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Aroma and Bioactive Compounds of Some Medicinal Plants' Leaves Used as Traditional Tea in Benin Republic

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Abstract

In Benin Republic, plants play a major role in people daily life, especially in rural communities. The usages of plants are associated with culture, tradition and heritage regarding their importance. In the present study, the different uses, aroma and bioactive compounds of the leaves of ten common medicinal plants including *Hibiscus sabdariffa*, *Hibiscus acetosella*, *Caesalpinia pulcherrima*, *Manihot esculenta* Crantz, *Boerhavia diffusa*, *Moringa oleifera* Lam, *Momordica charantia*, *Ocimum gratissimum*, *Adansonia digitata* and *Combretum micranthum* were reviewed. It appeared that these plants are used for various purposes mainly including nutrition, health, economic, magic as well. The leaves of these plants are rich in bioactive compounds as they contain phenolic acids, flavonoids, minerals, vitamins and fibers. They have many health benefits including high antioxidant capacity, anti-cancer properties, anti-inflammatory activities, anti-anemia, anti-depressive, anti-diarrhea and anti-aging as well as anti-diabetes. Their flavor resulted from a complex mixture of fatty acids, alcohols, aldehydes, esters, ketones, furans, pyrroles, pyrans, terpenes, lactones and volatile phenols. The supplementation of these plants with other foods should be recommended as they contain potential active compounds useful for the human being.

Keywords: Medicinal plants; Health; Aroma; Phytochemical; Benin Republic

INTRODUCTION

Since millennia, plants play key roles in the life of human. Plants are used for many purposes including medical, food, perfumery, environment purification, and furniture. Medicinal plants are used to relieve and to prevent illnesses in both modern and traditional communities. Interestingly, these plants have drawn the attention of both scientists and the World Health Organisation (WHO) of the United Nations. According to Muruganantham et al. (2016) [1], medicinal plants are the bases of natural drugs with no considerable toxicity, affordable, and facilely accessible. According to the WHO, the ethnical plant medicines take naturally place and consists of plant-based products with minimal or no industrial processing that have been employed to treat and prevent diseases within local or regional healing habits. For the same Organisation, about 80% of people living in developing countries rely on herbal medicines for their first aid [2]. Likewise, 25% of the modern medicines are derived from the medicinal plants and about 60% of these are considered as antitumor medicaments [3] and [4].

Hibiscus sabdariffa L. (Malvaceae), *Hibiscus acetosella* Welw. ex Hiern. (Malvaceae), *Caesalpinia pulcherrima* (Caesalpiniaceae), *Manihot esculenta* Crantz (*Euphorbiaceae*), *Boerhavia diffusa* (Nyctaginaceae), *Moringa oleifera* Lam (Moringaceae), *Momordica charantia* (Cucurbitaceae), *Ocimum gratissimum*, *Adansonia digitata* and *Combretum micranthum* G. Don (CM) (Combretaceae) are used in both food and healing purposes and are usually found in tropical and subtropical areas. In the Republic of Benin, on one hand, these plants are generally incorporated in the daily dishes either as vegetables or as spices, coloring agents, and flavoring elements. On the other hand, they are used in diverse forms including tea, powder, and crude to cure and to warn many kinds of ailments which can be summarized in malaria, fever, headache, hepatitis, cough, wound healing, infection, anemia, hemorrhoids, diarrhea, intestinal troubles, asthma, aging, cancer, and human reproduction troubles. *H. sabdariffa* L. and *H. acetosella* are mainly used to recover from crucial anemia problems while *B. diffusa* herbs are told to prevent hepatitis. Samely, *M. oleifera* is applied for fever, cough, anemia, and enhancement of the nutritional value of the local foods. *C. micranthum* and *C. pulcherrima* are traditionally employed to relieve infection, cough, hypertension, fatigue, and diabetes, whereas, *M. charantia* is known for its capacity to heal or to stop mainly infection, diabetes, vomiting, and hypoglycemia.

H. sabdariffa L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, and *C. micranthum*have been reported to display tremendous medicinal applications around the world. Indeed, studies on these plants revealed that they are essential for the treatment and prevention of ulcer, hypertension, cancer, epilepsy, low blood pressure, kidney pain, liver damage, heart troubles, rheumatism, digestive troubles, pneumonia, leukaemia, measles, toothache, abdominal tumours, cholera, malaria, worms, anemia, wounds, hypercholesterol, conjunctivitis, diarrhea, hernia, inflammation hepatitis, sores and abscesses, dysentery, and diabetes [5], [6], [7], [8], [9], [10], [11] and [12]. The health benefits of these plants are obviously linked to the thousands of phytochemical compounds they contained.

