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National inventory and usage of plant-based medicine to treat gastrointestinal disorders with cattle in Benin (West Africa)

J.M.-A.S. Ouachinou [a,*], G.H. Dassou [a], R. Idohou [b], A.C. Adomou [a], H. Yédomonhan [a]

[a] Laboratory of Botany and Plant Ecology, Faculty of Sciences and Techniques, University of Abomey-Calavi, Benin
[b] Laboratory of Biomathematics and Forest Estimations, Faculty of Agronomic Sciences, University of Abomey-Calavi, 04 BP, 1525 Cotonou, Benin

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ABSTRACT

Gastrointestinal disorders remained recurrent with livestock in Benin despite huge import of veterinary drugs at high costs. Nevertheless, the country abounds rich and varied anti-gastrointestinal flora which are hardly known, neglected and underutilized. The present study investigated the diversity of plants used to treat gastrointestinal disorders and documented the traditional knowledge associated with them. A total of 690 breeders and farmers were interviewed using open-ended and semi-structured interviews. Data were collected on the identity of the informants, plants and plant parts used, gastrointestinal disorders treated and usage types. Data were analyzed through calculation of relative frequency of citation (RFC), and use of descriptive statistics, multivariate analysis, bar charts and balloonplot. A total of 158 medicinal plant species belonging to 60 families and 130 genera were identified. The most represented were Leguminosae (18%) and Combretaceae (6.4%). Thirty-one plant families were mentioned to be highly utilized, among which the most important were Zygophyllaceae, Phytolaccaceae, Rubiaceae, Lamiaceae, Loranthaceae, Thymelaeaceae and Flacourtiaceae. The species were reported to treat seven gastrointestinal disorders. The most frequently cited were intern parasitosis (35%), diarrhea (29%) and constipation (17%). Leaves (40%) and stem barks (28%) are the plant parts mostly used to treat those disorders. The species with the highest value for RFC were: *Khaya senegalensis*, *Anacardium occidentale*, *Cassia sieberiana*, *Pterocarpus erinaceus* and *Vitellaria paradoxa*. Socioeconomic factors influencing ethnobotanical knowledge about these species were: age, profession and geographic location of the informants. Further analysis of chemical and pharmacological content of those species are necessary to ascertain the efficiency of their claimed properties and relieve farmers of these disorders.

1. Introduction

Thousands of people around the world rely on livestock production as income generating activities. This is more remarkable when sub-Saharan Africa is concerned (Wanzala et al., 2005). Recent works by FAO estimated the livestock size in Benin to be approximately 2,339,000 animals (FAO, 2016). The sector contributed to 16.67% to national economy and employed 70% of the local population, most of which lives in rural areas. Unfortunately, the sector is constrained by many factors such as the poor performance of local breeds, the deficiency or poor quality of foods for the livestock, the conflicts related to rangelands management), the recurrent occurrence of diseases, the endemicity of many infectious diseases, the reappearance risks of some epizootic diseases, the poor prophylaxis, and the deficiency of veterinary care in rural areas (FAO, 2012). Although these threats can considerably affect livestock, the diseases remain the factor which most affects the increase of the production (Ogni, 2016).

Among diseases, gastrointestinal disorders are of a major concern because of their periodicity in farms causing mortality of young animals and the decrease in production (Fabiyi, 1987). Like elsewhere, treating the cattle in Benin is challenging as breeders had to face the high costs of modern veterinary drugs and development of the resistance in front of some drugs. Other difficulties lie in the potential presence of residues in animal derived products (meat and milk) which poses a health hazard to the consumer; thus, reinforcing the need for user-friendly ethnoveterinary medicine (Mathias, 2004). In that case, relying on traditional medicine becomes last resort for safeguarding the livestock and minimizing the residues effects on public health.

Ethnoveterinary knowledge is the cumulative body of knowledge, practices and beliefs about veterinary cares handed down through generations by cultural transmission (McCorkle, 1986). Several scholars widely documented this knowledge across Africa: Tamboura et al. (1998), Bognounou (1993), Bâ (1994), Byavu et al. (2000) and Lulekal et al. (2014). This also applies for Benin, where researchers investigated plants treating animal pathologies (Toigbé, 1978; Assogba, 1984; Hounzangbé-Adoté, 2001; Fagnissè, 2006; Ahouangbènon, 2008; Attindéhou et al., 2012; Dassou et al., 2014, 2015a). However, plants

* Corresponding author.
E-mail address: ouajeronime@gmail.com (J.M.-A.S. Ouachinou).

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treating gastrointestinal disorders remained hardly investigated. Recent works by Ouachinou (2015) reported that medicinal plants are used to treat various gastrointestinal disorders ranging from simple types such as vomiting to more complex problems like stomach ulcer. The effectiveness of herbal remedies for gastrointestinal purposes can be explained by the presence of multiple constituents such as alkaloids, glycoside, flavonoids, terpenes, tannins etc., given medicinal plants use relatively safe (Gilani et al., 2005).

The main objective of this study was to document diversity and ethnobotanical knowledge of plants used by local communities to treat cattle gastrointestinal disorders in Benin. Hypothesis in the frame of the study are as follows:

i. Benin harbors a high diversity of multipurpose plants used to treat gastrointestinal disorders.
ii. The distribution and prevalence of gastrointestinal disorders are patterned along a climatic gradient across Benin.
iii. Overutilization of some anti-gastrointestinal plant families by indigenous communities is due to their versatility and not to random effect.
iv. Gastrointestinal disorders with high prevalence are treated by overutilized plants.
v. Popular anti-gastrointestinal plants used in livestock are multipurpose species.
vi. Geographical location, education level and ethnicity of informants influence the distribution of traditional knowledge.

2. Material and methods

2.1. Study area

The study was conducted in the Republic of Benin (West Africa) located between the latitude 6°10′N and 12°25′N and longitude 0°45′E and 3°55′E. The country is split into three climatic zones: the Guineo-Congolian zone, the Guineo-Sudanian zone and the Sudanian zone (Fig. 1). The mean annual rainfall fluctuates from 900 to 1400 mm per year. The vegetation types vary from a climatic zone to another. According to Adomou (2005), the Guineo-Congolian zone consists of savannah, grassland, farmland, and fallow intermingled with small islands of closed forest (semi-deciduous and swamp forests). In the Guineo-Sudanian and Sudanian zone, the natural vegetation is essentially a patchy of woodlands and savannahs with belts of riparian forest along rivers. Total number of plants used to treat animal pathologies was estimated at 241 species (Dassou et al., 2015a) among the 2807 plant species known for the country (Akoègninou et al., 2006). These were used to treat 45 diseases and symptoms, of which gastrointestinal disorders (Dassou et al., 2015a). The population of the country was estimated at 99,83,884 inhabitants with the majority involved in agriculture and breeding (UNDESA, 2017). The livestock mainly includes cattle (23,39,000), sheep and goats (25,76,000), pigs (4,14,200) and birds (2,00,02,000) (http://www.fao.org). The cattle production tends to be more concentrated in north.

The fieldwork was carried out in 23 localities across the 5 agropastoral zones defined as followed (Fig. 1):

- Sudanian zone with poor pastures: located in the far north where the charge rate in any season exceeds the carrying capacity of pastures.
- Sudanian zone with marginal pastures: where the productivity of natural pastures is relatively low. The exploitation of fallows and agricultural derived products is integrated to animals' herding and pastoral resources management.
- Sudanian zone with surplus pastures: in this area there is an abundance of fodder during the rainy season and a significant deficiency during the drought.
- Sudano-Guinean zone: where forage resources are abundant. However, their exploitation is conflicted by the presence of agricultural lands and the management of the transboundary transhumance particularly from Nigeria.
- Guinean zone: characterized by the presence of post-harvest pastures. Only the plains towards lagoons and rivers hold abundant green fodder all seasons.

2.2. Sampling and data collection

Twenty-three municipalities were selected based on the importance of livestock size and existence of pasture lands. In each municipality, with the help of a Technician in Animal rearing of the Agricultural Department, we selected localities according to their level of recognition in traditional medicine practices, district-wide reputation or popularity in traditional medicine and exclusive or main usages of plant products in healing process (Van den Eynden et al., 1993) and diversity of socio-linguistic groups (Dassou et al., 2015a). Based on their volunteership, 30 breeders and farmers were taken per municipality (leading to a total of 690 for all villages). Semi-structured interviews were conducted to gather information on medicinal uses of plant species. The questionnaire was split into two parts: the first part addressed information related to the informant such as age, gender, ethnicity, profession, level of education and knowledge of the medicinal plants; and the second part concerned information regarding the local plant names, parts used, methods of preparation and application. Additional data regarding taxonomic position (family), vernacular name, life forms and folk medicinal uses were also recorded. Some species were directly identified on the field by using Analytical Flora of Benin (Akoègninou et al., 2006). For others, herbaria were made and sent to the National Herbarium for identification by specialist.

2.3. Data analysis

2.3.1. Taxonomic diversity of multipurpose plant used to treat gastrointestinal disorders

Data gathered through interviews were used to generate the list of species used to treat gastrointestinal disorders. Then, we counted the number of species per taxon (family and genera) and described morphological type, and calculated their relative frequency. To assess the diversity of plants used to treat gastrointestinal disorders, we calculated the Generic coefficient (R_{GS}) which is the ratio of species richness to the generic richness (S/G) (an inverted form of the ratio defined by Fan et al. (2017) and originally developed by Jaccard (1926):

$$R_{GS} = \frac{\mathrm{Ns}}{\mathrm{Ng}} \quad (1)$$

where, Ns is the total number of species recorded and Ng the number of genera. When GC value is equal to 1 ($R_{GS} = 1$), recorded anti-gastrointestinal flora presents a low generic diversity; this means that a given genus counts only one species. When R_{GS} value is higher than 1 ($R_{GS} > 1$), this denotes high generic diversity for recorded anti-gastrointestinal flora (Jaccard, 1926; Fan et al., 2017).

2.3.2. Assessment of gastrointestinal disorders frequency and distribution

We established the list of gastrointestinal disorders, counted their citation number and determined their relative frequency countrywide study areas and per agropastoral zone. Afterwards, a balloonplot was realized for assessing their repartition across all agropastoral zones. For this, a matrix (agropastoral zone x gastrointestinal disorder) based on citation number of each disorder per agropastoral zone was built.

