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Consensus level in the traditional management of diabetes and chemical potentiality of plants from north Sudanese, Burkina Faso

Souleymane Compaore[1,2]*, Lazare Belemnaba[1], Moumouni Koala[1], René D. Magnini[1], Noufou Ouedraogo[1], Adjima Thiombiano[2] and Sylvin Ouedraogo[1]

[1]Département Médecine, Pharmacopée Traditionnelles et Pharmacie (MEPHATRA/PH), Institut de Recherche en Sciences de la Santé (IRSS), 03 BP 7047, Ouagadougou, Burkina Faso
[2]Laboratoire de Biologie et Ecologie Végétales (LaBEV), Université Joseph KI-ZERBO, UFR/SVT 03 BP 7021 Ouagadougou 03 Burkina Faso.

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Diabetes, has become a public health problem whose prevalence is increasing in subsahelian Africa. The present study aimed to determine the consensus level of plant use and their antidiabetic potentiality. Thus, a semi-structured interview carried out from May 2014 to April 2018 with 120 traditional healers allowed retaining nine species after selection according to the frequency of citation and the bibliographic review: *Crescentia cujete* L., *Ficus ingens* (Miq.) Miq. *Ficus platyphylla* Delile, *Lannea acida* A. Rich., *Balanites aegyptiaca* (L.) Delile, *Daniellia oliveri* (Rolfe) Hutch. & Dalziel, *Feretia apodanthera* Delile, *Cassia italica* (Mill.) Lam. ex F.W. Andrews and *Boscia angustifolia* A. Rich. Phytochemical screening of methanolic and aqueous extracts was performed by high performance thin layer chromatography and the total flavonoids, hydrolyzable and condensed tannins were determined by spectrophotometer method. Results showed that thirty-seven, fifty-five and sixty-five species were inventoried in the provinces of Bazega, Zounweogo and Sanmatenga respectively but the Informant Consensual Factor related to the plant use remains low (FIC<50%). Notwithstanding this, phytochemical screening of plant extracts showed the presence of flavonoids and tannins. The highest flavonoids and hydrolysable tannins content were obtained with *Cassia italica* (Mill.) Lam. ex F.W. Andrews methanolic extracts (11.03±0.07 mg EQ/100 g dry matter and 34.82±0.14 mg ETA /100 g dry matter respectively). The best condensed tannins content was noted with *Lannea acida* A. Rich. methanolic extract (543.94±18.67 mg ETA /100 g dry matter). These results constitutes a scientific basis that can be directed towards a pharmacological and toxicological investigation.

Keywords: Ethnobotanical surveys; Traditional healers; Consensus; Phytochemical screening; Diabetes.

INTRODUCTION

Diabetes in recent decades has become one of the major public health concerns worldwide (Mangambu et al., 2014) and particularly in sub-Saharan Africa (Sagna et al., 2014). It is a metabolic abnormality characterized by

*Corresponding author. E-mail: scompaore30@yahoo.com.

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a deficiency (type 1) or misuse of insulin (type 2) in the body (Ghourri et al., 2013). Its prevalence is increasing exponentially and more than 300 million people will have diabetes in 2025 worldwide according to the World Health Organization (Féry and Paquot, 2005). Sub-Saharan Africa characterized by poverty, insufficient infrastructures and health personnel, presented 19.1 million cases of diabetes in 2015 with a projection of 41.4 million in 2035 or 109% increase (Diop and Diédhiou, 2015).

In Burkina Faso, there is a progression of diabetes mainly due to ignorance, new and bad eating habits (Koevi et al., 2014). In 2015, prevalence rate of diabetes was 8.5% (10.4% among women and 6.9% among men) in urban areas of Ouagadougou (Millogo et al., 2015). The prevalence is linked to factors such as obesity, poor diet, low physical activity, gender and age (Koevi et al., 2014; Millogo et al., 2015).There is complexity in the drug treatment of diabetes due to its progressive nature and association with other cardiovascular risk factors such as hypertension, obesity, smoking, stroke, kidney failure, leg amputation, vision loss and nerve damage. Modern management of disease, particularly constraining, from insulin injections (type 1 diabetes) to anti-diabetic drugs (type 2 diabetes) and requires lifelong treatment and regular follow-up (Gbekley et al., 2015). This complexity of treatment and the complications of disease induce considerable economic losses for people. Thus, some patients in low-income countries refer to traditional herbal remedies (Mangambu et al., 2014) that have a cultural dimension and were considered as safe and nontoxic than one synthetic (Attar and Ghane, 2019).

Anti-diabetic properties of plants such as *Ximenia americana* L. (Shettar et al., 2017), *Moringa oleifera* L. (Khan et al., 2017), *Sclerocarya birrea* (A.Rich.) Hochst., *Annona senegalensis* Pers., *Cassia sieberiana* DC. and *Detarium microcarpum* Guill. & Perr. (Nguemo et al., 2018) were proved in many countries. In Burkina Faso, more than 33,000 traditional healers have been listed according to the Ministry of Health statistics. Out of 2,067 known plant species, only 36% were used for traditional medicine (Zizka et al., 2015).

However, in Burkina Faso, very few studies have proven the anti-diabetic properties of interest plants. Also, the traditional management of diabetes is not sufficiently developed due to the lack of knowledge of the symptom's disease. The present study aimed to determine the consensus level of plant use and their anti-diabetic potentiality. It could contribute to the management of diabetes but also to the preservation of these plants that are of great interest. Specifically it consisted to (i) inventorying the plants used by traditional healers for the management of diabetes; (ii) determine consensus level on the plant use in management of diabetes; (iii) characterize the chemical groups (total flavonoids and tannins) contained in the most cited plants extract, and (iv) evaluate the content of total flavonoids and tannins present in plant extracts.

MATERIALS AND METHODS

Study area

Ethnobotanical surveys were carried out in the departments of Kaya and Barsalogho in the province of Sanmatenga, the departments of Kombissiri, Doulougou, Toece and Sapone in province of Bazega and the departments of Manga, Bere, Binde, Guiba, Gomboussougou, Gogo and Nobere in province of Zounweogo (Figure 1). The province of Sanmatenga is located between 13°21' and 14° N and 1°3' and 2° W in the sub-Sahelian phytogeographical area. This area is characterized by a sahelian climate. The rainy season does not exceed four (04) months and runs from June to September, with rainfall not exceeding 600 mm. Vegetation is dominated by steppes, tiger bushes and thickets (Sambare et al., 2010). The main languages spoken in the locality are *Moore* and *Fulfulde* (Belem et al., 2008). The economy is essentially based on agriculture, livestock, handcraft and mining.

The provinces of Bazega is located between 11°30' and 12°30'N and 0°50' and 2°10' W and those of Zounweogo between 11°36' and 12° N and 1°30' and 2°30' W. The study sites in these provinces are located in north Sudan phytogeographical sector with a Sudano-Sahelian climate characterized by an annual rainfall between 700 and 900 mm and 6 to 7 dry months. Vegetation is dominated by savannah formations with tree and shrub being the most frequent (Sambare et al., 2010). The predominant ethnic groups are the *mossi* who live with *bissa, gourounsi* and *Fulfulde* population. Religions include indigenous, muslim and christian beliefs. Like the other provinces of Burkina Faso, according to the 2006 general population census, many people of Sanmatenga, Bazega and Zounweogo were young.

