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Evaluation of pharmacological properties, phytochemistry, and medicinal uses of *Baccharoides guineensis*

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ABSTRACT

The leaves, roots, and/or tubers of *Baccharoides guineensis* are used as traditional medicines in West Africa. This study is aimed to evaluate the pharmacological properties, photochemistry, and medicinal uses of *B. guineensis*. The results of this study are based on data derived from online databases such as Scopus, Google Scholar, PubMed, ScienceDirect, and MEDLINE and pre-electronic sources such as scientific publications, theses, books, dissertations, book chapters, and journal articles. This study revealed that the leaves, roots, and/or tubers of *B. guineensis* are widely used as anthelmintic, snakebite antidote, and ethnoveterinary medicine and as traditional medicine for toothache, gastrointestinal problems, jaundice, malaria, female, and male infertility. Phytochemical compounds identified from the species include anthraquinones, ceramide, fatty acids, flavonoids, glycerol esters, sesquiterpene lactones, steroids, stigmatanes, sucrose esters, and triterpenoids. The pharmacological research revealed that *B. guineensis* extracts and phytochemical compounds isolated from the species have antioxidant, anthelmintic, antiangiogenic, antibacterial, antiplasmodial, antiproliferative, antitrypanosidal, clonogenic, and antifungal activities. The future research on *B. guineensis* should focus on the possible biochemical mechanisms of both the crude extracts and phytochemical compounds including the toxicological, *in vivo*, and clinical studies to corroborate the traditional medicinal applications of the species.

INTRODUCTION

Baccharoides guineensis (Benth.) H. Rob. (Fig. 1) is a subshrub or perennial herb belonging to the *Asteraceae* or *Compositae* family. This species was originally treated under the genus *Vernonia* Schreb. (Isawumi *et al*., 1996), a genus confined to North America (Robinson *et al*., 2016). The genus name *Baccharoides* was first proposed by Moench in 1,793 and remained unused until it was resurrected by Robinson in 1990 (Robinson, 1999; Robinson *et al*., 2016). *Baccharoides guineensis* is a variable species with three recognized varieties based on the floral characteristics and geographical distribution. These varieties include the most widespread taxon, var. *guineensis* H. Rob., recorded in South Sudan, Central Africa Republic, Gabon, Guinea, Chad, Liberia, Ghana, Cameroon, Mali, Burkina Faso, Niger, Sierra Leone, Côte d'Ivoire, the Democratic Republic of Congo (DRC), Sudan, Togo, Angola, and Zambia; var. *procera* (O. Hoffm.) Isawumi, recorded in Benin and Nigeria; and var. *cameroonica* (C.D. Adams) Isawumi which is restricted to Cameroon. The synonyms associated with the name *B. guineensis* include *Cacalia firma* Kuntze, *C. guineensis* Kuntze, *Vernonia chevalieri* O. Hoffm., *V. firma* Oliv. & Hiern, *V. guineensis* Benth., *V. hierniana* S. Moore, *V. procera* O. Hoffm., *V. rotundisquama* S. Moore, *V. ulophylla* O. Hoffm., *V. guineensis* Benth. var. *cameroonica* C.D. Adams, *V. guineensis* Benth. var. *guineensis*, and *V. guineensis* Benth. var. *procera* (O. Hoffm.) C.D. Adams (Isawumi *et al*., 1996; Smith, 1971). *Baccharoides guineensis* has been recorded in variable habitats, ranging from high rainfall areas to open deciduous woodlands and savannas, grasslands, granite kopjes, and roadsides.

The *Baccharoides* genus is reported in the literature to have medicinal properties. For example, *Baccharoides adoensis* (Sch. ex Walp.) H. Rob., *B. antheintica* (L.) Moeh, and *B. lasipus* (O. Hofm.) H. Rob. are used in tropical Africa and India as ethnoveterinary medicine and traditional medicines for cough,