2.3.3. Relationships between plant family and gastrointestinal uses

A matrix was constructed based on the number of species per family recorded and the medicinal plant species used to treat gastrointestinal disorders. The such built matrix was submitted to a generalized linear model to test for the relationship between the number of species used

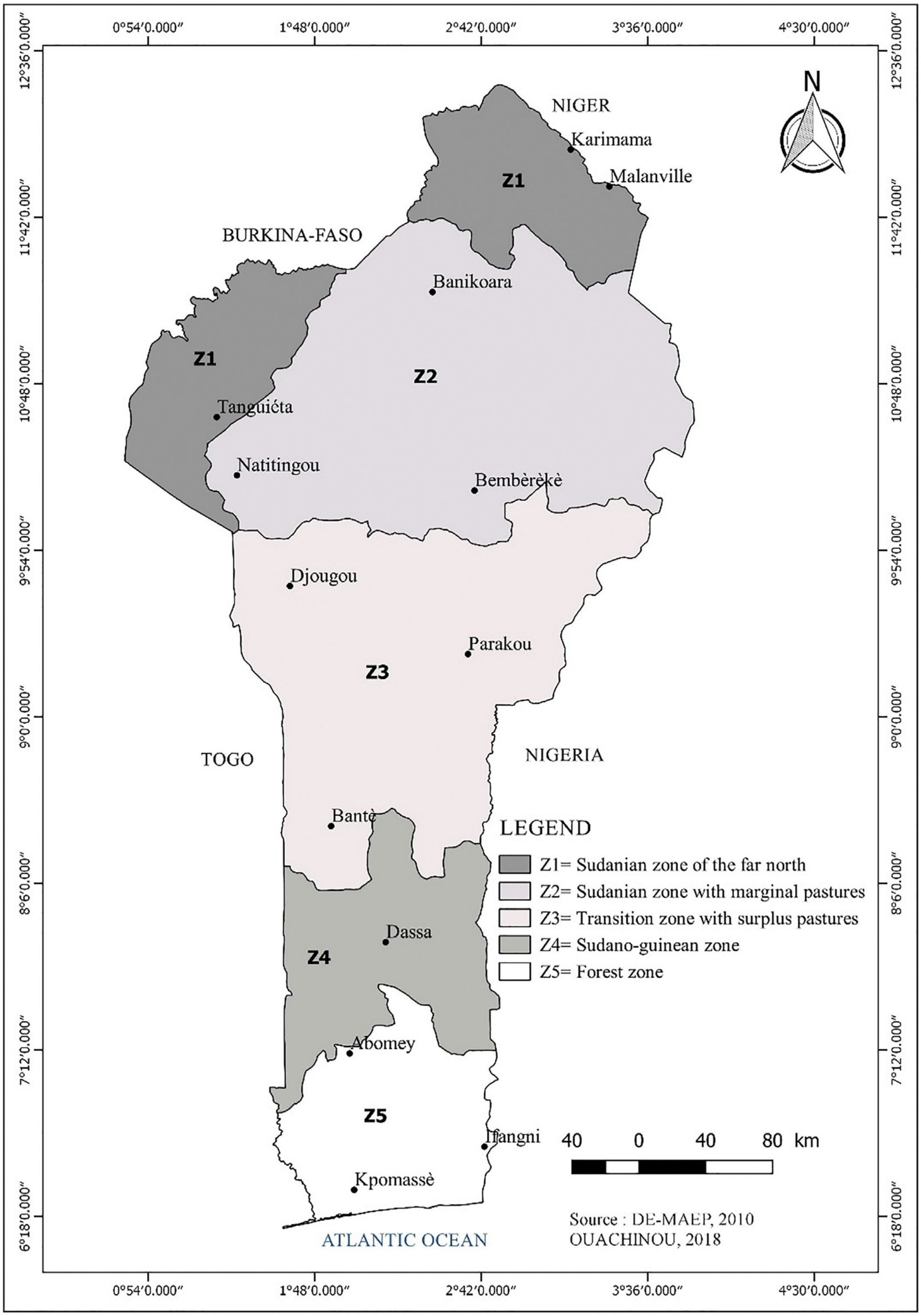

Fig. 1. Map showing location of the study sites.

to treat gastrointestinal disorders per plant family and the total number of species per family. Normality and homoscedasticity were tested for. As the diagnostic suggests a slight departure from normality and slightly increasing variance as function of fitted values, the variables were log $(x + 1)$ transformed.

To assess the level of utilization (which families are overutilized and which ones were underutilized) residuals were calculated per family. As recently stated by Ford and Gaoué (2017), families with negative residuals were considered as underutilized whereas families with positive residuals were considered overutilized.

To identify which gastrointestinal disorders were treated with the same plant families, a matrix was built and submitted to a correspondence analysis (CA). The analysis was performed on only the 30 overutilized plant families and the 4 highly reported gastrointestinal disorders. The least overutilized plant families were not involved in the treatment of these four disorders.

2.3.4. Popularity assessment of recorded plants

Overall popularity of anti-gastrointestinal plants within study area was calculated using relative frequency of citation (RFC). It is an index implying the local importance of each species in a study area (Ilker et al., 2009; Vitalini et al., 2013) and is calculated by the formula below:

$$RFC = \frac{n_i}{N} \quad (2)$$

where n_i is the number of informants citing a useful species and N the total number of informants in the survey.

Obtained values were reported in percentages and global mean value of RFC was also calculated. Afterwards, we grouped the recorded plant species into two categories according to their usage. There are: mono-property or unique usage plant species which are used by people for treating one only gastrointestinal disorder and multi-properties plant species which are involved in the treatment at least of two gastrointestinal disorders. At last, we compared number of species per group having RFC value superior at global mean. In this study, a group having the highest number of plants with RFC value superior than the mean is that hold popular plants.

2.3.5. Determination of sociocultural factors associated with the ethnobotanical knowledge

To determine main sociocultural factors associated with the ethnobotanical knowledge of a person, we used Generalized Linear Model (GLM). For this, we designed a matrix using sociocultural factors (age, gender, ethnic group, profession, agropastoral origin of the informants) like independent variables and number of anti-gastrointestinal plants mentioned by person like response variable. All statistical analyses were conducted in R 3.3.3 (R core Team, 2017) and Minitab 16.

3. Results

3.1. Demographic features of the informants

Informants belonged to four predominant sociolinguistic groups: Peulh and related (49.85%), Fon and related (19.42%), Yoruba and related (11.3%), Bariba and related (10.3%), Dendi and related (9.13%). Men were dominant gender (90% of the informants). The informants were categorized into three age classes and most of them were between 30 and 59 years old (Table 1).

Table 1
Demographic data of local informants.

Characteristics	Agropastoral zones						Frequency (%)
		Z1	Z2	Z3	Z4	Z5	
Sociolinguistic group	Peulh and related	90	132	96	61	41	49.85
	Fon and related	0	0	0	31	103	19.42
	Yoruba and related	0	0	0	49	6	11.3
	Bariba and related	0	18	35	6	0	10.3
	Dendi and related	0	0	19	3	0	9.13
Gender	Male	90	150	133	138	136	90
	Female	0	0	17	12	14	10
Age	< 30 years	26	3	6	6	17	10
	30–59 years	52	123	120	123	121	77
	≥ 60 years	12	24	24	21	12	13
Profession	Breeders	63	104	97	71	56	57
	Farmers	26	46	53	79	94	43

Note: Z1: sudanian zone with poor pastures; Z2: sudanian zone with marginal pastures; Z3: sudanian zone with surplus pasture; Z4: sudano-guinean zone; Z5: guinean zone.

3.2. Taxonomic diversity of plants used to treat gastrointestinal disorders

Results from the survey revealed a richness of 158 plant species belonging to 60 families and 130 genera Table 2. Forty percent (40%) of botanical families were represented by more than one species. The highest number of species was recorded for Leguminosae (28 species, 18%) followed by Combretaceae (9 species, 6.4%), Euphorbiaceae (8 species, 5.13%), Moraceae, Poaceae and Rubiaceae (7 species, 4.5% each). Eight of the reported botanical families i.e., Acanthaceae, Asparagaceae, Bignoniaceae, Bombacaceae, Convolvulaceae, Cucurbitaceae, Sapotaceae and Sterculiaceae were represented by only two species each (1.28%). The remaining families had a single species. The ratio of the number of genera to the number of species was 1.21; this implies that each genus holds approximately two species. The genera holding the highest number of species were *Ficus* (6 species), *Terminalia* (5 species), *Citrus* (4 species), *Acacia*, *Combretum* and *Senna* (3 species each).

Anti-gastrointestinal flora includes mostly trees (46%), followed by herbs (29%), shrubs (19%) and lianas and suffrutex (4% and 2% respectively).

3.3. Gastrointestinal disorders, distribution across agropastoral zones and treatment process

Plant species were reported to have seven anti-gastrointestinal properties. The highest proportion of disorders registered included intern parasitosis (35%), diarrhea (29%) and constipation (17%). These are followed by colic (10%), stomach ulcer (5%), vomiting (2%) and lack of appetite (2%). According to their distribution, intern parasitosis, diarrhea, constipation and colic appeared to be widespread ailments across agropastoral zones (Fig. 2). Other ailments like vomiting (in only one zone), stomach ulcer and lack of appetite (only in two zones) were poorly distributed across the country. We found also that sudanian zone with marginal pastures (Z2) and Sudano-Guinean zone (Z4) harbored more gastrointestinal disorders than three other zones.

On average, an informant uses 3.27 ± 1.65 plants (nearly 2% of all plant species identified) for producing 2.70 ± 1.43 recipes. Fifty-four (54) percent of anti-gastrointestinal plant species were used for treating diarrhea, whereas 39% were used for the treatment of intern parasitosis, and 20% for the treatment of the constipation (Table 3). Number of recipes to treat one ailment ranged from 3 (for vomiting) to 183 (for diarrhea).

The most used plant parts comprised the leaves (40%) followed by stem barks (28%), fruits (12%), and roots (7%) (Fig. 3). However, there was no consistent pattern across the disorders.

