissus leiocarpa DC. (Guill. And Perr.) (Combretaceae)	Marke	African birch (SSK121)	B, L	T/W	0.08	Decoction	Oral
Annona senegalensis Pers. (Annonaceae)	Gwandar daji	African custard apple	L	S/WorC	0.16	Decoction	Oral
Anthocleista djanlonensis A. Chavalier. (Gentianaceae)	Kandare	(SSK148)	B, L	T/W	0.14	Decoction	Oral
Artemesia annua L. (Asteraceae)	Tazargade	Sweet annie	L	S/C	0.10	Decoction	Oral
Azadirachta indica A.Juss (Meliaceae)	Bedi	Neem tree (SSK125)	L	T/WorC	0.19	Decoction	Oral
Balanites aegyptiaca (L.) Delile (Zygophyliaceae)	Aduwa	Desert date (SSK167)	B	T/W	0.11	Decoction	Oral
Bauhinia rufescens Lam. (Fabaceae)	Tsattsagi	Silver Butterfly tree (SSK168)	L, B	T/W	0.11	Decoction	Oral
Bauhinia reticulata DC. (Fabaceae)	Kalgo	Mountain ebony (SSK114)	B	T/W	0.13	Decoction	Oral
Boscia salicifolia Oliv. (Capparidaceae).	Zure	Willow-leaved Shepherds tree (SSK171)	L	S/W	0.01	Powder	Oral
Boswellia dalzielii Hutchinson	Hano	Frankincense tree	B	T/W	0.11	Decoction	Oral

Table 1. Contd.

(Connaraceae)		*(SSK115)*					
Byrsocarpus coccineus Schum and Thonn (Connaraceae)	Tsamiyar kasa	Tamarind of the valley	WP	H/W	0.03	Decoction	Oral
Cassia nigricans Vahl. (Fabaceae)	Gewaya tsamiya	Chamaecrista nigricans (SSK170)	L	H/W	0.11	Maceration	Oral
Cassia arereh Delile (Fabaceae)	Malga	(SSK137)	R	S/W	0.10	Decoction	Oral
Cassia mimosoides L. (Fabaceae)	Bagaruwar kasa	Fishbone cassia (SSK180)	WP	H/W	0.11	Decoction	Oral
Calotropis procera (Ait.) P.T Li (Apocynaceae)	Tumfafiya	Sodom apple (SSK182)	L, St	S/W	0.10	Decoction	Oral
Carica papaya L. (Bretschneideraceae)	Gwanda	Papaya	L	S/C	0.07	Decoction	Oral
Citrus aurentifolia (Christm.) Swingle (Rutaceae)	Lemun tsami	Lime (SSK113)	L, Fr	S/C	0.19	Decoction	Oral
Cochlospermum tinctorium Perr. A. Rich. (Cochlospermaceae)	Rawaya		Rh	S/W	0.17	Powder	Oral
Crateva adansonii DC. (Capparaceae)	Ungududu	Three-leaved caper (SSK185)	L	T/W	0.10	Decoction	Oral
Dichrostachys cinerea (L.) Wight and Arn. (Fabaceae)	Dundu	Kalahari christmas tree (SSK134)	L	S/W	0.03	Powder	Oral
Eucalyptus camaldulensis Dehnh (Myrtaceae)	Turare	River red gum (SSK174)	L	T/W	0.35	Decoction	Oral
Euphorbia convolvuloides Hochst.ex Benth (Euphorbiaceae)	Nonon kurciya	Athsma herb (SSK189)	WP	H/W	0.14	Decoction	Oral
Euphorbia balsamifera Aiton,Hort. (Euphorbiaceae)	Aliyara	Balsam spurge (SSK183)	L, St	S/W	0.08	Decoction	Oral

Table 1. Contd.