Culturally, herbal teas are prepared from the fresh or dried back stem, leaves, roots and flowers. Apart from their medicinal uses, the became an economic activity in Benin Republic. The leaves are not only sold in markets, from pharmacies and therapeutists but also their infusions are widely sold. Thus, it is appeared important to evaluate their phytochemical compounds and their flavor. From this point of view, this study will overview for the first time the bioactive compounds and aroma compounds of the herbal teas infused from different Beninese medicinal plants including *H. sabdariffa* L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum*.

Botany and preparation of teas

With regard to the botanical investigations, the plants studied in the present work belong to different families even though they can be distributed in the same areas. *H. sabdariffa* and *H. acetosella* are two species of Malvaceae family cultivated in both tropical and subtropical areas. *H.* sabdariffa is commonly known as roselle, hibiscus, Jamaica sorrel or red sorrel and is described as an erect, bushy, herbaceous subshrub which can grow up to 2.4 m tall, with smooth or nearly smooth and cylindrical stems. *H. acetosella* is called panama red, African rosemellow, maroon mallow, cranberry hibiscus, red leaved hibiscus or false roselle. It is an annual or perennial herb or shrub, typically with red foliage. *C. pulcherrima* comes under the Caesalpiniaceae and is a small thorny tree of 6-9 meters in height with a few prickly branches. Known as Brazil wood in English, *C. Pulcherrima* grows as wild and also can be cultivated as well. *Manihot esculenta* (manioc or cassava) is a woody shrub of the *Euphorbiaceae* family and widespread in the tropical regions. It is native to South America and extensively grown for its edible starchy root and leaves. *B. diffusa* is one of the species of Boerhavia genus and Nyctaginaceae family. *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum* are shurbs growing in tropical and subtropical areas, especially for their medicinal and nutritional properties. *M. oleifera* is one of the well known species of the genus *Moringacae* and *M. charantia* comes under Cucurbitaceae family. *M. charantia* is commonly recognized as bitter melon or bitter guard. It is used as remedy for many ailments and as tropical vegetable. Similarly, *O. gratissimum* (0.5 ila 3 meters in high) and *C. micranthum* (up to 20 meters in high) are very prized as tropical vegetables and they appartain to Labiatae and Combretaceae families, respectively. As for *A. digitata* commonly known as baobab, it is an exceptional giant tree from Bombacacea family.

Generally, every single part of these plants is valued. They are used as foods as well as remedy. The leaves are mostly used for the teas preparation, however, the stem, flowers and roots or the mixture of these different parts could be also used depending on their bioactivity. The plants are used fresh or dried. Traditionally, the tea is prepared by soaking a portion of the plant in hot or cold water for 4-24 hours. It can also prepared by heating the plant in water for 10 to 30 minutes. The herbal teas are taken hot or cold. They can also be taken with sugar as well as ice.

Aroma compounds of herbal teas

The formation of aroma compounds in vegetables occurs during the growth but they develop most when the cells are disrupted. Cellular disruption allows the contact of enzymes and substrates resulting in the formationof volatile components [13]. The aroma compounds in the herbal teas are generated during the preparation through various chemical reactions such as Maillard reaction, oxidation, fermentation and enzymatic reaction. The isolation techniques of aroma compounds of teas are based on the solubility and volatility of the phytochemicals. Amanpour et al. (2019) [14] have determined 35 aroma compounds classified into chemical groups of alcohols, acids, volatile phenols, lactones, aldehydes, ketone, pyrroles and furans from Borage (*Echium amoenum*) teas using the liquid-liquid method. The volatile compounds of teas have been correctly isolated with simultaneous distillation extraction, dynamic headspace and headspace solid - phase microextraction methods [15], [16], [17] and [18]. Their identification and quantification are generally performed thanks to gas chromatography coupled with mass spectrometry (MSD) and/or flame ionization (FID) detectors. The aroma-active compounds of herbal teas are evaluated by gas chromatography/olfactometry using dilutions techniques of aroma extract dilution analysis (AEDA) and Osme [14], [18], [19] and [20]. The aroma compounds of the herbal teas prepared from *H. sabdariffa* L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum* are found to result mainly from a mixture of the volatile compounds belonging to fatty acids, alcohols, aldehydes, esters, ketones, furans, pyrroles, pyrans, terpenes, lactones and volatile phenols.