The plant parts used were generally prepared in decoction (28%), and maceration (19%) forms or taken raw (17%). Sometimes they are pounded (15%) or triturated (9%) (Fig. 4). Traditional plant remedies were reported to be administered through oral, dermal or anal routes. Oral application was the best-represented route of administration (95%), followed by dermal (4%) and anal (1%) ones.

3.4. Relationships between plant family and anti-gastrointestinal plant uses

Results from the analyses suggested significant positive relationship between the number of species per family and number of species used to treat gastrointestinal disorders per plant family. Thus, diverse families also harbors more anti-gastrointestinal plant species (beta = 0.266; $p < .0001$). Approximately 52% (31 plant families) of reported plant families were overutilized (Fig. 5). Among these plant families, the most important with highest value of residuals were: Zygophyllaceae (1.38), Phytolaccaceae (1.13), Rubiaceae (0.76), Lamiaceae (0.73), Loranthaceae (0.68), Thymelaeaceae (0.56) and Flacourtiaceae (0.55). On the other hand, Verbenaceae (−0.97), Sapindaceae (−0.68), Rutaceae (−0.66), Polygalaceae (−0.59), Papaveraceae (−0.55), Ochnaceae (−0.53), Nyctaginaceae (−0.54) and Moringaceae (−0.50) with negative residuals and low value were

Table 2
List of ethnoveterinary medicinal plants used for the treatment of cattle gastrointestinal disorders.

Family	Species (voucher number)	LF	PP	Disorders	PM	AR	RFC
Acanthaceae	*Asystasia gangetica* (L.) T.: Anderson (MAS 201)	h	Le	Ulc	trit	der	10
	Nelsonia canescens (Lam.) Spreng. (MAS 56)	h	Le	Inter	dec	or	9.86
Alliaceae	*Allium sativum* L. (MAS 019)	h	Bulb	Inter, Diar	dec	or	12.61
Amaranthaceae	*Alternanthera brasiliana* (L.) Kuntze (MAS 187)	h	Le	Appe	raw	or	5.07
	Amaranthus cruentus L. (MAS 114)	h	Le	Const	po	or	3.48
	Amaranthus spinosus L. (MAS 705)	h	fl	Appe	po	or	4.78
	Pupalia lappacea (L.) Juss. (MAS 412)	h	Le	Diar	trit	or	9.57
Anacardiaceae	*Anacardium occidentale* L. (MAS 011)	sh	Ba	Inter, Diar, Const	mac, dec	or, an	34.78
	Lannea acida A.Rich. s.l. (MAS 528)	tr	Ba	Const, ulc	mac	or	16.23
	Mangifera indica L. (MAS 366)	tr	Le, Ba	Diar, Inter	raw, po	or	24.49
	Sclerocarya birrea (A.Rich.) Hochst. (MAS 243)	tr	Le	Diar	dec	or	3.77
	Spondias mombin L. (MAS 622)	tr	Le	Inter	trit	or	21.16
Annonaceae	*Annona muricata* L. (MAS 92)	sh	Ba	Diar	cal	or	2.32
	Annona senegalensis Pers. (MAS 86)	sh	Ba, Le	Diar, colic	pil, dec	or	23.19
	Xylopia aethiopica Oliv. (MAS 104)	tr	Fr	Diar, Inter, ulc	dec	or	15.07
Apocynaceae	*Carissa spinarum* L. (MAS 413)	sh	Fr	Inter	raw	or	3.62
	Pleiocarpa pycnantha (K.Schum.) Stapf (MAS 255)	sh	Le	Diar, Inter	dec	or	9.57
	Thevetia peruviana (Pers.) K.Schum. (MAS 1122)	sh	Le	Appe	raw	or	3.77
Araliaceae	*Cussonia arborea* Hochst. ex A. Rich. (MAS 212)	tr	Le	Diar, colic	trit	or	11.16
Arecaceae	*Elaeis guineensis* Jacq. (MAS 004)	tr	Fr	Const	dec	or	4.06
Asclepiadaceae	*Calotropis procera* (Aiton) W.T.Aiton (MAS 806)	sh	Le	Const	dec	or	10.43
Asparagaceae	*Asparagus africanus* Lam. (MAS 132)	h	Le	Diar	dec	or	3.04
	Asparagus flagellaris (Kunth) Baker (MAS 508)	h	Tub	Diar, ulc	mac	or	4.64
Asteraceae	*Aspilia bussei* O.Hoffm. & Muschl. (MAS 134)	h	Le	Diar	pil	or	1.45
Asteraceae	*Tridax procumbens* L. (MAS 1107)	h	Le	App	raw	or	19.57
Asteraceae	*Vernonia amygdalina* Delile (MAS 904)	h	Le, LS	Inter, Diar	trit, raw	or	27.97
	Vernonia cinerea (L.) Less. (MAS 740)	h	Wp	Inter	mac	or	9.71
Bignoniaceae	*Crescentia cujete* L. (MAS 126)	sh	Ba	Const	dec	or	4.20
Bignoniaceae	*Kigelia africana* DC. (MAS 83)	tr	Ba	Diar	dec	or	12.75
	Newbouldia laevis (P.Beauv.) Seemann ex Bureau (MAS 1204)	tr	Le	Inter, Diar	po, trit	der, or	10.43
Bombacaceae	*Adansonia digitata* L. (MAS 362)	tr	Ba, Le	Inter, Diar	dec	or	20.72
	Bombax costatum Pellegr. & Vuillet (MAS 174)	tr	Ba, Le	Colic, const, diar, inter	pil, dec	or	17.39
Boraginaceae	*Heliotropium indicum* L. (MAS 214)	h	Le	Appe	trit	or	4.20
Capparaceae	*Crateva adansonii* DC. (MAS 166)	tr	Le	Inter	trit	or	14.93
Caricaceae	*Carica papaya* L. (MAS 002)	tr	Le, Se, Fr	Inter, const	trit, mac, raw	or	20.87
Celastraceae	*Gymnosporia senegalensis* (Lam.) Loes. (MAS 908)	sh	Le	Inter	dec	or	0.72
Chenopodiaceae	*Chenopodium ambrosioides* L. (MAS 139)	h	Le, Ro	Inter, Const	po, pil	or	25.94
Cochlospermaceae	*Cochlospermum planchoni* Hook.f. (MAS 517)	sh	Le	Diar	trit	or	19.28
Combretaceae	*Anogeissus leiocarpa* (De.) Guill. & Perr. (MAS 389)	tr	Ba	Const, Diar, Inter, colic	dec, mac	or	22.46
	Combretum collinum Fresen. (MAS 204)	tr	Ro	Diar	mac	or	17.10
	Combretum molle R.Br. ex G.Don (MAS 420)	tr	Ba	Diar	dec	or	3.77
	Combretum mucronatum Schumach. & Thonn. (MAS 329)	tr	Le	Inter	raw	or	8.26
	Pteleopsis suberosa Engl. & Diels (MAS 895)	sh	Ba	Diar, Inter, colic	mac, po	or	17.54
	Terminalia avicennioides Guill. & Perr. (MAS 1178)	sh	Le	Inter, colic	dec	or	5.22
	Terminalia cattapa L. (MAS 307)	tr	Le	Inter, colic	dec	der	8.41
	Terminalia glaucescens Planch. ex Benth. (MAS 259)	tr	Le	Diar, Inter	pil	or	16.23
	Terminalia laxiflora Engl. (MAS 77)	sh	B	Inter	dec	or	3.19
	Terminalia macroptera Guill. & Perr. (MAS 418)	tr	Ro	Inter	dec	or	5.07
Commelinaceae	*Commelina erecta* L. (MAS 356)	h	Le, Wp	Inter	raw	or	18.41
Convolvulaceae	*Ipomoea batatas* (L.) Lam. (MAS 618)	h	Le	Inter	raw	or	4.06
	Ipomoea eriocarpa R.Br. (MAS 200)	h	Le	Inter	raw	or	4.06
Crassulaceae	*Kalanchoe crenata* (Andrews) Haw. (MAS 144)	h	Le	Diar, Inter	raw	or	14.64
Cucurbitaceae	*Adenopus breviflorus* Benth. (MAS 332)	l	Fr	Inter	mac	or	4.78
Cucurbitaceae	*Momordica charantia* L. (MAS 1047)	l	LS, Le	Diar, Inter, ulc, Vom, colic	trit, dec, pil, calc	or	21.30
Cyperaceae	*Cyperus articulatus* L. (MAS 118)	h	Wp	Appe	raw	or	0.87
Dioscoreaceae	*Dioscorea alata* L. (MAS 522)	h	Le	Const	trit	or	6.38
Ebenaceae	*Diospyros mespiliformis* Hochst. ex A.DC. (MAS 206)	tr	Le, Fr, Se	Colic, Const, Diar	trit, pil	or	31.88
Euphorbiaceae	*Bridelia ferruginea* Benth. (MAS 281)	sh	Ba, Le	Diar, Inter, ulc	dec, raw, trit	or	17.54
	Euphorbia unispina N.E.Br. (MAS 874)	sh	Ba, Le	Const, Diar	mac	or	2.32
	Flueggea virosa (Roxb. ex Willd.) Voigt (MAS 299)	h	LS	Diar, ulc, colic	dec	or	18.26
	Hymenocardia acida Tul. (MAS 313)	sh	Le, Ba	Diar, ulc	pil, dec	der, or	15.65
	Jatropha gossypiifolia L. (MAS 1108)	sh	Fr	Diar	cal	or	13.33
	Manihot esculenta Crantz (MAS 012)	h	Le, Tub	Diar, appe	raw, mac	or	29.13
	Margaritaria dioscoidea (Baill.) Webster (MAS 150)	tr	Le	Appe	raw	or	4.64
	Phyllantus muellerianus (Kuntze) Exell (MAS 696)	l	Le	Diar	pil	or	5.51
Flacourtiaceae	*Flacourtia indica* (Burm.f.) Merr. (MAS 99)	sh	LS	Diar	dec	or	16.96
Lamiaceae	*Ocimum gratissimum* L. (MAS 402)	h	Le, LS	Diar, Inter, ulc	trit, raw, dec	or	14.78
Leguminosae	*Afzelia africana* Sm. (MAS 739)	tr	Le, Ba	Colic, Diar	dec, pil	or	26.96
	Caesalpinia bonduc (L.) Roxb. (MAS 246)	sh	Le	Inter, ulc, Vom	dec	or	12.75
	Caesalpinia pulcherrima (L.) Sw. (MAS 94)	sh	Ro	Inter	mac	or	4.20
	Cassia sieberiana DC. (MAS 835)	tr	Ba	Inter, Diar	po, dec	or	33.19
	Daniellia oliveri (Rolfe) Hutch. & Dalziel (MAS 612)	tr	Le, Ba	Diar, Inter, Colic	po, dec	or	25.80
	Detarium microcarpum Guill. & Perr. (MAS 171)	tr	Ba, Ro	Diar, Inter	pil, mac	or	17.68
	Isoberlinia doka Craib & Stapf (MAS 1043)						