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diabetes, fever, gastrointestinal problems, malaria, sexually transmitted infections, tuberculosis, and wounds (Burkill, 1985; Hutchings *et al*., 1996; Toyang and Verpoorte, 2013). In countries such as Cameroon, the DRC, South Sudan, and Zambia, where *B. adoensis, B. guineensis*, and *B. lasiopus* have been recorded (Darbyshire *et al*., 2015; Dharani and Yenesew, 2010; Dharani *et al*., 2010; Dharani, 2019; Figueiredo and Smith, 2008; Friis and Vollesen, 1998; Neuwinger, 1996, 2000; Pope, 1992), there appear to be difficulties in identifying the species due to similar morphological characters. An ethnopharmacological research revealed that *B. adoensis*, *B. anthelmintica*, and *B. lasiopus* are characterized by antimicrobial, anthelmintic, antidiabetic, antioxidant, hepatoprotective, cytotoxicity, and antiplasmodial activities (Toyang and Verpoorte, 2013). Similarly, the tubers of *B. guineensis* are sold as traditional medicines by herbalists, informal traders, and hawkers in West Africa, particularly in Cameroon using the trade name *Ginseng* (Ngemenya *et al*., 2019; Toyang *et al*., 2012a; Toyang *et al*., 2013a; Wouamba *et al*., 2020). The common name *Ginseng* is based on the striking morphological resemblance between the carrot-like tubers or

Figure 1. *B. guineensis.* (A) entire plant showing leaves and inflorescence, (B) leaf showing leaf serrations, and (C) inflorescence (photo: A Maroyi).

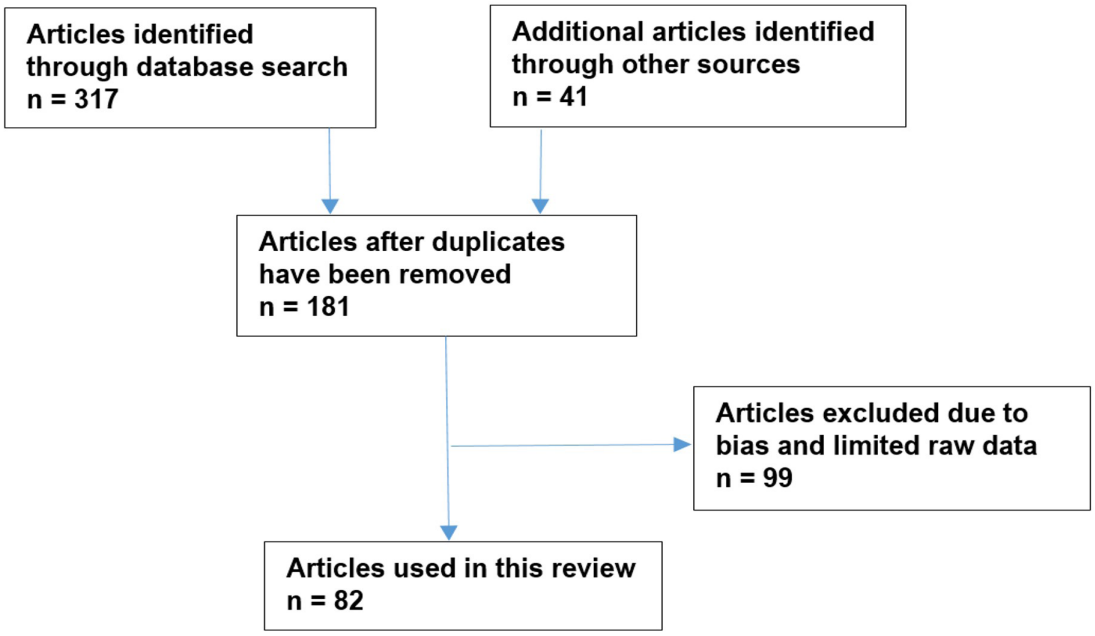

Figure 2. Flow diagram showing the literature search and selection processes.

roots of *B. guineensis* and the roots of the popular medicinal plant species *Panax ginseng* C.A. Mey (family *Araliaceae*) and other *Ginseng* species (Toyang *et al*., 2012a). Moreover, a patent highlighting the chemotherapeutic activities of the phytochemical compounds isolated from the species against abnormal cell growth was registered about 10 years ago (Toyang *et al*., 2012b). It is, therefore, within this context that this investigation was undertaken aimed to document the pharmacological properties, phytochemistry, and medicinal uses of *B. guineensis*.

MATERIALS AND METHODS

The results of this study are based on literature search on phytochemistry, pharmacological properties, and medicinal uses of *B. guineensis* using information derived from internet databases (Fig. 2), such as ScienceDirect, Google Scholar, PubMed, MEDLINE, and Scopus. Other sources of information included pre-electronic sources such as scientific publications, books, dissertations. and book chapters and other journal articles obtained from the university library.