Ethnobotanical surveys

Ethnobotanical surveys were carried out from May 2014 to April 2018 with 120 traditional healers (TH), including 48 in the province of Sanmatenga, 35 in the province of Bazega and 37 in the province of Zounweogo. The study was focused on TH members of associations without distinction of age and sex. However, traditional healers should know at least two clinical signs of diabetes including oedema, drowsiness, vertigo, tingling fingers or feet, slow cicatrizing, polyuria etc. The survey was consisted to a semi-structured interview (Tra Bi et al., 2008) using a questionnaire. During this survey, the symptoms disease, the local names of the species, the organs used, the patterns of organs harvesting, the patterns of formulation and the route administration of recipes were collected. Some species have been identified locally *in situ* while, for others, plant samples were harvested and compared with specimens of the national herbarium of Joseph KI-ZERBO University, Burkina Faso. An update of plant species names and botanical families was made according to the catalogue of vascular plants of Burkina Faso (Thiombiano et al., 2012).

Phytochemical screening and determination of total flavonoids and tannins content

Plant material and extraction methods

Nine (09) plants species were selected by focusing on the frequency of citation and the literature data (Traore et al., 2018). Thus, *Crescentia cujete* L. (leaves), *Ficus ingens* (Miq.) Miq (trunk bark), *Ficus platyphylla* Delile (trunk bark), *Lannea acida* A. Rich.

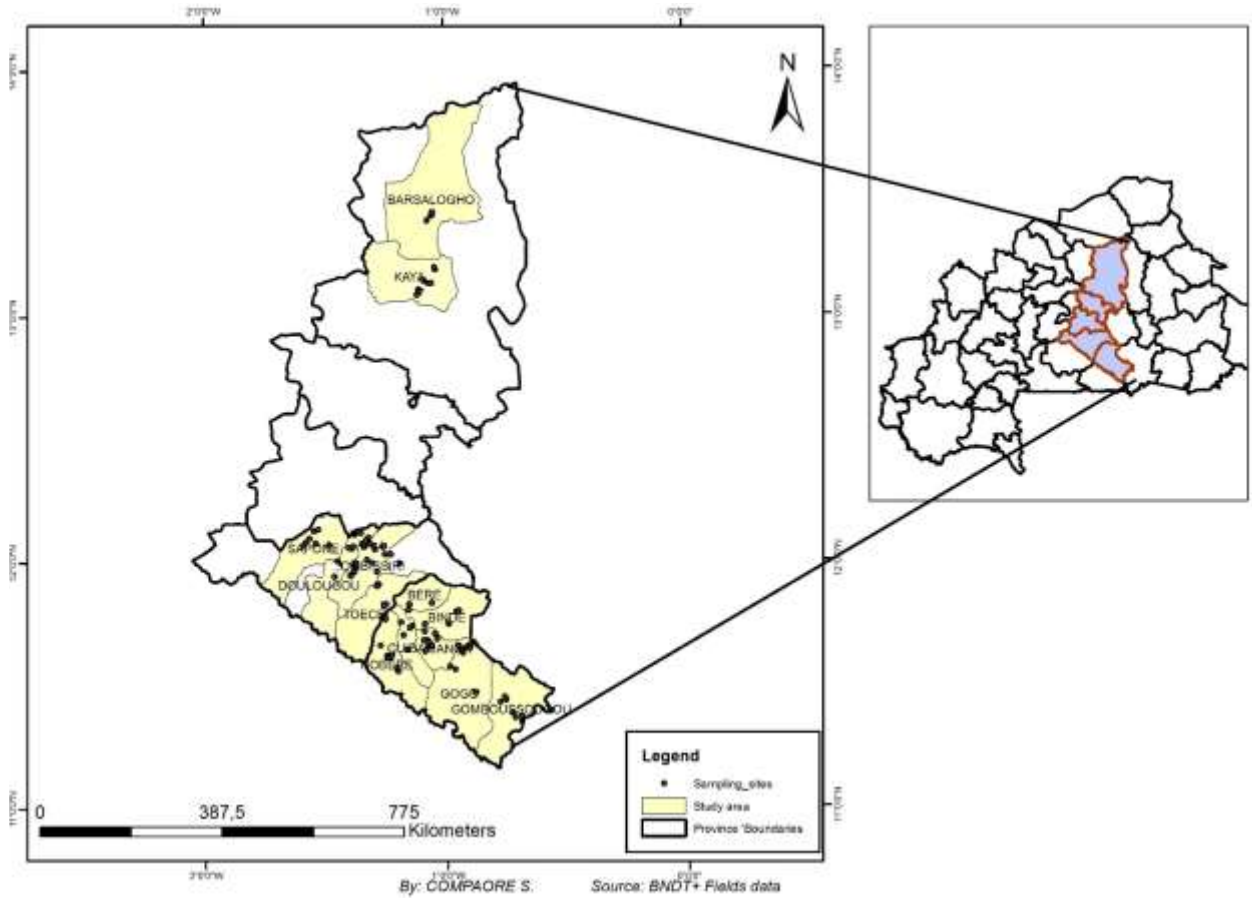

Figure 1. Location map of the study area.

(trunk bark), *Balanites aegyptiaca* (L.) Delile (trunk bark), *Daniellia oliveri* (Rolfe) Hutch. & Dalziel (trunk bark), and *Feretia apodanthera* Delile (root bark) were collected in July 2019 in the province of Zounweogo with the support of the traditional healers. *Cassia italica* (Mill.) Lam. ex F.W. Andrews (leaves) and *Boscia angustifolia* A.Rich (trunk bark) were collected in the province of Sanmatenga at the same time. All these species were authenticated at the national herbarium of Joseph KI-ZERBO University where voucher specimens have been deposited under the number N°6912, N°5337, N°6914, N°6913, N°6916, N°6915, N°5335, N°5334 and N°5336 respectively. The different plant organs (leaves, trunk and root bark) were dried for two weeks in a drying room at the Institute for Health Science Research. After drying, the plant material was crushed and stored in freezer bags.

Two methods of extraction namely decoction and maceration, were used in accordance with the indications of traditional healers. Each method was repeated three times.

Decoction: 20 g of powder from each plant was mixed with 100 mL of distilled water, homogenized in flask and boiled for 30 min.

Alcoholic maceration: 20 g of powder was mixed with 100 mL of methanol, homogenized in flask and kept for 24 h at room temperature with stirring.

The extracts obtained by decoction and maceration were first filtered with cotton and then centrifuged at 2000 rpm for 10 min. The supernatant of each extract was freeze-dried and stored for further chemical analysis.

Phytochemical screening

Phytochemical screening of methanolic and aqueous extracts was performed on high performance thin layer chromatography (CAMAG, Switzerland) plates ($20\ \text{cm} \times 10\ \text{cm}$ silica gel $60\ F_{254}$) according to analytical techniques already known (Dohou et al., 2003). Approximately 2 to 3 µL of each extract were deposited as 5 mm band with a semi-automatic plate spotter (CAMAG HPTLC LIONOMAT 5 system, Switzerland). The mobile phases used to develop the plates were the solvent systems [Ethyl acetate-Formic acid-Acetic acid-Water (100: 11: 11: 26, v/v/v/v)] for flavonoids and [Ethyl acetate-Water-Methanol-n-Hexane (11.9: 1.6: 1.4: 3.5, v/v/v/v)] for tannins. Concerning flavonoids, the chromatoplate was sprayed with Neu reagent after heating at 105°C for two (02) min and flavonoids were revealed at 366 nm. For tannins, the plate was sprayed with a 2% ferric trichloride ($FeCl_3$) reagent. Evaluation was performed under white light.