Table 2 (*continued*)

Family	Species (voucher number)	LF	PP	Disorders	PM	AR	RFC
	tr	Ba	Inter, Const, colic	dec	or	26.09	
	Piliostigma thonningii (Schumach.) Milne-Redh. (MAS 348)	tr	Ba, Ro, Le	Diar, Inter, colic	mac, dec, pil	or	22.46
	Senna alata (L.) Roxb. (MAS 1410)	sh	Le	Inter, Const	trit	or	27.39
	Senna obtusifolia (L.) H.S.Irwin & Barneby (MAS 349)	h	Le	Vom	trit	or	10.43
Leguminosae	*Senna occidentalis* (L.) Link (MAS 211)	h	Le	Diar	dec	or	9.57
Family	Species (voucher number)	LF	PP	Disorders	PM	AR	RFC
Leguminosae	*Tamarindus indica* L. (MAS 509)	tr	Le	Inter	trit	or	13.48
	Acacia nilotica (L.) Willd. (MAS 915)	tr	Fr	Diar	mac	or	12.46
	Acacia polyacantha Willd. (MAS 119)	tr	Ba, Le	Diar, Appe	dec, pil	or	17.39
	Acacia sieberiana DC. (MAS 54)	tr	Ba	Diar	dec, pil	or	19.86
	Dichrostachys cinerea (L.) Wight & Arn. (MAS 404)	tr	Ba	Appe	mac	or	7.54
	Entada africana Guill. & Perr. (MAS 109)	tr	Ba	Inter	mac	or	14.06
	Entada wahlbergii Harv. (MAS 843)	tr	Ro	Diar	mac	or	1.74
	Leucaena leucocephala (Lam.) De Wit (MAS 1164)	tr	Le	Appe	raw	or	11.45
	Parkia biglobosa (Jacq.) R.Br. ex Benth. (MAS 239)	tr	Fr, Ba	Const, Diar, Inter	pil, mac, dec	or	24.93
	Pithecellobium dulce (Roxb.) Benth. (MAS 702)	tr	Le	Appe	po	or	3.33
	Prosopis africana (Guill. & Perr.) Taub. (MAS 851)	tr	Ba	Diar, Inter	pil	or	14.20
	Cajanus cajan (L.) Millsp. (MAS 103)	sh	Le	Diar	po	or	14.20
	Desmodium velutinum (Willd.) DC. (MAS 619)	h	Le	Diar	mac	or	15.51
	Pericopsis laxiflora (Benth. ex Baker) Meeuwen (MAS 207)	tr	Ba	Diar, colic	mac	or	11.30
	Pseudarthria confertiflora (A.Rich.) Baker (MAS 541)	h	Ro	Diar	mac	or	2.32
	Pterocarpus erinaceus Poir. (MAS 1084)	tr	Ba	Diar, Ulc, Const, colic	mac, dec	or	32.61
	Pterocarpus santalinoides L'Hér. ex DC. (MAS 218)	tr	Le	Diar	raw	or	3.33
Loganiaceae	*Strychnos innocua* Delile (MAS 223)	sh	Fr, Se	Const	pil	or	11.59
Loranthaceae	*Agelanthus dodoneifolius* (DC.) Polh. & Wiens (MAS 107)	sh	Le	Inter, colic	cal	or	1.45
	Tapinanthus globiferus (A.Rich.) Tiegh. (MAS 1013)	sh	Le	Diar	dec	or	16.38
Malvaceae	*Sida acuta* Burm.f. (MAS 403)	H	LS, Ro	Diar, colic	pil, trit	or	12.61
Meliaceae	*Azadirachta indica* A.Juss. (MAS 123)	tr	Le, Se	Diar, Inter, ulc	mac, po	or, der	14.06
	Khaya senegalensis (Desr.) A.Juss. (MAS 401)	tr	Ba	Const, Diar, ulc, Inter, colic	trit, dec, mac	or	34.93
	Pseudocedrela kotschyi (Schweinf.) Harms. (MAS 1211)	tr	Ba, Le	Colic, Const, Diar	pil, dec, mac	or	27.39
	Trichilia emetica Vahl (MAS 145)	tr	Le	Ulc	dec	or	10.43
Moraceae	*Antiaris toxicaria* Lesch. (MAS 513)	tr	Le, Ro	Diar, ulc	raw, dec	or	6.52
Moraceae	*Ficus exasperata* Vahl (MAS 66)	tr	Le	Ulc	trit	der	11.16
	Ficus glumosa Delile (MAS 718)	tr	Ba	Diar	mac	or	7.97
	Ficus platyphylla Delile (MAS 309)	tr	Ba	Diar	mac	or	3.77
	Ficus polita Vahl (MAS 1234)	tr	Le	Diar	raw	or	2.61
	Ficus sur Forssk. (MAS 1310)	tr	Fr, Ba	Diar, Inter	pil, mac	or	22.32
	Ficus sycomorus L. (MAS 911)	tr	Ba	Const	pil	or	3.19
Moringaceae	*Moringa oleifera* Lam. (MAS 44)	tr	Le	Diar, Inter	po, raw, trit	or	7.83
Musaceae	*Musa sp.* L. (MAS 003)	h	Fr	Const	raw	or	1.45
Myrtaceae	*Psidium guajava* L. (MAS 594)	sh	Le	Diar, colic	raw	or	16.23
Nyctaginaceae	*Boerhavia diffusa* L. (MAS 78)	h	Wp	Inter	raw	or	7.97
Ochnaceae	*Lophira lanceolata* Tiegh. ex Keay (MAS 146)	tr	Ba	Colic, Diar, Inter	pil	or	15.94
Oleaceae	*Ximenia americana* L. (MAS 913)	sh	Ro, Ba	Diar, Inter	dec	or	8.99
Opiliaceae	*Opilia amentacea* Roxb. (MAS 152)	l	Wp, Le	Const, Colic, Diar	cal, pil	or	12.61
Papaveraceae	*Argemone mexicana* L. (MAS 623)	h	Le	Inter	dec	or	4.64
Phytolaccaceae	*Petiveria alliacea* L. (MAS 1145)	h	Le	Diar	raw	or	7.83
Poaceae	*Andropogon gayanus* Kunth (MAS 386)	h	Le, Wp	Appe, Diar	raw, mac	or	8.70
	Bambusa vulgaris Schrad. ex Wendel (MAS 461)	tr	Le	Const	inf, trit, dec	or	6.67
	Oryza sativa L. (MAS 100)	h	Fr	Appe	po	or	9.57
	Saccharum officinarum L. (MAS 731)	h	ch	Appe	dec	or	5.51
	Sorghum bicolor (L.) Moench (MAS 153)	h	Wp	Diar	dec	or	11.01
	Striga hermonthica (Delile) Benth. (MAS 22)	h	Wp, Le	Const, Diar	pil	or	16.52
	Zea mays L. (MAS 006)	h	Fr	Diar	mac	or	20.72
Polygalaceae	*Securidaca longepedunculata* Fresen. (MAS 1215)	h	Ro, Ba	Const, Inter, colic	pil, dec	or	16.67
Portulacaceae	*Talinum triangulare* (Jacq.) Willd. (MAS 241)	h	Le	Appe	raw	or	9.57
Rubiaceae	*Crossopteryx febrifuga* (G.Don) Benth. (MAS 261)	tr	Le	Const	dec	or	6.38
	Feretia apodanthera Delile (MAS 514)	sh	Le	Const	dec	or	1.74
	Macrosphyra longistyla (De.) Hiern (MAS 93)	sh	Le	Inter	dec	or	2.61
	Mitracarpus hirtus (L.) DC. (MAS 237)	h	Le	Const	dec	or	11.45
	Mitragyna inermis (Willd.) Kuntze (MAS 156)	tr	Le, Ba	Diar, Inter, colic	dec	or	12.46
Rubiaceae	*Mitragyna inermis* (Willd.) Kuntze (MAS 156)	tr	Le, Ba	Diar, Inter, colic	dec	or	12.46
	Morinda lucida Benth. (MAS 178)	tr	Le	Diar	raw, dec	or	4.64
	Sarcocephalus latifolius (Sm.) E.A. Bruce (MAS 644)	sh	Ro	Inter	dec	or	9.57
Rutaceae	*Citrus aurantifolia* (Christm. & Panzer) Swingle (MAS 009)	tr	Fr	Diar, Inter	ext	or	12.9
	Citrus limon (L.) Burm.f. (MAS 81)	tr	Fr	Const, Diar, Inter	ext	or	9.42
	Citrus reticulata Blanco (MAS 1011)	tr	Fr	Const, ulc	ext	or	9.86
	Citrus sinensis Osbeck (MAS 070)	tr	Se	Inter	po	or	11.45
	Zanthoxylum zanthoxyloides (Lam.) Zepernick & Timler (MAS 191)	tr	Le	Diar, Inter	raw	or	15.65
Sapindaceae	*Paullinia pinnata* L. (MAS 429)	suf	Le	Diar	dec	or	13.91
Sapotaceae	*Pouteria alnifolia* (Baker) Roberty (MAS 31)	tr	Le	Const	raw	or	3.19

(continued on next page)

Table 2 (*continued*)