Evolvulus alsinoides L. (Convolvulaceae)	Kafi malam	Dwarf morning glory (SSK190)	WP	H/W	0.09	Decoction	Oral
Faidherbia albida (Delile) A.Chev. (Fabaceae)	Gawo	Winter thorn	B	T/W	0.09	Decoction	Oral
Ficus congensis Engl. (Moraceae)	Baure	Fig (SSK154)	B	S/W	0.12	Decoction	Oral
Ficus polita Var. Persicicarpa Hutch. (Moraceae)	Durumi	Heart-leaved fig	L, B	T/W	0.08	Powder	Oral
Ficus platyphylla Del. (Moraceae)	Gamji (SSK155)	Guttapercha tree	L, B	T/W	0.13	Powder	Oral
Ficus thonningii Bl. (Moraceae)	Cediya	Strangler fig (SSK150)	L	T/W	0.64	Decoction	Oral
Hibiscus sabdariffa L. (Malvaceae)	Soborodo	Roselle (SSK188)	L, F	S/C	0.13	Decoction	Oral
Indigofera astragalina DC. (Fabaceae)	Kaikai koma kan mashekiya	Silky indigo (SSK173)	WP	H/W	0.09	Decoction	Oral
Ipomea asarifolia (Desr.) Roem. And Schult. (Convolvulaceae)	Duman kada	Morning glory	WP	H/W	0.12	Decoction	Oral
Jatropha curcas L. (Euphorbiaceae)	Cin da zugu	Barbados nut (SSK118)	L	S/WorC	0.42	Decoction	Oral
Khaya senegalensis (Desv.) A. Juss (Meliaceae)	Madaci	African mahogany (SSK177)	B	T/W	0.09	Decoction	Oral
Lannea acida A.Rich (Anacardiaceae)	Faru	Grape (SSK172)	B	T/W	0.14	Decoction	Oral
Leptadenia hastata (Pers.) Decne (Asclepladaceae)	Yadiya	(SSK165)	WP	H/W	0.13	Decoction	Oral

Table 1. Contd.

Mangifera indica L. (Anacardiaceae)	Mangwaro	Mango (SSK142)	L, B	T/WorC	0.12	Decoction	Oral
Mitragyna inermis (Willd.) Kuntze (Rubiaceae)	Giyayya	False abura	B	S/W	0.08	Decoction	Oral
Momordica balsamina L. (Curcubitaceae)	Garahuni	Balsam apple (SSK126)	WP	S/W	0.10	Decoction	Oral
Moringa oleifera Lam. (Moringaceae)	Zogala	Drumstick tree (SSK122)	L, R	S/WorC	0.53	Decoction	Oral
Ocimum basilicum L. (Lamiaceae)	Doddoya	Sweet basil (SSK164)	WP	H/W	0.09	Decoction	Oral
Parkia biglobosa (Jacq.) G. Don (Fabaceae)	Dorowa	African locust bean tree (SSK128)	B	T/W	0.12	Decoction	Oral
Peristrophe bicalyculata (Retz) Nees (Acanthaceae)	Tubanin dawaki	Horse flower (SSK179)	WP	H/W	0.07	Decoction	Oral
Prosopis africana (Guill. And Perr.) Taub. (Fabaceae)	Kirya	African mesquite (SSK133)	B	T/W	0.13	Decoction	Oral
Psidium guajava L. (Myrtaceae)	Gwaba	Guava (SSK158)	L	S/WorC	0.11	Decoction	Oral
Senna obtusifolia (L.) H.S. Irwin and Barneby (Fabaceae)	Tafasa	Sickle pod (SSK162)	L	S/W	0.11	Powder	Oral
Senna occidentalis L. (Fabaceae)	Tafasar masar	Coffee senna (SSK176)	WP	S/W	0.75	Decoction	Oral
Senna singueana (Delile) Lock (Fabaceae)	Runhu	Wild cassia (SSK127)	L	S/W	0.15	Decoction	Oral
Sclerocarya birrea (A.Rich.) Hochst. (Anacardiaceae)	Danya	Marula (SSK157)	B	T/W	0.01	Maceration	Oral
Striga hermonthica (Delile) Benth (Scrophulariaceae)	Gaugai	Purple witchweed (SSK178)	WP	H/W	0.10	Decoction	Oral
Tamarindus indica L. (Fabaceaea)	Tsamiya	Indian date (SSK169)	B, L	T/W	0.11	Decoction	Oral

Table 1. Contd.

Vernonia amygdalina Delile (Asteraceae)	Shuwaka	Bitter leaf (SSK186)	L	S/W	0.03	Powder	Oral
Vitellaria paradoxa C.F.Gaertn (Sapotaceae)	Kadanya	Shea butter tree (SSK187)	B	T/W	0.08	Powder	Oral
Ximenia americana L. (Olacaceae)	Tsada	Tallow wood (SSK131)	B	T/W	0.11	Powder	Oral
Zaleya pentandra (L.) C. Jeffrey (Aizoaceae)	Gadon maciji		WP	H/W	0.14	Decoction	Oral
Ziziphus mauritiana Lam. (Rhamnaceae)	Magarya	Indian jujube (SSK130)	L	S/W	0.17	Powder	Oral
Zingiber officinale Roscoe (Zingiberaceae)	Citta	Ginger	Rh	S/C	0.17	Decoction	Oral

RFC = Relative Frequency of Citation, H = Herbs, S = Shrubs, T = Tree, W = Wild, C = Cultivated, WorC = Wild or Cultivation, B = Bark, L = Leaves, F = Flower, R = Root, Fr = Fruit, Rh = Rhizome, Sd = Seed, St = Stem, WP = Whole plant.