Terpenes. Volatile terpenes are very important for the sensory quality of foods, especially for the scent of teas. They contribute up to 50% of the overall of some herbal teas [14], [17], [22], [23], and [24]. The biosynthesis of terpenes occurs through cytosolic mevalonic acid (CMA) and methylerythritol phosphate (MEP) pathways [24]. Compounds 1,4-cineole, 1,8-cineole, limonene, linalool oxide, linalool, α-terpineol, *exo*-2-hydroxycineole, α-farnesene, dehydroxylinalool oxide, dehydroxylinalool oxide, *p*-cymene, (*Z*)-β-ocimene, (*E*)-β-ocimene and (*E*)-β-terpineol are major terpenic compounds in *H. sabdariffa* teas [20], [21] and [25]. Other minor terpenic contributors including β-caryophyllene and geraniol have indicated among the most important aroma compounds in *H. sabdariffa* powder and essential oil [15], [26], [27] and [28]. The essential oil of *C. pulcherima* is dominated by terpenes estimated at 86.8% of the total aroma compounds which are constituted of α-phellandrene, α-pinene, *p*-cymene, sabinene, γ-terpinene, limonene, β-phellandrene, 1,8-cineole, (*Z*)-linalool oxide and (*E*)-linalool oxide [29]. The headspace of *M. charantia* flowers and the aromatic distillate of *M. oleifera* flowers were found to be prevailed by terpenes with linalool, terpinen-4-ol, D,L-limonene, (*E*)-linalool oxide, 1,8-cineole, α-thujene, limonen-4-ol and (Z)-β-ocimene as major contributors [30], [31] and [32]. Similarly, the essential oils of *M. charantia*, *O. gratissimum* and *M.oleifera* are mostly characterized by terpenic compounds such as limonene, (*Z*)-β-ocimene, (*E*)-β-ocimene, γ-terpinene, geraniol, caryophyllene and linalool [32], [33], [34] and [35]. These essential oils are used as antimicrobial, insecticidal and cytotoxic agent [31] , [33] and [34]**.** These terpenes have been previously indicated in many herbal teas to give pleasant odors of citrusy, woody, geranium, floral, fruity, mint and rosy [14], [18], [19], [23], [36] and [37].

Alcohols. They represent one of the most aromatic contributors in the herbal teas due mainly to their hydrophilic characters. More than 15 aroma compounds have been detected in *H. sabdariffa* teas. The alcohol contents vary in *H. sabdariffa* teas depending on the origin, raw material (fresh or dried), variety and preparation parameters. Among of these compounds, hexanol, octen-3-ol, 2-etheyl-1-hexanol, octanol, nonanol, 2-hexenol, (*Z*)-3-hexenol, isobutanol, phenylethyl alcohol, 3-methyl-1-butanol and 2-methyl-1-butanol were reported to be the most important volatile alcohols in *H. sabdariffa* [20], [21], [25], [38] and [39]. In addition to alcohols detected in *H. sabdariffa* teas, ethanol, menthol, 2-nonanol and (Z)-2-octen-1-ol have been revealed in the powder [27] and [40]. Owolabi et al. (2013) [33] have analyzed the essential oil of *M. charantia* leaves with gas chromatography and discovered three main alcohol compounds including (3*Z*)-hexenol, *n*-hexanol and 1-octen-3-ol. Similarly, (3*Z*)-hexenol, (Z)-2-pentenol, (E)-3-hexenol and (E)-2-hexenol have detected among the major volatile contributors in the essential oil *M. charantia* flowers [32]. Several volatile alcohols have been revealed as aroma contributors of *M. oleifera* leaves, fruits, flowers and essential oils. Among these, 2-ethyl cyclobutanol, 1-pentanol, (Z)-2-

pentenol, hexanol, (Z)-3-octenol, (E)-2-ethyl-2-hexen-1-ol, octanol, 1-pentadecanol, nonanol, undecanol, benzyl alcohol, phenethyl alcohol, dodecanol, (*Z*)-3-hexenol, (*E*)-2-hexenol and 1-octen-3-ol represent the most dominant alcohol constituents in *M. oleifera* [31], [34], [41] and [42]. The aromatic alcohols in these plants have been reported in oolong, pu-erh, congou, Borage, green, black as well as honeybush teas providing odor notes of pungent, balsamic, resin, floral, green, grass, mushroom, chemical, metal, burnt, wood, sweet, honey, spice, rose, lilac, herbal, fruity, mint and butter [14], [18], [19], [23] and [36].