Family	Species (voucher number)	LF	PP	Disorders	PM	AR	RFC
	Vitellaria paradoxa C.F.Gaertn. (MAS 1041)	tr	Ba	Const, Diar, colic	mac, dec, pil	or, an, der	
Solanaceae	*Capsicum annuum* L. (MAS 1221)	h	Fr	Ulc	raw	or	11.59
	Nicotiana tabacum L. (MAS 914)	suf	Le	Const	pil	or	1.30
	Solanum aethiopicum L. (MAS 397)	h	Le	Appe	raw	or	3.77
Sterculiaceae	*Sterculia setigera* Delile (MAS 1077)	tr	Ba, Le	Const, Inter	pil, dec, trit	or, der	10.43
	Waltheria indica L. (MAS 805)	h	Le, Ro	Colic, Appe	dec, pil	or	13.91
Thymelaeaceae	*Gnidia kraussiana* Meisn. (MAS 773)	suf	Wp	Ulc	mac	or	1.74
Tiliaceae	*Corchorus olitorus* L. (MAS 1018)	h	Le	Appe	po	or	1.74
	Grewia cissoides Hutch. & Dalziel (MAS 340)	sh	Ro	Colic, Diar	dec	or	11.16
	Grewia venusa Willd. (MAS 101)	sh	Ba	Colic	dec	or	5.8
Verbenaceae	*Gmelina arborea* Roxb. (MAS 1180)	tr	Le	Appe	raw	or	9.57
	Vitex doniana Sweet (MAS 111)	tr	Ba	Diar	pil	or	11.6
Vitaceae	*Cissus quadrangularis* L. (MAS 471)	l	Ba	Diar	mac	or	3.19
Zingiberaceae	*Aframomum melegueta* (Roscoe) K.Schum. (MAS 005)	h	Fr	Diar, Inter	dec, pil	or	17.83
Zygophyllaceae	*Balanites aegyptiaca* (L.) Delile (MAS 1059)	tr	Ba	Diar	dec	or	10.14

Notes: LF: life form (h: herb; tr: tree; sh: shrub; l: liana; suf: suffrutex); PM: preparation mode (trit: trituration; dec: decoction; po: powder; mac: maceration; pil: pounded; calc: calcination); AR: administration route (or: oral; der: dermal; an: anal); RFC: relative frequency of citation; gast: stomach ulcer; inter: intern parasitosis; diar: diarrhea; appe: appetite stimulant; const: constipation: vom: vomiting.

underutilized plant families in the treatment of gastrointestinal disorders (Fig. 5).

Plant families showed highly significant dependencies (X-squared = 11,743, df = 145, p-value <2.2e-16) upon the gastrointestinal disorders. The Correspondence Analysis (CA) performed on these plant families and gastrointestinal disorders explained 84.89% of the total variation on the first two components (PC) (Fig. 6). Analysis of correlation between plant families and gastrointestinal disorders revealed that species from the family of Sapotaceae, Arecaceae, Asclepiadaceae, Dioscoreaceae, Musaceae, Opiliaceae and Rubiaceae were used to treat constipation and colic. Species from the family of Apocynaceae, Combretaceae, Acanthaceae, Anacardiaceae and Convolvulaceae were used to treat intern parasitosis whereas species from Asparagaceae, Araliaceae, Poaceae, Myrtaceae, Amaranthaceae, Annonaceae, Vitaceae, Flacourtiaceae, Leguminosae, Phytolaccaceae and Zygophyllaceae families were used to treat diarrhea. Another group holds common species used to treat intern parasitosis and diarrhea belonging to the family of Oleaceae, Zingiberaceae, Alliaceae, Asteraceae, Crassulaceae, Loranthaceae and Lamiaceae.

In whole, 29 underutilized plant families were reported for the treatment of 7 disorders (Table 4). Among them, some were used to treat a high number of disorders. These were: Meliaceae, Euphorbiaceae and Cucurbitaceae, which contributes to treating 5 disorders.

Table 3
Useful plants per gastrointestinal disorder in livestock.

Gastrointestinal ailments recorded	Number of families	Number of species	Percentage of species	Number of recipes
Diarrhea	14	87	54	183
Intern parasitosis	10	62	39	110
Constipation	6	31	20	134
Colic	4	11	6	82
Lack of appetite	4	27	16	31
Stomach ulcer	3	19	11	32
Vomiting	1	3	1	3

3.5. Popularity of reported anti-gastrointestinal plants

Overall, popularity of plant species assessed by RFC showed *Khaya senegalensis* (34.93%), *Anacardium occidentale* (34.78%), *Cassia sieberiana* (33.19%), *Pterocarpus erinaceus* (32.61%), *Diospyros mespiliformis*

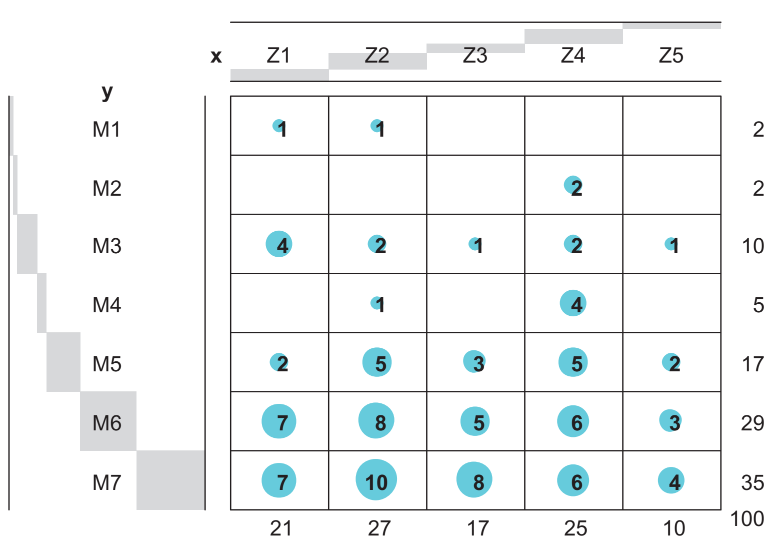

Fig. 2. Distribution of gastrointestinal disorders across agropastoral zones in Benin. Legend: M1: lack of appetite, M2: vomiting, M3: colic, M4: stomach ulcer, M5: constipation, M6: diarrhea and M7: intern parasitosis; Z1: sudanian zone with poor pastures; Z2: sudanian zone with marginal pastures; Z3: sudanian zone with surplus pasture; Z4: sudano-guinean zone; Z5: guinean zone. Horizontal scores range mean the cumulated percentages of each gastrointestinal disorder per agropastoral zone. Vertical scores range mean cumulated percentages of each gastrointestinal disorder across national area.

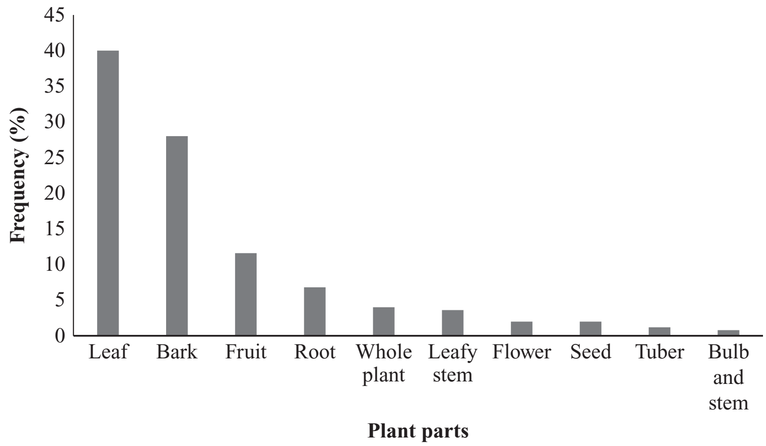

Fig. 3. Percentage of plant parts used for the preparation of recipes.

(31.88%), *Vitellaria paradoxa* (31.45%), *Manihot esculenta* (29.13%), *Vernonia amygdalina* (27.97%), *Pseudocedrela kotschyi* and *Senna alata* (27.39% each), *Afzelia Africana* (26.96%), *Isoberlinia doka* (26.09%), *Chenopodium ambrosioides* (25.94%), *Daniellia oliveri* (25.08%), *Parkia biglobosa* (24.93%), *Mangifera indica* (24.49%), *Annona senegalensis* (23.19%), *Piliostigma thonningii* and *Anogeissus leiocarpa* (22.46% each), *Ficus sur* (22.32%), *Momordica charantia* (21.30%), *Spondias mombin* (21.16%) to be the most important anti-gastrointestinal plant species known by local populations in Benin. The lowest value of RFC (0.72) was obtained for *Gymnosporia senegalensis* used in the treatment of intern parasitosis.

Considering plant species categorization, we distinguished 90 mono-property against 68 multi-purpose plant species. Only 20% of the first group species hold a value of RFC higher than the global RFC mean value (12.03%) whereas about 74% of the multipurpose plants had a value above the mean. Thus, the most popular anti-gastrointestinal plant species was largely dominated by multi-properties plant species.

3.6. Socio-economic factors affecting traditional knowledge of plant species

Results from the analysis of variance suggested that variables such as age, profession and agropastoral origin of the informants significantly influenced the knowledge of plants used for treating gastrointestinal disorders ($p < .05$; Table 5). In contrast, influence of gender, ethnic group and education level were not significant ($p > .05$).

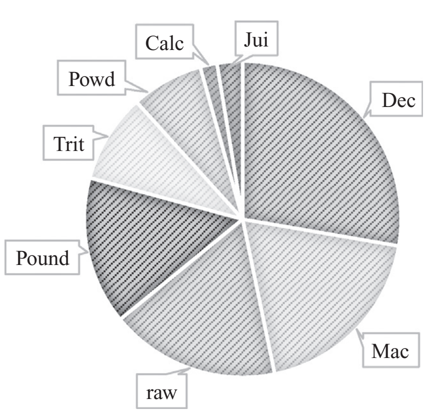

Fig. 4. Representation of the method of preparation per plant parts. Legend: Dec: decoction; Mac: maceration; Pound: pounding; Trit: trituration; Powd: powder; Calc: calcination; Jui: juice.