Quantitative determination of total flavonoids and tannins content

Flavonoids and tannins are known to be bioactive antidiabetic (Mangambu et al., 2014). The determination of flavonoids was carried out according to the method of Kumaran and Karunakaran

Table 1. Distribution (%) of traditional healers by age and sex.

Province	Age		Sex	
	30-59	≥60	M	F
Sanmatenga	66.67	33.33	72.92	27.08
Zounweogo	45.95	54.05	91.89	8.11
Bazega	60	40	80	20
Average	57.54	42.46	81.60	18.40

M: Male; F: Female.

(2007) adapted by Abdel-Hameed (2009). Two milliliter of extract (1 mg/mL in methanol) were mixed with 2 mL of Aluminum trichloride (2%). After 40 min incubation at room temperature, the absorbance was measured at 415 nm using a spectrophotometer (Agilent 8453) against a standard quercetin curve (R^2 = 0.999), a white control tube containing 2 ml of methanol and the tests were realized in triplicate. The flavonoids content in the extract was determined in milligram-equivalent quercetin (EQ) per 100 g dry matter (mg EQ/ 100 gMS).

Hydrolyzable and condensed tannins were quantified. The hydrolyzable tannins were determined using the method of Mole and Waterman (1987). One (1) mL of extract was mixed with a solution prepared from 10^{-2} M ferric trichloride ($FeCl_3$) in 10^{-3} M hydrochloric acid (HCl). After 15 s, the absorbance of the mixture was measured at 660 nm. All test was carried out in triplicate. The content of hydrolysable tannins [T (%)] was determined using the following formula:

$$T(\%) = \frac{A \cdot PM \cdot V \cdot FD}{\varepsilon_{mole} \cdot P}$$

A: absorbance; ε_{mole} : 2169 for gallic acid; PM: molecular weight of gallic acid (170.12 g/mol); V: volume of extract used; P: weight of the sample; FD: dilution factor.T expressed in % or in milligram-equivalent gallic acid (EGA) per 100 g of dry matter (mg EGA/100 gMS)

Condensed tannins were measured according to Swain and Hillis (1959) method. One milliliter of the extract was added to 2 mL of a solution prepared from 1% vanillin in 70% sulphuric acid. The entire mixture was incubated for 15 min in a water bath at 20°C and the absorbance was read at 500 nm. The quantity of condensed tannins T (%) was determined using the following formula:

$$T\,(\%) = 5.2x\,10^{-2} \times \frac{A \cdot V}{P}$$

5.2x 10^{-2}: Cyanidine equivalence constant; A: Absorbance; V: volume of extract used; P:sample weight. T expressed in % or in milligram-equivalent Cyanidine (EC) per 100 g of dry matter (mg EGA/ 100 g MS) (Swain and Hillis, 1959; Mole and Waterman, 1987)

Statistical analysis

The frequency of citation (Fc) (Appendix 1) and the Informant Consensual Factor (FIC) were obtained by analyzing the survey data. The frequency of citation (Fc) reflects the regularity in the distribution of species within the community of traditional healers (Gnagne et al., 2017). Fc was computed according to the formula:

$Fc = (n_i / N) x100$

where n_i is the number of citations for species i and N is the total number of citations for all species.

To assess the consensus level of plant use among traditional healers, the Informant Consensual Factor (FIC) was determined by the following formula:

FIC= (Nur - Nt) / (Nur - 1)

Nur was the number of citations of use in pathology and Nt is the number of species cited for the management of the pathology. The FIC varies between 0 and 1; if FIC near 1, there is more consensus among informants on the use of plants in the management of diabetes (Latoundji et al., 2019).

The results of the determination of total flavonoids and tannins contents were expressed as mean ±SEM (Standard error of the mean). The results were compared using One-way analysis of variance (ANOVA) with R. 3.6.0 software (R Core Team, 2020). A significant difference was considered for $p<0.05$.

RESULTS

Traditional healers' socio-demographic parameters and diabetes diagnosis

The majority of the traditional healers surveyed in the provinces of Sanmatenga, Bazega and Zounweogo were men with 72.92, 80 and 91.89% respectively (Table 1). The lowest proportion of women (8.11%) was observed in the province of Zounweogo while the highest was recorded in Sanmatenga (27.08 %). The majority of traditional healers in the provinces of Sanmatenga (66.67%) and Bazega (60%) was less than 60 years old. However, more than half (54.05%) of those in Zounweogo were at least 60 years old.

On average in the three provinces, most of the surveyed were men (81.60%) and 57.54% were between 30 and 59 years of age.

The diagnosis of diabetes by THs was mainly based on its symptoms. On average, polyuria (25.91%) and oedema (21.75%) were the most common symptoms cited by THs for the management of diabetes in all three provinces. The others cited symptoms were drowsiness (14.29%), tiredness or weakness (14.29%), slow cicatrizing (13.87%) and vertigo (9.89 %) (Table 2). Considering the provinces individually, the polyuria was the most symptom used by the THs of Sanmatenga (32.35%) following by Zounweogo (31.08%) province, while oedema (37.14%) was the symptom most cited

Table 2. Symptoms use (%) for diagnosis of diabetes.

Province	Oedema	Drowsiness	Vertigo	Tiredness/weakness	Polyuria	Slow cicatrizing
Sanmatenga	7.84	16.67	15.69	13.73	32.35	13.73
Zounweogo	20.27	16.22	5.41	14.86	31.08	12.16
Bazega	37.14	10	8.57	14.29	14.29	15.71
Average	21.75	14.29	9.89	14.29	25.91	13.87

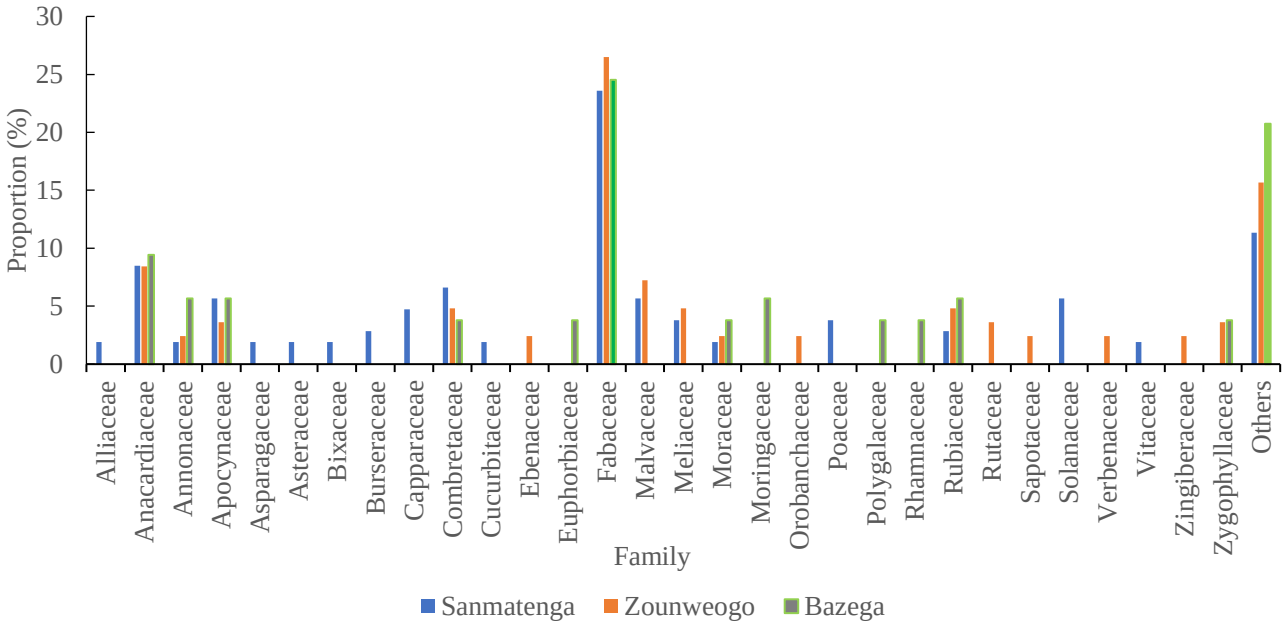

Figure 2. Spectrum of botanical families of species used for the management of diabetes in Bazega, Zounweogo and Sanmatenga.

by those of Bazega.