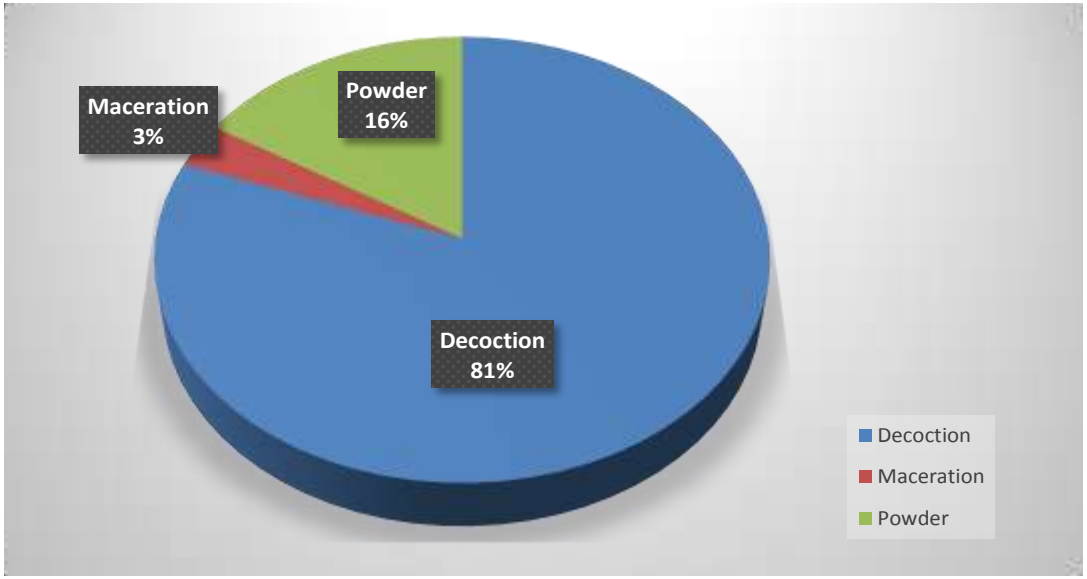

Figure 5. Mode of preparation of medicinal plants used for the management of hepatic ailments in Katsina State, Nigeria.

decoctions to inactivate the bitter taste of the medications. Various additives such as, cow milk, porridge, honey, etc were mixed with the powdered medicines in remedy preparations. More than one plant species have been reported to be used by the people in remedy preparation for hepatic ailments. This could be attributed to additives or synergistic effect that they could have during treatment (Haile and Delenasaw, 2007), while some plants are prepared singly and this agrees with other findings in Bolivia (Macia, 2005).

Following the interview with traditional healers it has been reported that majority were found to have poor knowledge of dosage and antidote while giving prescription of remedy to the patients, and most of the preparations were said to have no side effect except vomiting and in rare cases watery stool and this may be attributed to the low toxicity of medicinal plant species used by the local herbalist (Haile and Delenasaw, 2007).

The major threat to the availability of medicinal plants in the study area was deforestation. This could be attributed to the additional values of the majority of ethnomedicinal plants in the study area as well as current high demand for fuel wood as an energy source. Therefore effort should be made to conserve the diversity of these vital resources.

Conclusion

This study provides the first ethnobotanical data on the use of plants to manage hepatic ailments in the study area. From the study, it is evident that people in the study area still rely on medicinal plants for their primary healthcare. There is no doubt that this study will greatly help in preventing the erosion of indigenous knowledge. Considering the fact that most of the plants reported in this study appeared to be rare, there is an urgent need for strategies towards conserving such vital resources. Further researches aimed at validating the folkloric use of the surveyed plants is also ideal.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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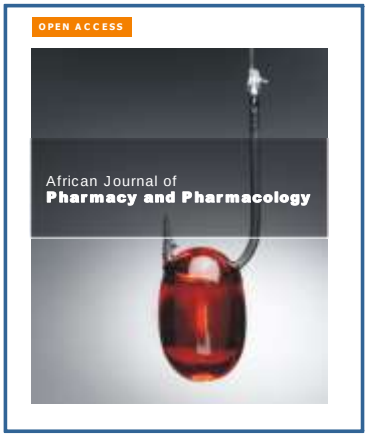

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