3.6.1. Variation in plant species uses according to informant age

The number of species cited by each informant was positively and significantly different among age class ($p = .007$) with a mean value of 3.27 ± 1.65 (mean ± standard deviation) plant species. The boxplot (Fig. 7) showed a clear increase of the number of species reported related to the informant age classes. Informants from age class C1 mentioned an average number of 3.15 ± 1.34 plants whereas informants from age class C3 cited an average of 3.20 ± 1.47 plants. The number decreased slightly with the second class (30 years ≤ age ≤ 59 years).

3.6.2. Variation in plant uses according to informant profession

Overall, the number of recipes prepared increases with the plants used. On average, breeders and farmers used 34.30 ± 29.90 species for preparing 82.10 ± 64.60 recipes. Breeders used an average number of 24.29 ± 19.53 plants for preparing 39.40 ± 31.70 recipes whereas farmers used an average number of 17.86 ± 12.38 species for preparing 34.14 ± 24.83 recipes. Breeders reported 133 plant species of which 54 and 48 were respectively used for the treatment of diarrhea and intern parasitosis (Fig. 8a). Among the 122 species cited by farmers, 39 and 26 species were respectively used for the same disorders (Fig. 8a). We found strong correlation between number of species and number of recipes ($r = 0{,}976$; p-value = 0,000). Reported plants were used to formulate 89 and 77 recipes by breeders and farmers respectively, which were indicated in diarrhea treatment (Fig. 8b).

3.6.3. Variation in plant knowledge and uses according to location of informants

On average, the number of plant species mentioned per informant ranged from 2.86 ± 1.41 for zone 4 to 3.48 ± 1.76 plant species for zone 2 (Fig. 9). Overall, we found that the highest number of species was recorded in zone 3 (69 species), followed by zone 1 (56 species), zone 2 (44 species), zone 4 (43 species) and zone 5 (23 species). Number of recipes prepared followed this ranking i.e. people of zone 3 prepared highest number of recipes (136 recipes), followed by zone 1 (124 recipes), zone 2 (98 recipes), zone 4 (96 recipes) and zone 5 (41 recipes).

4. Discussion

4.1. Taxonomic diversity of plant used to treat gastrointestinal disorders

This study aimed at investigating the traditional knowledge associated with the use of plants to treat gastrointestinal disorders. In whole, 158 plant species were reported as having anti-gastrointestinal properties countrywide. This represents 5.63% of the floristic diversity in Benin, which is estimated at 2807 plant species (Akoègninou et al.,

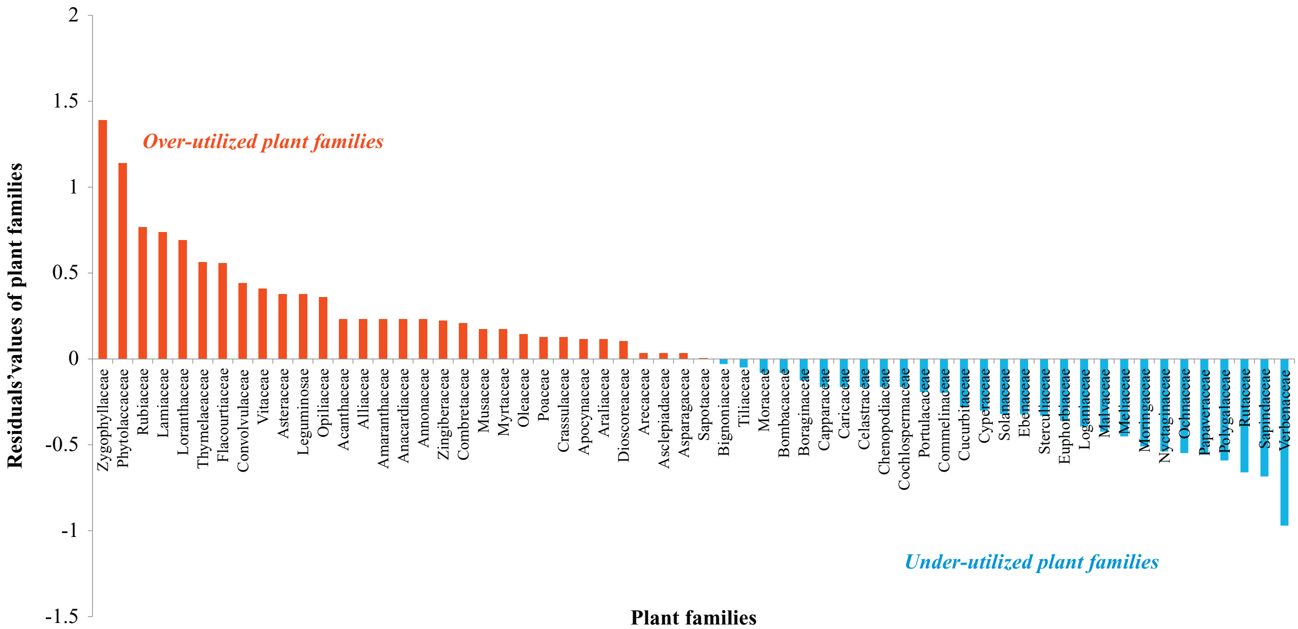

Fig. 5. Values of residuals of plant families used in the treatment of cattle gastrointestinal disorders compared to total abundance of Benin plant families.

2006). This species richness is higher compared to the 138 plant species reported by other authors such as: Djoueche et al. (2011), Okombe et al. (2014), Hounzangbé-Adoté (2000), Lans et al. (2007), Offiah et al. (2011), Woldeab et al. (2018). This confirms the first hypothesis stipulating that Benin harbors high anti-gastrointestinal plant diversity. Consequently, when a plant species appears to be unavailable within an area, people can find substitute species to treat gastrointestinal disorders. Difference between specific richness can be explained by the fact that this study was countrywide comparatively to other investigations, which were restricted to specific areas of the countries or specific gastrointestinal diseases.

Approximately 59% of the reported plants were documented as medicinal plants used for treating animal pathologies and symptoms in Benin (Dassou et al., 2015a). Among them, 79 plants having the same primary use were cited in the current study, while the remaining 63 are used for the treatment of different ailments or have additional uses. Interestingly, *Securidaca longepedunculata* and *Entada africana* reported in our survey as anthelmintic were previously reported as anti-venomous by Dassou et al. (2015a). These differences in uses can be explained by the multipurpose use to which the plants were associated. The species first reported were: *Carissa spinarum, Aspilia bussei, Crescentia cujete, Phyllantus muellerianus, Flacourtia indica, Senna obtusifolia, Desmodium velutinum, Indigofera kerstingii, Jatropha gossypiifolia, Pseudarthria confertiflora, Strychnos innocua, Lophira lanceolata, Tapinanthus globiferus, Feretia apodanthera, Citrus aurantifolia, Balanites aegyptiaca.*

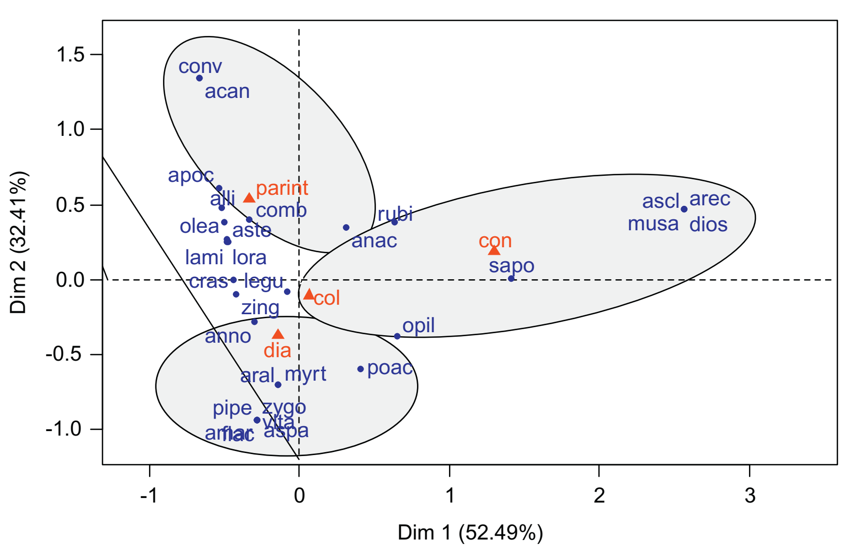

Fig. 6. Correspondence analysis (CA) showing relationship between 30 overutilized plant families and 4 highly reported gastrointestinal disorders. Abbreviations: Gastrointestinal disorders (parint: intern parasitosis; col.: colic; dia: diarrhea; con: constipation). Plant families (sapo: Sapotaceae; aspa: Asparagaceae; vita: Vitaceae; zygo: Zygophyllaceae; pipe: Phytolaccaceae; myrt: Myrtaceae; aral: Araliaceae; anno: Annonaceae; opil: Opiliaceae; zing: Zingiberaceae; legu: Leguminosae; cras: Crassulaceae; lora: Loranthaceae; lami: Lamiaceae; aste: Asteraceae; olea: Oleaceae; alli: Alliaceae; comb: Combretaceae; apoc: Apocynaceae; acan: Acanthaceae; conv: Convolvulaceae; anac: Anacardiaceae; rubi: Rubiaceae; musa: Musaceae; ascl: Asclepiadaceae; are: Arecaceae; dios: Dioscoreaceae; poac: Poaceae; opil: Opiliaceae; Amar: Amaranthaceae; Flac: Flacourtiaceae).

Table 4
Underutilized plant families and disorders treated.