Species diversity and consensus factor for their use in diabetes management

In the province of Bazega, 37 species belonging to 36 genera and 24 families were inventoried. In Zounweogo 55 species belonging 49 genera and 29 families were recorded while 65 species belonging to 58 genera and 31 families were recorded in Sanmatenga. The Fabaceae were the most cited family and represented by 24.53, 26.51 and 23.58% of the species collected in Bazega, Zounweogo and Sanmatenga respectively. Twelve (12) families of the provinces of Bazega and Sanmatenga and 13 families in Zounweogo was each represented by a single species cited (Figure 2).

The most cited species for the management of diabetes by the THs of Bazega were *Sclerocarya birrea* (9.43%), *Afzelia africana* Sm. ex Pers. (5.66%), *Moringa oleifera* (5.66%) and *Tamarindus indica* L. (5.66%). In the province of Zounweogo, the most cited species were *Tamarindus indica* (8.43%), *Sclerocarya birrea* (4.82%), *Balanites aegyptiaca* (3.61%), *Cassia sieberiana* (3.61%) and *Khaya senegalensis* (Desr.) A. Juss. (3.61%). The THs of Sanmatenga mainly cited *Cassia sieberiana* (8.49%), *Capsicum frutescens* L. (3.77%), *Cassia italica* (3.77%), *Daniellia oliveri* (2.83%), *Khaya senegalensis* (2.83%), *Lannea acida* (2.83%) and *Tamarindus indica* (2.83%) (Appendix 1). In addition, other species such as *Feretia apodanthera*, *Crescentia cujete*., *Ficus ingens* and *Ficus platyphylla* which were used by traditional healers in the three provinces, are also included.

Table 3 has presented the factor of informant consensus for each of the THs of provincial associations. Analysis of this table shows a higher FIC in the province of Sanmatenga (0.39) and the lowest in Bazega (0.31). However, in no case did the FIC reach 50%.

Plant use patterns in the management of diabetes

Several parts of plants were collected by traditional

Table 3. Informant consensual factor (FIC) about plant species uses.

Province	Number of citations	Number of species	FIC
Bazega	53	37	0.31
Zoundweogo	83	55	0.34
Sanmatenga	106	65	0.39

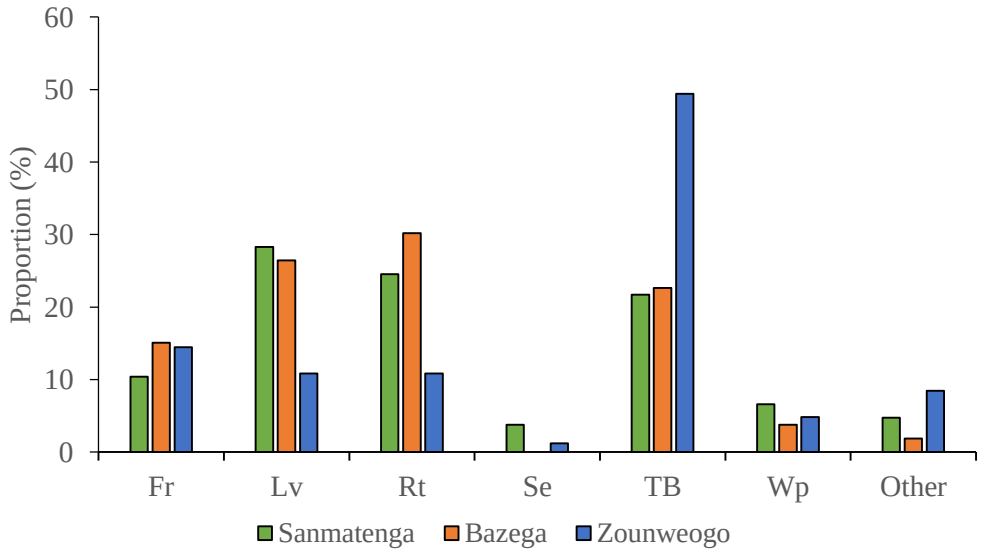

Figure 3. Frequency of plant organs used. Fr: Fruit; Lv: leaves; Rt: Root; Se: Seed; TB: Trunk bark; Wp: Whole plant.

healers in each of the three provinces to formulate medicinal recipes (Figure 3). The THs in province of Bazega used mainly roots (30.19%) followed by leaves (26.42%) and trunk bark (22.64%). Those of Sanmatenga used mainly leaves (28.3%) followed by roots (24.53%) and trunk bark (21.7%). In the province of Zounweogo, TH mainly used trunk bark (49.40%). The main method of recipes formulation was decoction (Figure 4) with frequency of citation reaching at 49, 66 and at 43% in Bazega, Zounweogo and Sanmatenga provinces respectively. The most frequently cited route of administration was the oral route.

Phytochemical screening and determination of phenolic compounds

Phytochemical screening by HPTLC of all plants investigated aqueous and methanolic extracts revealed the presence of flavonoids and tannins. The results of the quantitative evaluation of total flavonoids and tannins (Table 4) showed that the total flavonoids contents did not vary significantly according to the type of extract concerning *Ficus platyphylla* ($P = 0.318$), *Lannea acida* ($P = 0.125$), *Balanites aegyptiaca* ($P = 0.196$) and *Daniellia oliveri* ($P = 0.263$). This was not the case for the other five species. Thus, the total flavonoids quantities of *F. ingens* and *F. apodanthera* aqueous extracts were higher than those of their methanolic extracts ($P = 0.029$, $P < 0.001$). For the cases of *Crescentia cujete*, *Cassia italica* and *Boscia angustifolia*, total flavonoid contents of the methanolic extracts were significantly higher ($P < 0.001$, $P = 0.005$ and $P = 0.008$ respectively) than those of the aqueous extracts (Table 4).