Fatty acids.The aromatic fatty acids are originated from the metabolisms of fatty acids and amino acids through different kinds of pathways. Acidic note of *H. sabdariffa* teas is provided by acetic acid, isobutanoic acid, 2-methyl butanoic acid, dodecanoic acid, tetradecanoic acid, pentadecanoic acid, hexadecanoic acid and (Z)-9-hexadecenoic acid [20], [21], [25] and [38]. Other volatile fatty acids like *n*-nonanoic acid, heptadecanoic acid, pentanoic acid, hexanoic acid, levulinic acid, heptanoic acid, 2-ethyl caproic acid and octanoic acid have been reported in *H. sabdariffa* powder and essential oils [28] and [40]. The volatile acids in *M. oleifera* leaves were found to be acetic acid, propionic acid, dimethyl-propanedioic acid, butyric acid, pentanoic acid, 3-methyl butanoic acid, hexanoic acid, 4-hexenoic acid, 2-hexenoic, nonanoic acid, decanoic acid, dodecanoic acid, octanoic, octadecanoic acid,tetradecanoic acid, hexadecanoic acid and (*E*)-9-octadecenoic acid [41]. While 6-octadecenoic acid and hexadecanoic acid have been indicated in *M. oleifera* fruits and flowers, respectively [42] and [31]. Likewise, the aqueous, ethanol and petroleum extracts of *A. digitata* steam bark released various volatile fatty acids including n-hexadecanoic acid, nonadecanoic acid, nonanoic acid, 9-octadecynoic acid, 9-octadecenoic acid, docosanoic acid and octadecanoic acid [43]. These aromatic fatty acids have been reported to be responsible for sweet, cheesy, green, vanilla, groundy, rancid, pungent and acidic odors in herbal teas [14], [19], [22] and [44].

Aldehydes. The herbal teas contain a large number and amount of aldehydes. These are bio-produced from saturated and unsaturated fatty acids and contribute mainly to green notes of teas. In *H. sabdariffa* teas, nonanal, hexanal, octanal, decanal, (*E*)-2-hexenal and heptanal were detected as the most representative aldehydes [20], [21], [25] and [38]. 2,2-dimethyl-pentanal, 9-octadecenal have been revealed in the aqueous extract of bark stem of *A. digitata* [43], 2-hydroxybenzaldehyde and nonanal in of *M. charantia* flowers [30] and 14 aldehyde compounds including mainly (*E*)-2-butenal, (*E*)-2-pentenal, 2-hexenal, (*Z*)-2-heptenal, nonanal, (*E*,*E*)-2,4-heptadienal, benzaldehyde, 2-phenylacetaldehyde in *M. oleifera* leaves [41]. These aldehydes have been reported as aroma-active compounds with green, citrusy, fatty, herbal and almond odors in various herbal teas [14], [19], [22], [36] and [44].

Esters. Even though esters are found in slight concentrations in fruits, vegetables and their byproducts, they are very important for the evaluation of the sensory quality as esters provide pleasant flavor and fragrance. The ester compounds of methyl salicylate, methyl decanoate, methyl anthranilate and methyl hexadecanoate have been detected to participate to the overall aromatic potential of *H. sabdariffa* teas [20], [25] and [38]. Moreover, hexadecanoic acid ethyl ester, (*E*)-9-octadecenoic acid ethyl ester, octadecanoic acid ethyl ester, hexadecanoic acid 2,3-dihydroxypropyl ester, phthalic acid 6-ethyloct-3-yl 2-ethylhexyl ester and docosanoic acid, ethyl ester have detected as the major esters in the ethanolic extract of *A. digitata* [43]. Similar volatile esters could be figured out in different plants as major contributors. For instance, the methyl salicylate, hexyl benzoate, methylanthranilate, methyl hexadecanoate, hexyl salicylate, (*Z*)-3-hexenyl salicylate, 2-propenoic acid pentadecyl ester, propanoic acid decyl ester, hexadecyl acetate, methyl-2-furoate, (*Z*)-hexyl oleate, hexyl 3-methylbutanoate, propyl 3-methylbutanoate andoctyl 2-methyl butyrate have been individually or in assembly detected in *H. sabdariffa*, *C. decapetala*, *M. charantia*, *M. oleifera* [25], [30], [32], [33], [34], [41], [42]. Methyl salicylate and methyl hexadecanoate have been detected in congou, pu-erh and oolong herbal teas releasing peppermint, roast, sweet, and green odors [18] and [36].

Volatile phenols. A small amount of the volatile phenols have been reported in *H. sabdariffa* [20], [21], [25] and [38], *E. amoenum* [14], *C. sinensis* L. and *C. sinensis* var. *Assamica* [19] and [22], oolong and dianhong [36] teas. Eugenol, 2,4-di-tert-butyl phenol, 4-vinylguaiacol, 2-methoxy-4-vinylphenol, *p*-cresol and methyl eugenol were revealed as the common volatile phenols contributing to phenolic, spicy and burnt in some herbal teas.