Family	Disorders	Family	Disorders
Verbenaceae	Lack of appetite, diarrhea, constipation	Thymelaeaceae[a]	Stomach ulcer
Sapindaceae	Diarrhea	Cyperaceae	Lack of appetite
Rutaceae	Stomach ulcer, diarrhea, constipation, intern parasitosis	Cucurbitaceae	Vomiting, colic, Stomach ulcer, diarrhea, intern parasitosis
Polygalaceae	Colic, constipation, intern parasitosis	Commelinaceae	Lack of appetite, intern parasitosis
Papaveraceae	Intern parasitosis	Portulacaceae	Lack of appetite
Ochnaceae	Colic, diarrhea, intern parasitosis	Capparaceae	Intern parasitosis
Nyctaginaceae	Intern parasitosis	Caricaceae	Constipation, intern parasitosis
Moringaceae	Diarrhea, intern parasitosis	Celastraceae	Intern parasitosis
Meliaceae	Colic, stomach ulcer, diarrhea, constipation, intern parasitosis	Chenopodiaceae	Constipation, intern parasitosis
Malvaceae	Colic, diarrhea	Cochlospermaceae	Diarrhea
Loganiaceae	Constipation	Boraginaceae	Lack of appetite
Euphorbiaceae	Lack of appetite, stomach ulcer, diarrhea, constipation, intern parasitosis	Bombacaceae	Colic, diarrhea, constipation, intern parasitosis
Sterculiaceae	Lack of appetite, colic, constipation, intern parasitosis	Moraceae	Stomach ulcer, diarrhea, constipation, intern parasitosis
Ebenaceae	Colic, diarrhea, constipation	Tiliaceae	Lack of appetite, colic, diarrhea
Solanaceae	Lack of appetite, stomach ulcer, constipation	Bignoniaceae	Diarrhea, constipation, intern parasitosis

[a] From the generalized linear model, Thymelaeaceae was identified as an overutilized plant family. But it was reported to treat one only non-frequent disorder and was not associated with correspondence analysis.

4.2. Prevalence and distribution of gastrointestinal disorders and treatment process

Intern parasitosis, diarrhea and constipation were three commonly gastrointestinal disorders of cattle treated by local people, with widespread distribution countrywide. Sudanian zone with marginal pastures (Z2) and sudano-guinean zone (Z4) harbored more gastrointestinal disorders than the other zones, thus confirming the hypothesis related to disorders' distribution along a climatic gradient across the country. While diarrhea is not intrinsically considered as a disease, but rather a sign of other health problems in livestock caused by infectious and non-infectious agents, it is still the most common and costly condition affecting livestock (Randolph et al., 2007). These disorders are quite prevalent in terms of morbidity among livestock in many regions of Africa especially in areas affected by poor nutrition and hygiene (Faye et al., 2003; Sharkhuu, 2001). Unsafe water supplies and inadequate levels of sanitation and hygiene may also increase their transmission (Djoueche et al., 2011; Embeya et al. 2014; Hounzangbé-Adoté, 2000). Factors causing these diseases are water, pastures and night kraals soiled by feces from infected animals. This calls for education on hygiene and an improvement of livestock conditions in order to limit spread of those diseases, and reduce economic loss related to their frequency.

Leaves appeared to be the plant parts most used in the preparation of remedies as compared to other parts. The widespread use of leaves for traditional medicine in our study is in accordance with the findings of Ayantunde et al. (2009) in South-western Niger, where leaves were the most widely used plant part by agropastoralists in traditional medicine. This could come from the fact that it is easier to be collected than the underground parts, flowers and fruits (Giday et al., 2009). Scientifically, leaves are actively involved in photosynthesis and the production of metabolites (Ghorbani, 2005); thus, the components found in leaves could explain their efficacy in the treatment of various ailments for both human beings and animals. Decoction was the most common preparation method. This observation confirms the findings by Maphosa and Masika (2010), Masika and Afolayan (2003) who reported that, in the Cape region in South Africa, decoction is the preparation method most widely used by livestock farmers. The high water temperature at the point of extraction using this method could lessen or alter the effects and even reduce the toxicity due to thermolabile compounds.

Table 5
Output of the analysis of the relation between socio-economic variables and traditional knowledge.

Variable	DF	SS	MS	F	P
Age	7	2031	290	2.04	0.048*
Gender	1	0.69	0.69	0.25	0.616
Ethnic group	10	35.26	3.53	1.29	0.234
Zagrop	4	37.65	9.41	3.47	0.008***
Prof	1	24.1	24.1	8.86	0.003***
Total	659	1812.91	–	–	–

DF: degrees of freedom, SS: sequential sums of squares, MS: adjusted means squares, F: Fisher statistic from the adjusted means squares, and P: probability value related to F-statistic.
*** highly significant probability
* significant probability.

4.3. Relationships between plant family and anti-gastrointestinal uses

As shown elsewhere, medicinal plants mainly belong to the family of Lamiaceae (Rokaya et al., 2014; Sarac and Ugur, 2007; Yineger et al., 2007), even it appears to be among under-utilized families in Hawaiian traditional medicine (Ford and Gaoué, 2017). These findings reflect the variability of traditional knowledge worldwide. According to Dassou et al. (2015a), Leguminosae should be classified first overutilized family but surprisingly, randomization tests did not classify it to the first rank in spite of its high proportion (14.8%) in Benin flora (Akoègninou et al., 2006). Indeed, Leguminosae are commonly represented among medicinal plants simply because they are common in the Benin flora. In addition species from the Leguminosae family are less commonly used against gastrointestinal disorders than would be expected from their representation in the medicinal flora of Benin. This indicates they are important medicinal plants, but most often used to treat other ailment types. Somehow, plant families overutilized should contain some useful chemical groups in the treatment of gastrointestinal disorders (Ford and Gaoué, 2017; Rokaya et al., 2014).

Anti-gastrointestinal plants contain various secondary metabolites which may be acting synergistically to produce antimicrobial, digestive or laxative effects (Eloff, 1998; Joshua and Takudzwa, 2013). Most of medicinal plants which are cited in this study contained saponins, tannins, alkaloids, flavonoids, sterol substances, terpernoids, coumarins, glycosides (Abiona et al., 2015; Abioye et al., 2013; Ijaiya et al., 2014; Joseph et al., 2017; Kosh-Komba et al., 2017; Kubmarawa et al., 2008; Offor, 2014; Rashed and Ono, 2013; Tanko et al., 2008; Udochukwu et al., 2015). Tannins, benzyl isothiocyanate, pentacyclic triterpenoids and flavonol glycosides are known to have important anthelmintic activities (Barrau et al., 2005; Begum et al., 2008; Brunet and Hoste, 2006; Hounzangbé-Adoté, 2004; Olounladé et al., 2011). Plants such as *Carica papaya, Khaya senegalensis, Anogeissus leiocarpa, Daniellia oliveri, Zanthoxylum zanthoxyloides* contain some chemicals and showed their efficacy in the elimination of intestinal worms (Hounzangbé-Adoté et al., 2008; Koné et al., 2005; Ndjonka et al., 2010). Several scholars also contributed to validating the antidiarrheal and laxative effects of some plants (*Adansonia digitata, Cajanus cajan, Psidium guajava, Daniellia oliveri* etc) using castor oil for inducing diarrhea in

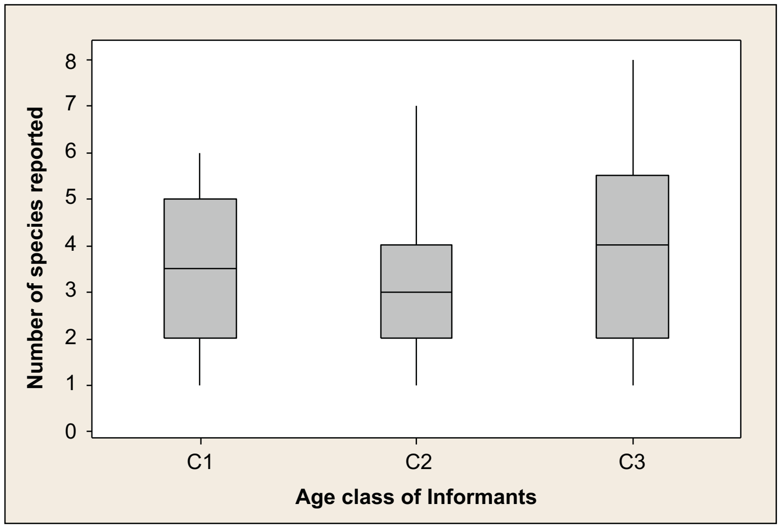

Fig. 7. Variation between class ages of number of anti-gastrointestinal plants reported. C1: age < 30 years; C2: 30 years ≤ Age ≤ 59 years and C3: age ≥ 60 years.

rats or mice and/or antimicrobial activity of extracts (Ahmadu et al., 2007; Birdi et al., 2010; Soudy et al., 2016). Evaluation of possible toxicity and improved traditional drugs would be envisaged about these plants species in order to relieve difficulties of rural communities.

4.4. Popularity of reported anti-gastrointestinal plants

Several authors such as Djoueche et al. (2011), Okombe et al. (2014), Koné et al. (2004), Lans et al. (2007), Offiah et al. (2011) reported the majority of popular plant species in the treatment of many gastrointestinal disorders. The report underlines and confirms that popular anti-gastrointestinal plants used in livestock are those plants having multiple properties.

Among these species, *Khaya senegalensis* holds many medicinal properties for the effective management of venereal disorders including diarrhea, intern parasitosis, colic, constipation and stomach ulcer. This large use is related to its chemical composition (saponins, flavonoids, tannins, steroids, alkaloids, glycosides and volatile oils). Among chemical compounds some have many properties like tannins that are as much responsible of the antidiarrheal activity (Galvez et al., 1993; Mukherjee et al., 1998; Otshudi et al., 2000; Shoba and Thomas, 2001) as anthelmintic properties. Ademola et al. (2004) and Chabi China et al. (2016) showed that tannins have inhibitory effect on larval migration, egg hatching and reduce nematodes prolificacy.

Medicinal properties of *Momordica charantia* include anti-ulcerogenic (Gürbüz et al., 2000) and antioxidative (Scartezzini and Speroni, 2000). Its leaves have excellent antibacterial activity negatively affecting the growth of several bacteria including *Escherichia*, *Staphylococcus*, *Pseudomonas*, *Salmonella*, *Streptobacillus* and *Streptococcus* (Patil and Patil, 2011); majority of these bacteria are responsible of diarrhea in livestock. Also, its fruits extract has demonstrated activity against the stomach ulcer caused by *Helicobacter pylori* (Gupta et al., 2010).

Senna alata has been recognized as a potent laxative (Gritsanapan and Mangmeesri, 2009; Sule et al., 2011). It contains important secondary metabolites including alkaloids, terpenoids, and steroids. The presence of these bioactive compounds of *S. alata* provide insight for their usage for relieving constipation (Oke et al., 2018).