The quantities of hydrolyzable and condensed tannins varied significantly between the types of extracts for all plant species except *B. aegyptiaca* where the contents were practically the same ($P = 1$). The total flavonoids, hydrolyzable tannins and condensed tannins contents also varied significantly from one species to another ($P < 0.001$). Indeed, the lowest quantities of total flavonoids were obtained with the trunk bark of *B. aegyptiaca* aqueous extracts (4.81 ± 0.96 mg EQ/100 g dry matter) and methanolic extracts (3.91 ± 0.31 mg EQ/100 g dry matter). The leaves of *C. italica* methanolic extract (11.03 ± 0.07 mg EQ/100 g dry matter) and the trunk bark of *F. platyphylla* aqueous extract (11.02 ± 0.19 mg EQ/100 g dry matters) contained the highest contents of total flavonoids (Table 4). The highest hydrolysable tannins contents were observed with the leaves of *C. italica*

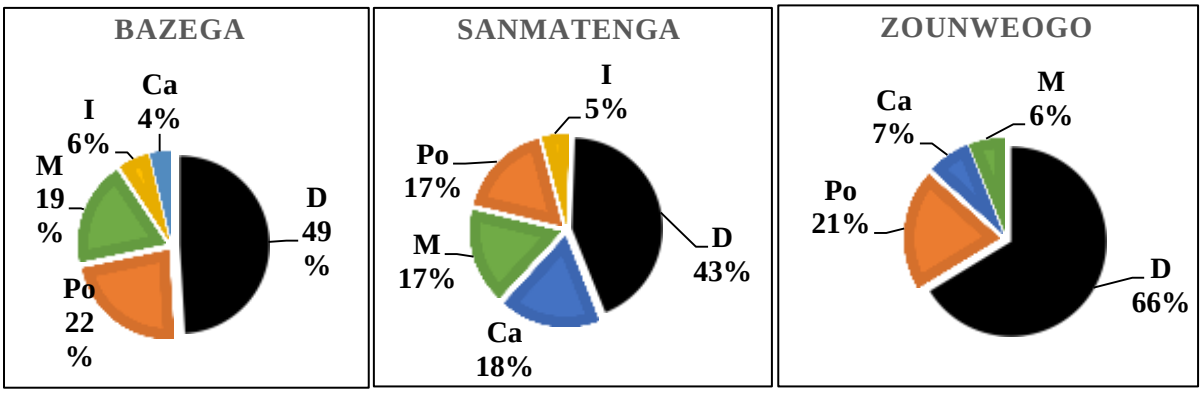

Figure 4. Distribution of recipe formulation modes. D: Decoction; M: Maceration; Ca: Calcination; Po: Powder; I: Infusion.

methanolic extract (34.82 ± 0.14 mg ETA/100g dry matter) while the highest condensed tannins quantity was noted in the *Lannea acida* methanolic extract (543.94 ± 18.67 mg ETA /100 g dry matter) (Table 4).

DISCUSSION

Demographic profile of informants and their diabetes knowledge

In the provinces of Sanmatenga, Bazega and Zounweogo, several THs use plants in diabetes management. The majority of those surveyed were men and their ages ranged from 30 to 59 years. In African societies, customs, culture and illiteracy remain the main obstacle to women emergence (Belemnaba et al., 2014). Men were privileged in the transmission of knowledge about the treatment of general diseases and women were interested in children's diseases (Zizka et al., 2015). The knowledge about diabetes management has been acquired after a long experience accumulation. The high number of traditional healers range between these two ages (30 and 59) could be explained by the rejuvenation of the population of Burkina Faso. Although the main symptoms (polyuria, oedema, slow cicatrizing and vertigo) used to diagnose diabetes were known to all THs, their citations remain low compared to other work (Gbekley et al., 2015). This reflects a low knowledge of the disease by rural people. Indeed, the etiopathogenesis of diabetes mellitus is complex and remains imperfectly known (Féry and Paquot, 2005).

Consensus level in plant species use for diabetes management

Plant species used by THs belonged mainly to the family of Fabaceae. Considering their numerical importance, the Fabaceae represented one of the most dominant families in the savannahs of Burkina Faso. They were also known for their particular importance in traditional medicine (Zizka et al., 2015).

Several species namely *F. platyphylla*, *L. acida*, *B. aegyptiaca*, *D. oliveri, F. apodanthera, C. cujete*, *C. italica* and *B. angustifolia*, were commonly cited by THs in the provinces of Bazega, Sanmatenga and Zounweogo. However, the Informant Consensual Factor (FIC) related to the use of these species did not reach 50%. Thus, there was a low consensus among respondents on the use of plants in the management of diabetes in the three traditional healer associations. This does not inevitably reflect the inefficacy of the proposed medicinal recipes but could be explained by the desire of some THs to keep their knowledge secretly. On the other hand, low FIC values may indicate a low prevalence of diabetes in the study area. In addition, FIC values below average may reflect the result of confusion during interviews or indicate that the species cited have become rare or were under the influence of cultural adaptation (Heinrich et al., 2009).

Plant use patterns in the management of diabetes

For the recipes formulation, the results showed that the THs of investigated province used mainly the roots, leaves and trunk bark of the plants. The predominant use of these organs confirms the previous studies results carried out in Côte d'Ivoire (Tra Bi et al., 2008) and in Togo (Karou et al., 2011). The use of the leaves would be explained by their photosynthetic capacity but also by their accessibility, availability and their easy harvesting. Intensive leaf harvesting does not significantly affect plant survival. On the other hand, the massive harvest of roots and bark are prejudicial to it (Wangny et al., 2019). About the medicinal recipes, recent studies have indeed shown that decoction was the most commonly used method of

Table 4. Total flavonoids and tannin contents.

Plants	AE	ME	Df	F value	Pr(>F)
Flavonoids (mg EQ /100 g of extract)					
*Balanites aegyptiaca*_(TB)	4.81 ± 0.96^{a}	3.91 ± 0.31^{b}	1	2.41	0.196
*Boscia angustifolia*_(TB)	10.04 ± 0.30^{b}	10.90 ± 0.04^{cd}	1	23.63	0.008**
*Cassia italica*_(Lv)	10.40 ± 0.19^{b}	11.03 ± 0.07^{d}	1	30.93	0.005**
*Crescentia cujete*_(Lv)	10.74± 0.00^{b}	10.92 ± 0.03^{cd}	1	100.9	<0.001***
*Daniellia oliveri*_(TB)	10.82 ± 0.04^{b}	10.87 ± 0.05^{cd}	1	1.69	0.263
*Feretia apodanthera*_(RB)	10.90± 0.05^{b}	3.30 ± 0.42^{a}	1	978.9	<0.001***
*Ficus ingens*_(TB)	10.80± 0.04^{b}	10.46 ± 0.17^{c}	1	10.91	0.029*
*Ficus platyphylla*_(TB)	11.02 ± 0.19^{b}	10.88 ± 0.07^{cd}	1	1.297	0.318
*Lannea acida*_(TB)	10.85 ± 0.05^{b}	10.99 ± 0.12^{cd}	1	3.754	0.125
Pr(>F)	<0.001***	<0.001***			
Hydrolyzable tannins (mg ETA /100 g of extract)					
*Balanites aegyptiaca*_(TB)	1.79 ± 0.04^{a}	3.97 ± 0.09^{a}	1	509.4	<0.001***
*Boscia angustifolia*_(TB)	2.72 ± 0.08^{a}	6.61 ± 0.40^{b}	1	39.49	0.003 **
*Cassia italica*_(Lv)	5.70 ± 0.05^{b}	34.82 ± 0.14^{g}	1	130247	<0.001***
*Crescentia cujete*_(Lv)	8.76 ± 0.41^{c}	32.64 ± 0.15^{f}	1	2882	<0.001***
*Daniellia oliveri*_(TB)	16.77 ± 0.37^{e}	17.35 ± 0.05^{d}	1	13.44	0.021*
*Feretia apodanthera*_(RB)	4.62 ± 0.08^{b}	18.43 ± 0.08^{d}	1	1692	<0.001***
*Ficus ingens*_(TB)	9.33 ± 0.35^{c}	28.51 ± 0.26^{e}	1	4065	<0.001***
*Ficus platyphylla*_(TB)	14.71 ± 0.25^{d}	9.37 ± 0.21^{c}	1	359.9	<0.001***
*Lannea acida*_(TB)	21.57 ± 1.97^{f}	17.92 ± 1.25^{d}	1	13.03	0.022*
Pr(>F)	<0.001***	<0.001***			
Condensed tannins (mg ETA /100 g of extract)					
*Balanites aegyptiaca*_(TB)	44.41 ± 0.54^{b}	44.41 ± 0.54^{a}	1	0	1
*Boscia angustifolia*_(TB)	33.39 ± 2.17^{ab}	492.80 ± 2.85^{d}	1	14437	<0.001***
*Cassia italica*_(Lv)	31.44 ± 1.83^{ab}	445.10 ± 7.49^{c}	1	528	<0.001***
*Crescentia cujete*_(Lv)	19.02 ± 2.45^{a}	62.84 ± 0.94^{a}	1	1214	<0.001***
*Daniellia oliveri*_(TB)	512.73 ± 8.64^{e}	53.76 ± 1.50^{a}	1	15945	<0.001***
*Feretia apodanthera*_(RB)	468.60 ± 4.32^{d}	52.60 ± 0.23^{a}	1	2732	<0.001***
*Ficus ingens*_(TB)	519.37 ± 6.23^{e}	32.02 ± 0.22^{a}	1	3535	<0.001***
*Ficus platyphylla*_(TB)	70.45 ± 194.^{c}	262.57 ± 4.22^{b}	1	1339	<0.001***
*Lannea acida*_(TB)	75.29 ± 4.68.^{c}	543.94 ± 18.67^{e}	1	2474	<0.001***
Pr(>F)	<0.001***	<0.001***			