Ketones, furans, pyrans, lactones, pyrazines and hydrocarbons. Other aroma compounds originated through many different pathways have been figured out in teas. They belong to the chemical groups of ketones, furans, pyrans, lactones, pyrazines and hydrocarbons as well. These aroma compounds count hugely for the overall aroma compounds of the herbal teas and might contribute as aroma-active compounds. Among these aroma compounds, 3-octanone, geranyl acetone, 6-methyl-5-hepten-2-one, 5-methyl furfural, 2-acetylfuran, 2-ethylfuran, furfural, 2-pentylfuran, 6-methyl-5-hepten-2-one, 2-acetylpyrrole, 2-formylpyrrole, 2-pyrrolidinone, γ-butyrolactone, pantolactone, 5-dimethylpyrazine and 2,3,5-trimethylpyrazine have detected amongst the most contributors [14], [19], [20], [22], [25], [36] and [38].

Phytochemical compounds

The phytochemical compounds are naturally found in fruits, vegetables and plant-derivatives. The phytochemicals have shown antioxidant properties and help to prevent or to protect human being from cancer, infections, cardiovascular, immune system deficiency, inflammatory, intestinal disorders, microbial and neurodegenerative diseases. They are also used in food, pharmaceutical and cosmetical industries. In benin Republic, plants including mainly *H. sabdariffa* L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum* are used as vegetables but most as herbal teas. Due to their contents of phenolic acids, flavonoids and carotenoids, they are used not only in the traditional medicines but also as colorings and flavorings. The phytochemical compounds in these plants vary depending on the genetics, environment, harvest conditions and processing parameters. The phychemicals with health benefits isolated from these plants are summarized in Table 1.

H. sabdariffa, *H. acetosella*, *M. oleifera*, *O. gratissimum* and *M. charantia* have been reported to contain organic and phenolic acids, polysaccharides anthocyanins and other flavonoids. *Hibiscus* genera have been revealed to display many phytochemical constituents including ascorbic acid, β-carotene, anisaldehyde, hibiscus acid, arachidic acid, citric acid, hydroxycitric acid, malic acid, caffeic acid, tartaric acid, glycinebetaine, chlorogenic acid, trigonelline, cyanidin-3-rutinoside, delphinidin, galacturonic acid, delphinidin-3-glucoxyloside, protocatechuic acid, delphinidin-3-monoglucoside, pelargonidic acid, cyanidin-3-monoglucoside, eugenol, cyanidin- 3-sambubioside, cyanidin-3,5-diglucoside, hibiscetin-3-monoglucoside, gossypetin-3-glucoside, gossypetin-7-glucoside, gossypetin-8-glucoside, sabdaritrin, quercetin, protocatechuic acid, pectin, polysaccharides and mucopolysaccharides[12],

[45] and [46]. Similarly, *O. gratissimum* has been reported to display the contents of caffeic acid, chlorogenic acid, luteolin, quercetin, rutin as well as verbascoside [12]. The main phenolic acid *H. acetosella* is 2-*O*-trans-caffeoyl-hydroxycitric acid, whereas, neochlorogenic acid is found to be the major phenolic acid in *H. Sabdariffa* [12]. Furthermore, *M. charantia* is an important in the traditional medicines in terms of therapeutic effects. It has been revealed to contain a wide rang of bioactive compounds including mainly gallic acid, quinic acid, protocatechuic acid, gentistic acid, chlorogenic acid, catechin, 3-coumaric acid, vanillic acid, luteolin-7-*O*-glycoside, syringic acid, apigenin-7-*O*-glycoside, epicatechin, caffeic acid, *p*-coumaric acid, naringenin-7-*O*-glycoside, benzoic acid, protocatechuic acid, sinapinic acid, charantin, o-coumaric acid, charine, *t*-cinnamic acid, galacturonic acid, momordicin, momordin and ferulic acid [47], [48] and [49].

B. diffusa, *M. esculenta*, *C. micranthum*, *A. digitata* and *C. pulcherima* are widely used for their medicinale properties. They contain phytochemical which belong to the groups of phenolic acid, flavonoids, phenolic glycosides, tannins and rotenoids. *Boerhavia* genera were revealed to be rich in bioactive compounds useful for immune system reinforcement. Among these bioactive substances, punarnavoside, ferulic acid, eupalitin-3-*O*-β-D-galactopyranoside, vanillin, betanin, kaempferol, quercetin, catechin, ferulic acid, syringic acid, gentisic acid, *O*-coumaricacids, caffeoyltartaricacid, boeravinone, coccineon, camphor, fumaric acid, ketoglutaric acid, pyruvic acid and oxalic acid have been detected as main contributors [10] and [50]. In addition, the phytochemical compounds with bio-protective effects such as quercetin, rhamnetic and ombuin have been figured out in *C. pulcherima* [6]. Also, it has been reported that *M. esculenta* contains bioctive compounds like coniferaldehyde, isovanillin, 6-deoxyjacareubin, scopoletin, syringaldehyde, pinoresinol, p-coumaric acid, ficusol, balanophonin and ethamivan [8]. However, the leaves might some cyanogenic substances described as toxic [8] and [51]. The tea obtained from *C. micranthum* has been analyzed for its phytochemicals and the results have shown that tea of *C. micranthum* contains vitexin, isovitexin, epicatechin, orientin, epigallocatechin, homoorientin, pentahydroxyflavan, catechinic acid and tetrahydroxyflavan [11]. Similarly, the HPLC analysis of the fruit, seed and leaves of *A. digitata* have been revealed that it contains citric acid, epicatechin, tartaric acid, malic acid, α-tocopherol, succinic acid as well as ascorbic acid [52] and [53].