4.5. Factors affecting traditional knowledge of anti-gastrointestinal plant species

Among factors suspected by Dassou et al. (2015b) as influencing anti-gastrointestinal plant knowledge in Benin, only one (geographical

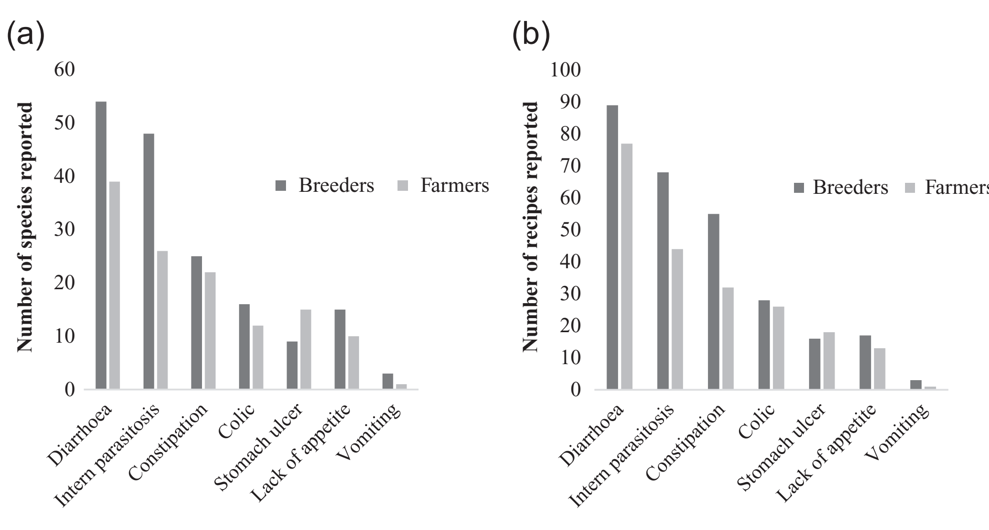

Fig. 8. Number of species (a) and recipes (b) recorded by gastrointestinal disorder and by profession.

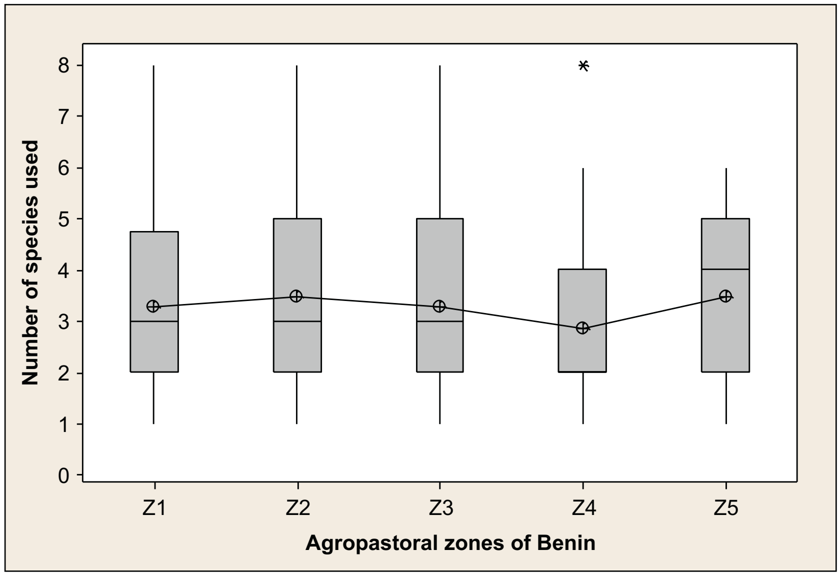

Fig. 9. Number of species used per informant in the agropastoral zones in Benin. Z1: sudanian zone with poor pastures; Z2: sudanian zone with marginal pastures; Z3: sudanian zone with surplus pasture; Z4: sudano-guinean zone; Z5: guinean zone.

position) was verified in our case. Thus, our hypothesis was not verified. As far as age is concerned, some studies have found a positive association between age and traditional ethnobotanical knowledge (Ryan et al., 2008) while some other studies found a negative relation (Dassou et al., 2015b). Through this study, a positive correlation was noted; this being a cultural evidence in Africa, particularly in Benin. Generally traditional knowledge is a time-dependent process of learning (Albuquerque and Hanazaki, 2009). Therefore, older informants, having spent a longer time with their natural environment, would normally be more knowledgeable than younger informants (Dovie et al., 2008). Meanwhile, unless younger generations receive and absorb the wisdom of their parents, that knowledge stands to be lost (Elgar, 2013). In old times, youngs accompanied their parents in all movements with the family herd, which allowed the permanent transfer of pastoral knowledge through generations. However, with the new policy of increasing the number and level of educated people, children and adolescents are removed from their natural, cultural and physical environment to obtain a better formal education, which in turn limits the opportunity to learn about and participate in activities related to the transmission of traditional knowledge from their elders (McMillen, 2012; Reyes-García et al., 2014; Wyndham, 2010). Sometimes this task is entrusted to children who are involved with work when they have time and do it for enjoyment. According to the United Nations Environment Programme (UNEP, 2006), formal education is one of the 23 barriers to traditional knowledge transmission in Africa. In contrary some studies have shown that education is essential for retaining some aspects of traditional knowledge and not an explanatory variable for its erosion (Adékambi et al., 2014; Godoy et al., 2009; Mathez-Stiefel et al., 2012). By comparing plant knowledge of children of different generations in southeastern Mexico, Zarger and Stepp (2004) showed that plant knowledge has persisted in spite of several decades of modernization and increased formal education, and that formal education can even help in supporting pastoralism systems. However, one alternative to overcome the decline of traditional knowledge among young generations would be to bring it into formal education system by a traditional way of learning.

Other factors (profession and geographical origin) are related to primary activities i.e., farming and stockbreeding. These factors have a critical role in increasing the ethnobotanical knowledge (Beltrán-Rodríguez et al., 2014). Our findings showed that number of species cited by breeders is higher than those cited by farmers. This report can be explained by the degree of involvement in this activity. The majority of people surveyed were of Peulh sociolinguistic group who are recognized to have an excellent knowledge in ethnoveterinary medicine in Africa (Tamboura et al., 1998). They devote themselves entirely to their animals and ensure their well-being. This is expressed by the observation of animal's alimentary habits with respect to wild and fodder plants that are helpful in the treatment of cattle's gastrointestinal and other diseases. Thus, livestock has a shining future in our study area.

The association between agropastoral origin and knowledge was more significant in the sudanian zone which covers three agropastoral zones (Z1, Z2 and Z3). An agropastoral zone corresponds to an ecosystem with homogeneous edaphoclimatic and geomorphological conditions that determine the distribution of people in this environment (Sinsin and Kampmann, 2010). Thus, the floristic diversity found in an environment occupied by a people is a function of the ecological zone or zones it covers. It should be noted that the influence of some factors on knowledge varies according to the type of knowledge and involves other factors. With the new policy of sending all children to school, this agropastoral origin would affect again animal rearing in the near future.

4.6. Implications for valorization and sustainable use of recorded anti-gastrointestinal plants

Worldwide, the methane emission due to indigestion of fodders consumed by ruminants has seen the highest increase last decades. This production amplifies the climate change, which has negative feedback on animal breeding. In order to limit its production, we defined double approaches: (1) establish locally checklist of fodder resources for further anatomical investigation in order to determine methanogens' factors contained within plant parts in a perspective of possible improvement of food diet and (2) identify medicinal plant species that could limit the consequences of the gastrointestinal disorders. However, in this paper, we focused only about anti-gastrointestinal plants. Indeed, the control of gastrointestinal disorders like constipation, helminthiasis and colic in livestock would limit the indigestion rate, would facilitate defecation and would decrease methane production. In this context, we recommend large usage of popular plant species but this needs additional studies as phytochemical and biological researches. However, farmers and breeders can already exploit medicinal plants with proved efficacy like *Khaya senegalensis*, *Momordica charantia* and *Senna alata*.

Ecologically, the increasing demand for medicinal plants and the associated increase in the rate of collection negatively affected the wild populations of many species, to the point that nine species, about 5.69% of the recorded plants are now considered to be threatened with extinction according to International Union for Conservation of Nature (IUCN) and red list for Benin (Neuenshwander et al. 2011). There are: *Afzelia africana* (IUCN: VU; Benin: EN), *Caesalpinia bonduc* (Benin: EW), *Carissa spinarum* (Benin: VU), *Khaya senegalensis* (IUCN: VU; Benin: EN), *Kigelia africana* (Benin: VU), *Pterocarpus erinaceus* (Benin: EN), *Vitellaria paradoxa* (IUCN: VU; Benin: VU), *Xylopia aethiopica* (Benin: VU), *Zanthoxylum zanthoxyloides* (Benin: VU). The convention on biodiversity suggests for such species that urgent decisions should be taken to ensure their protection. These would include aspects such as multiplication and plantation of threatened plant species, and above all the training of people on good harvest practices.

5. Conclusion

Benin flora is that rich in medicinal plants used to treat cattle gastrointestinal disorders. In this study, we described their taxonomical characteristics, usage, use value, plant parts used, formulation and administration process of drugs, and factors patterning their uses. Nearly 52% of reported plant families are overutilized, the most important were: Zygophyllaceae, Phytolaccaceae, Rubiaceae, Lamiaceae, Loranthaceae, Thymelaeaceae and Flacourtiaceae. Further chemical analysis would help to identify secondary metabolites having the reported properties. In veterinary medicine, the traditional knowledge about anti-gastrointestinal plants is associated with age, profession and agropastoral origin of informants. These findings will contribute to integrate the local knowledge of communities into appropriate proposals to preserve anti-gastrointestinal plants. It is also important to contribute sustainable use of threatened medicinal plants through reforestation campaigns and environmental education.

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Authors' contributions

JMASO, GHD and ACA conceived, and designed the research. JMASO collected the data. ACA and HY provided the botanical identification of the species. JMASO, GHD, and RI analyzed the data. JMASO wrote the manuscript. All authors read and approved the final version manuscript.

Competing interests

The authors declare that they have no competing interests.

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