On the columns, values with the same letters are no significantly different (at the 5% threshold) among species. Df: Degree of freedom; AE: Aqueous extract; ME: Methanolic extract, Lv: Leaves, TB: Trunk bark, RB: Root bark.

formulation and that the oral route was frequently proposed by traditional healers in the management of diabetes (Gbekley et al., 2015; Gnagne et al., 2017). Indeed, it is well know that the decoction allows to extract the most active plant ingredients, reduces or eliminates the toxic effects of recipes and warm the body (Redouan et al., 2020).

Plants anti-diabetic potentiality and content variation of phenolic compounds

The presence of flavonoids and tannins in aqueous and methanolic extracts of species selected namely *C. cujete, F. ingens*, *F. platyphylla*, *L. acida*, *B. aegyptiaca*, *D. oliveri*, *F. apodanthera*, *C. italica* and *B. angustifolia* indicate that these species cited by the THs have antidiabetic properties. Several studies had shown the link between the antioxidant property and the pharmacological properties of tannins and flavonoids (Laddha and Kulkarni, 2018; Traore et al., 2018). Flavonoids are very powerful antioxidant compounds, that help reduce the incidence of stroke, diabetes and cancer (Ghasemzadeh and Ghasemzadeh, 2011). Thus, quercetin at higher dose completely prevented elevation

of plasmatic glucose values. Chrysin at a dose of 50 mg/kg body weight also significantly prevented alloxan-induced plasmatic glucose increase in rats (Lukačínová et al., 2008). *Per os* administration of tannins (100 and 200 mg/kg body weight) in rat had significant ($p<0.05$) decrease blood glucose levels at 7^{th}, 14^{th} and 30^{th} day comparable to that of metformin (Ravichandiran et al., 2012). Flavonoids are mainly involved in venous insufficiency, cause a decrease in the permeability of capillary walls and increase their resistance. The dosage of these phenolic compounds showed a non-significant variation in the contents of total flavonoids according to the two types of extracts (methanolic and aqueous) concerning *F. platyphylla*, *L. acida*, *B. aegyptiaca* and *D. oliveri* while for *F. ingens*, *F. apodanthera*, *C. cujete*, *C. italica* and *B. angustifolia* this variation was significant. In addition, the quantitative evaluation of tannins showed significant variation between types of extracts for all plants except *B. aegyptiaca.* The phenolic compounds content depends on several parameters including the extraction method, the solvent but also the part of the plant used as well as the presence of other interfering substances (Zhao et al., 2005). A study on extraction methods (Aires, 2017) showed that ethyl acetate and methanol were the best solvents for the extraction of flavonoids and tannins, respectively. Konaré et al. (2020) had also shown that methanol was the best solvent for *F. platyphylla* extraction and flavonoid content were higher in the leaf extract than the bark extract. Due to the possible interaction between these compounds and other compounds such as carbohydrates and proteins, it is therefore difficult to find a suitable method to extract all phenolic compounds (Yu et al., 2005). The most advantageous method is one that is simple, quick, less expensive and takes into account the environment. Thus, in this case, in addition to *F. platyphylla*, *L. acida*, *B. aegyptiaca* and *D. oliveri* where the contents did not vary, water can therefore be considered the most suitable solvent of flavonoid extraction in *F. ingens* trunk bark and *F. apodanthera* roots. This is valid for the extraction of hydrolyzable tannins in trunk bark of *F. platyphylla* and *L. acida* and condensed tannins in *F. ingens, F. apodanthera, B. aegyptiaca* and *D. oliveri.*

B. aegyptiaca was one of the species with the lowest total flavonoid content especially. A similar result was reported in a previous study (Traore et al., 2018). The nature of the chemical compounds and their content variation between species can be explained by the influence of some ecological factors such as soil type, soil pH, ultraviolet rays, organic matter and annual precipitation (Liu et al., 2015). Indeed, a phytochemical analysis carried out on the leaves of *Cassia italica* (*Senna italica*) methanolic extracts collected in several areas had given flavonoid contents varying between 1.17± 0.123 and 3.33 ± 0.175 mg EQ/g extract and total tannins contents varying between 8.23 ± 0.235 and 40.7 ± 1.48 mg GAE/g extract (Gololo et al., 2018). In addition, the determination of total phenolics and total flavonoids of trunk bark extracts of *L. acida* harvested in the southern Sudanian area of Burkina Faso revealed 40.55+0.26 g GAE/100g and 8.70+0.02 g QE/100g, respectively (Ouattara et al., 2011). The dosage of total flavonoids and tannins confirms the presence of these compounds in the aqueous and methanolic extracts of all the plants investigated, justifying their use by traditional healers.

Conclusion

The management of diabetes by the traditional healers in the provinces of Bazega, Sanmatenga and Zounweogo is a reality. Although several plant species were used by the traditional healers for the management of diabetes, the survey results indicated that there was a lost consensus about the information provided by the traditional healers in each of the three provinces. This means that knowledge was still keeping in a small community. However, the phytochemical screening performed on the aqueous and methanolic extracts of all the plants selected among the most cited revealed the presence of total flavonoids and tannins corroborating their use in the management of diabetes. The total flavonoids, hydrolyzable tannins and condensed tannins contents varied significantly from one species to another. Thus, among the plant species selected, *C. italica* and *L. acida* methanolic extract presented the best total flavonoids and tannins content respectively. Therefore, there is an interest in continuing the chemical and biological investigations on these species for effective management of diabetes and hypertension.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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APPENDIX

Appendix 1. Species most used for the management of diabetes in the provinces of Bazega, Sanmatenga and Zounweogo.