Table 1. Some phytochemicals isolated from *H. sabdariffa* L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum*

Chemical category/class/subclass	Chemical compounds	Contents	Plants	Reference
Organic acid	Ascorbic acid	14-141.09 mg/100g	*H. sabdariffa*	[63] and [64]
		67.01 mg/100g	*H. acetosella*	[65]
		7.29 µ/ml	*O. gratissimum*	[66]
		6.26 mg/ml	*M. oleifera*	[56]
		16.512 mg/100g	*B. diffusa*	[67]
		6.25-15.17 mg/100g	*M. esculenta*	[68]
		38-352 mg/100ml	*A. digitata*	[52], [53], [69] and [70]
	Hibiscus acid	51-3187 mg/100g	*H. sabdariffa*	[12], [46], [72] and [73]
	Citric acid	0.51 mg/100g	*H. sabdariffa*	[46] and [63]
		2570-3300 mg/100g	*A. digitata*	[52], [53], [70] and [71]
	Dimethyl hibiscus acid	34-1451 mg/100g	*H. sabdariffa*	[12], [46], [72] and [73]
	Hydroxycitric acid	27-133 mg/100g	*H. sabdariffa* *H. acetosella*	[12],[46], [72] and [73]

	Vanillic acid	9-370 mg/100g	*H. sabdariffa*	[72]
		0.04 mg/g	*O. gratissimum*	[74]
		1.25-169.4 mg/100g	*M. charantia*	[75], [76] and [77]
	Protocatechuic acid	2-53 mg/100g	*H. sabdariffa*	[72]
		0.99-1.06 mg/100g	*A. digitata*	[78]
		0.34 mg/100g	*M. oleifera*	[79]
		2.07-53.5 mg/100g	*M. charantia*	[75], [76] and [77]
	Hydroxybenzoic acid	28-223 mg/100	*H. sabdariffa*	[72]
		0.63-4.91 mg/100g	*A. digitata*	[78]
		0.14 mg/g	*O. gratissimum*	[74]
	Isovanillic acid	8-13 mg/100g	*H. sabdariffa*	[72]
	Gentisic acid	16.99-27.47 mg/100g	*M. charantia*	[75] and [76]
	Ferulic acid	0.317 mg/g	*M. charantia*	[77]
		18-51 mg/100g	*H. sabdariffa*	[72]
		0.11-0.26 mg/100g	*A. digitata*	[78]
		0.0837 %	*B. diffusa*	[80]
		0.243 mg/100g	*M. oleifera*	[79]
		0.11 mg/g	*O. gratissimum*	[74]
Phenolic acid	Ellagic acid	34-75 mg/100	*H. sabdariffa*	[72]
		3.96 mg/g	*O. gratissimum*	[66]
		51.13 µg/ml	*H. acetosella*	[12] and [81]
	Caffeic acid	80-361 mg/100g	*H. sabdariffa*	[45], [46] and [72]
		0.07-20.19 mg/100g	*A. digitata*	[78]
		22.13 mg/g	*B. diffusa*	[82]
		0.02-0.48 mg/g	*O. gratissimum*	[12], [66] and [74]
		0.1278 %	*B. diffusa*	[80]
		3.788 mg/100g	*M. oleifera*	[79]
		3.932 mg/g	*M. charantia*	[47], [48], [49] and [77]
	Rosmarinic acid	0.22 mg/g	*O. gratissimum*	[74]
	Gallic acid	52-68.5 mg/100g	*A. digitata*	[69], [70] and [78]
		84-902 mg/100g	*H. sabdariffa*	[72] and [73]
		0.53 mg/g	*O. gratissimum*	[66]
		0.189 mg/100g	*C. micranthum*	[84]
		19.692 mg/100g	*M. oleifera*	[79]
		8.04-39.76 mg/100g	*M. charantia*	**[75],** [76] and [77]
		14.22 µg/ml	*H. acetosella*	[81]
	Chlorogenic acid	70-187 mg/100g	*H. sabdariffa*	[12], [45], [46], [72] and [85]
		1.79 mg/g	*O. gratissimum*	[12] and [66]
		4.55-3105.9 mg/100g	*M. charantia*	[75], [76] and [77]
		0.47-8.37 mg/100g	*A. digitata*	[78]