Species	Family	Local name (Mooré)	Part used	Formulation	Administration route	Frequency of citation (%)		
						BAZ	SAN	ZOU
Acacia ataxacantha DC.	Fabaceae	*Goaga*	Trunk bark	Po	OR	1.89	-	1.20
Acacia nilotica (L.) Willd. ex Delile	Fabaceae	*Ping-nenga*	Fruit	D	OR	-	-	1.20
Acacia sieberiana DC.	Fabaceae	*Gonponsgo*	Trunk bark	D	OR	-	0.94	-
Acacia tortilis (Forssk.) Hayne	Fabaceae	*Gonsablga*	Root	D	OR	-	-	1.20
Adansonia digitata L.	Malvaceae	*Toèga*	Trunk bark, flower	D, Ca	OR	-	1.89	2.41
Aframomum melegueta K. Schum	Zingiberaceae	*Zoumbri*	Fruit	Po	OR	-	-	1.20
Afzelia africana Sm. ex Pers.	Fabaceae	*Kankalga*	Root, trunk bark	M	OR	5.66	-	-
Allium sativum L.	Alliaceae	*Laye*	Tuber	D	OR	-	1.89	-
Aloe vera (L.) Burm.f.	Asphodelaceae	*Zimsallé*	Whole plant	D	OR	-	-	1.20
Annona senegalensis Pers.	Annonaceae	*Badkoudga*	Leaves, root	D	OR	3.77	-	1.20
Anogeissus leiocarpa (DC.)Guill. & Perr.	Combretaceae	*Siiga*	Leaves, trunk bark	I, D	OR	-	0.94	2.41
Azadirachta indica A.Juss.	Meliaceae	*Niim*	Leaves	D	OR	-	0.94	-
Baissea multiflora A.DC.	Apocynaceae	*Nongm-taaba*	Leaves	Po	OR	-	-	1.20
Balanites aegyptiaca (L.) Delile	Zygophyllaceae	*Kièglga*	Trunk bark, root	D	OR	3.77	0.94	3.61
Bauhinia rufescens Lam.	Fabaceae	*Tiipoèga*	Fruit, trunk bark	D, Po	OR	1.89	-	1.20
Bombax costatum Pellegr. & Vuill.	Malvaceae	*Voaka*	Trunk bark	M, D, Po	OR	1.89	0.94	2.41
Boscia angustifolia A.Rich.	Capparaceae	*Zigrezika*	Trunk bark	M	Bb	-	0.94	-
Boscia salicifolia Oliv.	Capparaceae	*zogrega*	Leaves	D	OR	-	0.94	-
Boscia senegalensis (Pers.) Lam.	Capparaceae	*Nabré/Lamboètga*	Root	Po	OR	-	-	1.20
Boswellia dalzielii Hutch.	Burseraceae	*Komdayouingo*	Trunk bark	D	OR	-	0.94	-
Cadaba farinosa Forssk.	Capparaceae	*kinsga*	Root	Ca	OR	-	0.94	-
Calotropis procera (Aiton) R.Br.	Apocynaceae	*Poutrepouga*	Root, leaves	D, M	OR, Bb	3.77	0.94	-
Capsicum frutescens L.	Solanaceae	*Kiparé*	Fruit	D, Po	OR	-	3.77	-
Carica papaya L.	Caricaceae	*Bog-firé*	Root, leaves	Po	OR	1.89	-	-
Cassia italica (Mill.) Lam. ex F.W.Andrews	Fabaceae	*Nontoulm-songré*	Leaves	D, M, Po	OR	-	3.77	2.41
Cassia obtusifolia L.	Fabaceae	*soagda*	Root	D	OR	-	0.94	-
Cassia sieberiana DC.	Fabaceae	*Koubresaka/Yâmtiiga*	Root, trunk bark	D, Po, M	OR	-	8.49	3.61
Ceratotheca sesamoides Endl.	Pedaliaceae	*Boundou*	Whole plant	Po	OR	-	0.94	-
Cissus quadrangularis L.	Vitaceae	*wobyon-raaga*	Leaves	Ca	OR	-	1.89	-
Citrus limon (L.) Burm.f.	Rutaceae	*Citro-tiiga*	Fruit, trunk bark	D, M	OR	-	-	2.41
Cochlospermum tinctorium Perr. ex A.Rich.	Bixaceae	*Sonsga*	Root	Po, D	OR	1.89	1.89	1.20
Coldenia procumbens L.	Boraginaceae	*koulpousssa*	Whole plant	Po	OR	-	0.94	-
Combretum glutinosum Perr. ex DC.	Combretaceae	*Koèguenga*	Leaves	I	OR	-	0.94	-
Combretum micranthum G.Don	Combretaceae	*Kânga/Ranega*	Leaves, root	D, M, I	OR	1.89	1.89	-
Combretum paniculatum Vent.	Combretaceae	*Koudgou-loungou*	Leaves	D	OR	-	1.89	-

Appendix 1. Contd.

Commiphora africana (A.Rich.) Engl.	Burseraceae	*Sâbranoudga*	Trunk bark	Ca, M	Bb, OR	-	1.89	-
Crateva adansonii DC.	Capparaceae	*kalgm-toèga*	Leaves	D	OR	-	0.94	-
Crescentia cujete L.	Bignoniaceae	*Wamde-tiiga*	Leaves	D	OR	1.89	0.94	-
Crossopteryx febrifuga (Afzel. ex G.Don) Benth.	Rubiaceae	*Koumbrewanga*	Root, fruit	D	OR	1.89	-	-
Cucurbita pepo L.	Cucurbitaceae	*yogré*	Fruit	M	OR	-	0.94	-
Daniellia oliveri (Rolfe) Hutch. & Dalziel	Fabaceae	*Aonga*	Trunk bark	Po, D, Ca	OR	3.77	2.83	-
Detarium microcarpum Guill. & Perr.	Fabaceae	*Kagdga*	Trunk bark	Po	OR	-	-	1.20
Dicoma tomentosa Cass.	Asteraceae	*Gomtidga*	Whole plant	D	OR	-	1.89	-
Diospyros mespiliformis Hochst. ex A.DC.	Ebenaceae	*Gâaka*	Trunk bark, fruit	D, M	OR	-	-	2.41
Eragrostis tremula Hochst. ex Steud.	Poaceae	*saag-pugla*	Root	D	OR	-	1.89	-
Excoecaria grahamii Stapf	Euphorbiaceae	*Koin-nem*	Root	D, Po	OR	1.89	-	1.20
Feretia apodanthera Delile	Rubiaceae	*Kitenga*	Root, leaves	D, I, Ca	OR	1.89	1.89	2.41
Ficus ingens (Miq.) Miq.	Moraceae	*Kuisinkuiga*	Root, trunk bark	D	OR	1.89	-	1.20
Ficus platyphylla Delile	Moraceae	*Kamsongo*	Trunk bark, leaves	D	OR	1.89	0.94	-
Ficus sur Forssk.	Moraceae	*Womsèga*	Leaves	Po	OR	-	-	1.20
Ficus sycomorus L.	Moraceae	*Kankanga*	Trunk bark	D	OR	-	0.94	-
Gardenia sokotensis Hutch.	Rubiaceae	*Tang-rakoènga*	Leaves	D	OR	-	-	1.20
Glossonema boveanum (Decne.) Decne.	Apocynaceae	*Kotin-loondo*	Whole plant	Ca, D	OR	1.89	0.94	-
Grewia bicolor Juss.	Malvaceae	*yoalg-sablga*	Fruit	Po	OR	-	0.94	-
Guiera senegalensis J.F.Gmel.	Combretaceae	*Wilinwiga*	Leaves	D, I, Po	OR	1.89	0.94	1.20
Gymnosporia senegalensis (Lam.) Loes.	Celastraceae	*Tok-vugri*	Trunk bark	Ca	OR	-	-	1.20
Hibiscus sabdariffa L.	Malvaceae	*Biito*	Seed	Ca	OR	-	0.94	-
Ipomoea asarifolia (Desr.) Roem. & Schult.	Convolvulaceae	*Balbanto*	Whole plant	D	OR	-	-	1.20
Jatropha curcas L.	Euphorbiaceae	*Wâbin-bâguema*	Leaves	Po, M	OR	1.89	0.94	-
Khaya senegalensis (Desr.) A.Juss.	Meliaceae	*Kouka*	Trunk bark	D, Po, Ca	OR, Bb	-	2.83	3.61
Lagenaria siceraria (Molina) Standl.	Cucurbitaceae	*Kândé*	Leaves	Ca	OR	-	0.94	-
Lannea acida A.Rich.	Anacardiaceae	*Sâbtoulga*	Trunk bark	M, D	OR	-	2.83	2.41
Lannea microcarpa Engl. & K.Krause	Anacardiaceae	*Sâbga*	Trunk bark, leaves	D, M	OR	-	1.89	1.20
Leptadenia hastata (Pers.) Decne.	Apocynaceae	*Leulongo*	Leaves, root	D, Ca	OR	-	1.89	1.20
Lippia chevalieri Moldenke	Verbenaceae	*Wissao-raaga*	Leaves , stem bark	D, Ca	OR	-	-	2.41
Maerua angolensis DC.	Capparaceae	*Zilgo*	Root	Ca	OR	-	0.94	-
Mangifera indica L.	Anacardiaceae	*Mangré*	Whole plant, root	D	OR	-	1.89	-
Mentha spicata L.	Lamiaceae	*Menthe*	Leaves	D	OR	-	-	1.20
Mitragyna inermis (Willd.) Kuntze	Rubiaceae	*Yiilga*	Root, leaves	D	OR	1.89	0.94	-
Moringa oleifera L.	Moringaceae	*Arzentiiga*	Leaves	Po, D	OR	5.66	0.94	-
Musa xparadisiaca L.	Musaceae	*Banandé*	Stem	I	Bb	1.89	-	-
Ocimum americanum L.	Lamiaceae	*Youninyou-raaga*	Whole plant	Ca	OR	1.89	-	-