Flavonoid	Delphinidin-3-sambubioside	1417-1556 mg/100g	*H. sabdariffa*	[46], [72] and [73]
	Cyanidin- 3-sambubioside	903-1065 mg/100g	*H. sabdariffa*	[46], [72] and [73]
	Catechin	23.06-255.9 mg/100g	*M. charantia*	[12], [45], [46], [75] and [76]
		18.62 mg/100g	*C. micranthum*	[11] and [84]
		3.07-122 mg/100g	*A. digitata*	[69] and [78]
		0.51 mg/g	*O. gratissimum*	[66]
		749.606 mg/100g	*M. oleifera*	[79]
		120-465 mg/100g	*H. sabdariifa*	[72]
	Quercetin	2.16-5.86 mg/g	*H. sabdariffa*	[12,45,46] and [85]
		2.021 mg/100g	*M. oleifera*	[79]
		7.26-38.55 mg/100g	*A. digitata*	[78]
		0.07-1.26 g/100g	*M. oleifera*	[83]
		0.54 mg/g	*O. gratissimum*	[12]
		19.89 mg/g	*B. diffusa*	[10], [50] and [82]
	Epicatechin	112-1213 mg/100g	*H. sadariffa*	[72]
		1.32 mg/g	*O. gratissimum*	[66]
		89.556 mg/100g	*M. oleifera*	[79]
		16.61-32.38 mg/100g	*M. charantia*	[75]
	Kaempferol	25.02 mg/g	*B. diffusa*	[10], [50] and [82]
		1.03 mg/g	*O. gratissimum*	[66]
		0.05-0.67 g/100g	*M. oleifera*	[83]
		112-1213 mg/100g	*H. sadariffa*	[72]
Rotenoids	Boeravinone B	27.16 mg/g	*B. diffusa*	[82]
Carotenoids	β-carotene	3409.04 μg/100g	*H.acetosella*	[65]
	Lycopene	164.34 μg/100g	*H. sabdariffa*	[63]
	β-carotene	1.88 mg/100g		

Health benefits of the herbal teas

The herbal teas are mostly used for their versatile health advantages. The teas are consumed for their antioxidant, anti-inflammatory, anticancer and antimicrobial potentialities. These health benefits are the results of the synergic activities that the phytochemicals displayed. The health benefits of *H. sabdariffa* L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum* are given in Table 2. In India, Africa and Mexico, infusions of the leaves or calyces of Hibiscus species are traditionally used for their diuretic, choleretic, febrifugal and hypotensive effects, decreasing the viscosity of the blood and stimulating intestinal peristalsis [12] and [46]. The extracts of *A. digitata* are used in the treatment of diarrhea, dysentery, antioxidant, antimalaria, sore throat and anti-inflammation [43]. In Benin Republic, the tea of *C. pulcherrima* is employed to prevent and to cure cough, fever, malaria, fatigue, hypertension and gastrointestinal diseases. Likewise, in Philippines, India and Taiwan *C. pulcherrima* is applied as purgative, emmenagogue, tonic, stimulant, cathartic as well as a remedy for pyrexia, menoxenia, wheezing, bronchitis and malarial infections [6], [54] and [55]. It has been revealed that the intake of *M. oleifera* showed many positive effects on human health and immune system including coronary heart diseases, diabetes, high blood pressure, cataracts, degenerative diseases and obesity [56]. The decoction of *M. oleifera* leaves is used not ony to increase milk flow for the nursing mother but also to relieve wounds and burns, skin diseases, sore eyes, toothache, diarrhea, intestinal worms, anemia and ulcers [35]. *O. gratissimum* is used as a vegetable and traditional tea. It is widely consumed for its antibiotic properties. Its tea or infusion is reported to treat abdominal pain, cough, colds, pruritus, stress, headache, upper respiratory tract infections, pneumonia, conjunctivitis and skin diseases [32]. Furthermore, the investigations performed the ethyl acetate, methanol, water, chloroform, n-hexan and dichloromethane extracts of *C. pulcherrima* revealed that it has high antioxidant activity, inhibitory effects on cancerogenic cells as well as anti-inflammatory, immunosuppressive and antidiabetic properties [57]. Popoola et al. (2007) [58] and Okpuzor & Oloyede, (2009) [59] have proved that the leaves of *M. esculenta* have strong anti-hemorrhoid, anti-inflammation and antimicrobial activities. Similarly, the anti-cancer, anti-obesity and anti-HIV studies undertaken on *M. charantia* have indicated that the extracts of *M. charantia* have the abilities to inhibit the cancerogenic and tumorous cells, to decrease cholesterol level and can be effective for HIV treatment [60]. Moreover, *Boerhavia spp* is very important for the prevention and treatment for aging and hepatitis in Benin Republic. It is also indicated for the treatment of chronic alcoholism, toothache and infections. The tea of *C. micranthum* has also many health benefits as it is used for fever, fatigue and infection in Benin Republic; for gastrointestinal ailments and diabetes in Nigeria [61]; for liver disorders, fatigue, headache, cancer and diabetes in Senegal and Mali.