Appendix 1. Contd.

Parkia biglobosa (Jacq.) R.Br. ex G.Don	Fabaceae	*Roanga*	Leaves, seed, fruit	Po, D	OR	1.89	0.94	2.41
Pennisetum glaucum (L.) R.Br.	Poaceae	*Kazui*	Root, seed	Ca, M	OR	-	1.89	-
Persea americana Mill.	Lauraceae	*Avoca-tiiga*	Leaves	D	OR	-	-	1.20
Piliostigma reticulatum (DC.) Hochst.	Fabaceae	*Baguen-daaga*	Fruit	Ca, M	OR	-	1.89	-
Piliostigma thonningii (Schumach.) Milne-Redh.	Fabaceae	*Baguen-yanga*	Trunk bark	D	OR	-	-	1.20
Piper guineense Schum. et Thonn.	Piperaceae	*Fèfè*	Fruit	Po	OR	-	-	1.20
Prosopis africana (Guill. & Perr.) Taub.	Fabaceae	*Ronsondoanga*	Root	Po	OR	1.89	-	-
Pseudocedrela kotschyi (Schweinf.) Harms	Meliaceae	*Sègdré*	Trunk bark	D	OR	-	-	1.20
Pterocarpus erinaceus Poir.	Fabaceae	*Noèga/ Noèka*	Trunk bark	D	OR	-	-	1.20
Pterocarpus lucens Lepr. ex Guill. & Perr.	Fabaceae	*Pipèrga*	Root	D	OR	-	-	1.20
Pupalia lappacea (L.) A.Juss.	Amaranthaceae	*Yoins-tabendo*	Fruit	D, Po	OR	1.89	0.94	-
Raphionacme splendens Schltr	Apocynaceae	*Sinnogo*	Tuber, stem bark	Po, D	OR	-	0.94	1.20
Saba senegalensis (A.DC.) Pichon	Apocynaceae	*Wèdga*	Leaves	D	OR	-	0.94	-
Sansevieria liberica Gérôme & Labroy	Asparagaceae	*Fadga*	Root	M	OR	-	1.89	-
Sansevieria senegambica Baker	Asparagaceae	*Kantoabga*	Root	D	OR	1.89	-	-
Sarcocephalus latifolius (Sm.) E.A.Bruce	Rubiaceae	*Gouinga*	Trunk bark	D	OR	-	-	1.20
Sclerocarya birrea (A.Rich.) Hochst.	Anacardiaceae	*Noabga*	Leaves, trunk bark	Po, I, D, M	OR, Bb	9.43	1.89	4.82
Securidaca longipedunculata Fresen.	Polygalaceae	*Pèlga*	Root, trunk bark	D, M, Ca	OR	3.77	0.94	1.20
Solanum incanum L.	Solanaceae	*Noraog-kumbré*	Root	Ca	OR	-	1.89	-
Sorghum bicolor (L.) Moench	Poaceae	*Kazinga*	Seed	D	OR	-	-	1.20
Stachytarpheta indica (L.) Vahl	Verbenaceae	*kiinga*	Whole plant	Ca	OR	-	0.94	-
Sterculia setigera Delile	Malvaceae	*Ponsomponrgo*	Trunk bark	M, D	OR	-	0.94	2.41
Striga hermonthica (Delile) Benth.	Orobanchaceae	*Waongo*	Whole plant	M, Ca	OR	-	-	2.41
Tamarindus indica L.	Fabaceae	*Pousga*	Root, trunk bark, fruit, leaves	M, D, Ca	OR	5.66	2.83	8.43
Terminalia avicennioides Guill. & Perr.	Combretaceae	*Kondpoko*	Trunk bark	D	OR	-	-	1.20
Tinospora bakis (A. Rich) Miers	Menispermaceae	*Begsendé*	Root	D	OR	-	0.94	-
Trichilia emetica Vahl	Meliaceae	*Kikir-taanga*	Trunk bark	Po	OR	1.89	-	-
Urginea glaucescens Engl. Krause	Asparagaceae	*Tons-nab-koyoudo*	Bulb	D	OR	-	-	1.20
Vigna subterranea (L.) Verdc.	Fabaceae	*Souma*	Seed	Po	OR	-	0.94	-
Vigna unguiculata (L.) Walp.	Fabaceae	*Bènga*	Fruit	D	OR	1.89	-	-
Vitellaria paradoxa C.F.Gaertn.	Sapotaceae	*Taanga*	Trunk bark, leaves	D, M	OR	-	-	2.41
Ximenia americana L.	Ximeniaceae	*Lennga*	Root	Po	OR	-	0.94	-
Xylopia aethiopica (Dunal) A.Rich.	Annonaceae	*Kiparin-sablga*	Fruit	M, D, Po	OR	1.89	1.89	1.20
Zanthoxylum zanthoxyloides (Lam.) Zepern. & Timler	Rutaceae	*Salg-rapéko*	Trunk bark	Po	OR	-	-	1.20
Zea mays L.	Poaceae	*Kamaana*	Fruit	D	OR	1.89	-	-
Zingiber officinale Roscoe	Zingiberaceae	*Yâmakou*	Tuber	M, D	OR	1.89	-	1.20
Ziziphus mauritiana Lam.	Rhamnaceae	*Mougouniga*	Leaves, root, trunk bark	D, Po, M	OR	3.77	0.94	1.20

BAZ: Bazega; SAN: Sanmatenga; ZOU: Zounweogo; D: Decoction; M: Maceration; Po: Powder; Ca: Calcination; I: Infusion; OR: Oral route; Bb: Body bath.