Table 2: Health benefits of *H. sabdariffa* L., *H. acetosella*, *C. pulcherrima*, *M. esculenta*, *B. diffusa*, *M. oleifera*, *M. charantia*, *O. gratissimum*, *A. digitata* and *C. micranthum*

Plants	Common name	Therapeutic uses	References
H. sabdariffa	Red sorrel or roselle, bissap (English) / Sinko (Fon)	Laxative effect, ability to increase urination, relief during hot weather and treatment of cracks in the feet, bilious, sores and wounds, emollient, antipyretic, diuretic, anti-helmentic, sedative properties and as a soothing cough remedy	[86]
H. acetosella	Panama red or False roselle (English)	Anti-anaemia, antipyretic	[12]
M. charantia	bitter gourd or bitter melon (English) / Yinsinken (Fon)	Asthma, burning sensation, constipation, colic, diabetes, cough, fever, gout, helminthiases, leprosy, inflammation, skin diseases, ulcer hepatitis, emmenogogue, wound, pneumonia, psoriasis, rheumatism etc.	[48] and [49]
A. digitata	Baobab (English) / Kpassa (Fon)	Diarrhoea, fever, inflammation, kidney and bladder diseases, blood clearing, asthma, fever, dysentery, diaphoretic, toothache, gingivitis	[52] and [53]
C. pulcherrima	Brazil wood (English)	Tridosha, fever, ulcer, abortifacient, emmenagogue, asthma, tumors, vata, skin diseases, purgative, stimulant, cathartic, as remedies for pyrexia, menoxenia, wheezing, bronchitis and malarial infections	[[54] and [55]
M. esculenta Crantz	Cassava (English), Finyin (Fon)	For the treatment of ringworm, hemorrhoid, tumor, rheumatism, fever, headache, diarrhea, loss of appetite, conjunctivitis, sores and abscesses	[8]
B. diffusa	Spreading Hogweed, red hogweed (English)	for the treatment of diuretic, arthritis, cramp, joint pain, rheumatism, kidney pain, anaemia, scanty urine and ascites	[10]
M. oleifera Lam,	Drumstick tree, horseradish tree (English), Kpatiman (Fon)	anti-inflammatory, anti-helminthic, antipyretic, anti-diabetic, antifertility, antihypertensive, lipid lowering, antitumor, antiulcer, hepatoprotective	[87]
O. gratissimum	Clove basil, lemon basil (English), Gbodoglin (Fon)	For treating various diseases such as pyorrhea, bronchitis, dysentery, headache and fever. Antimalarial, antidiarrheal, antidiabetic, anti-carcinogenic, insecticidal, antimutagenic, antiurolithiatic	[88]
C. micranthum	Kinkeliba (English)	Against diabetes, obesity and hypertension, anthelminthic, liver disorders, antimalarial	[89]

**Fon* is one the local languages of Benin Republic

CONCLUSION

It is evident that plants have many ethnomedicinal usages. The herbal teas obtained from *Hibiscus sabdariffa*, *Hibiscus acetosella*, *Caesalpinia pulcherrima*, *Manihot esculenta* Crantz, *Boerhavia diffusa*, *Moringa oleifera*, *Momordica charantia*, *Ocimum gratissimum*, *Adansonia digitata* and *Combretum micranthum* contain many bioactive compounds including organic and phenolic acids, polysaccharides, tannins, vitamins, minerals, proteins and peptides, anthocyanins and other flavonoids. These bioactive compounds are responsible of the nutritive and health protective effects of plants. The herbal teas have displayed strong antioxidant, antimicrobial, anti-inflammatory, immuno-protective and anti-diabetic activities. These plants might provide important aroma compounds which were identified to belong to fatty acids, alcohols, aldehydes, esters, ketones, furans, pyrroles, pyrans, terpenes, lactones, volatile phenols and pyrazines as well. Even though many studies have been worldwide done on these plants, further studies are needed to be performed on the Beninese herbal teas in order to identify their bioactive compounds and to characterize their aroma-active compounds.

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