RESULTS AND DISCUSSION

Medicinal uses of B. guineensis

The medicinal uses of *B. guineensis* have been recorded in Cameroon, Angola, Côte d'Ivoire, Nigeria, DRC, Ghana, Guinea, Sierra Leone, and Gabon representing 50% of the countries, where the species is indigenous. Major medicinal applications of *B. guineensis*, which have been recorded in three countries and supported by at least two literature records, include the use of the species as an anthelmintic, snakebite antidote, and ethnoveterinary medicine and as traditional medicine for toothache, gastrointestinal problems, jaundice, malaria, and female and male infertility (Table 1 and Fig. 3). The other medicinal uses of *B. guineensis* documented in two countries include the use of the extracts of the species as an aphrodisiac (Burkill, 1985; Iwu, 1993; Jiofack *et al*., 2009; Smith, 1971; Sobrinho *et al*., 2015) and purgative (Smith, 1971; Burkill, 1985) and as traditional medicine for hernia (Burkill, 1985; Göhre *et al*., 2016; Smith, 1971), urogenital disorders (Burkill, 1985; Focho *et al*., 2009b; Noumi and Ebwelle, 2011; Odugbemi, 2006), and sores and wounds (Burkill, 1985; Göhre *et al*., 2016; Yamada, 1999).

Phytochemistry of B. guineensis

The compounds such as vernolepin and vernodalin have been identified from *B. guineensis* (Toubiana *et al*., 1975). Tchinda *et al*. (2002) identified vernoguinosterol and vernoguinoside peracetate from stembark of *B. guineensis*. Tchinda *et al*. (2003) identified vernoguinoside, 16β,22R;21,23S-diepoxy-21S,24-dihydroxy-5α-stigmasta-8,14-diene-3,28-dione,

Table 1. Medicinal uses of *B. guineensis*.

Medicinal use	Parts used	Country	References
Aphrodisiac	Leaves and roots	Cameroon and Sierra Leone	Burkill, 1985; Iwu, 1993; Jiofack *et al*., 2009; Smith 1971; Sobrinho *et al*., 2015
Anthelmintic	Roots	Angola, Cameroon, and Nigeria	Göhre *et al*., 2016; Iwu, 1993; Sobrinho *et al*., 2015
Dysmenorrhea	Roots	Cameroon	Focho *et al*., 2009a; Jiofack *et al*., 2009
Ease delivery	Leaves	Cameroon	Choffnes, 2016
Epilepsy	Roots	Cameroon	Jiofack *et al*., 2009
Female and male infertility	Leaves and roots	Cameroon, Nigeria, and Sierra Leone	Burkill, 1985; Focho *et al*., 2009a, 2009b; Noumi *et al*., 2011; Odugbemi, 2006
Gastritis	Roots	Cameroon	Focho *et al*., 2009b
Gatrointestinal problems (abdominal pain, dysentery, and stomach ache)	Leaves and roots	Angola, Côte d'Ivoire, and the DRC	Burkill, 1985; Göhre *et al*., 2016; Yamada, 1999
Hernia	Leaves and roots	Angola and DRC	Burkill, 1985; Göhre *et al*., 2016; Smith, 1971
Jaundice	Leaves and roots	Cameroon, Côte d'Ivoire, and Nigeria	Burkill, 1985; Iwu, 1993; Odugbemi, 2006
Malaria	Leaves and roots	Cameroon, Côte d'Ivoire, and Nigeria	Burkill, 1985; Iwu, 1993; Jiofack *et al*., 2010; Odugbemi, 2006
Memory loss	Roots	Cameroon	Ngoungoure *et al*., 2019
Parasites infection	Roots	Cameroon	Jiofack *et al*., 2010
Prostatitis and prostate cancer	Roots	Cameroon	Noumi and Yumdinguetmun, 2010; Noumi, 2010; Toyang, 2014
Purgative	Leaves and roots	Côte d'Ivoire and the DRC	Burkill, 1985; Smith, 1971
Sexually transmitted infections (gonorrhea, syphilis, and venereal diseases)	Roots	Cameroon	Focho *et al*., 2009a
Snakebite antidote	Leaves and roots	Cameroon, Gabon, and Nigeria	Burkill, 1985; Houghton and Osibogun, 1993; Iwu, 1993; Sobrinho *et al*., 2015; Toyang, 2014
Sores and wounds	Leaves and roots	Angola and the DRC	Burkill, 1985; Göhre *et al*., 2016; Yamada, 1999
Stimulant and stress	Roots	Cameroon	Sobrinho *et al*., 2015; Toyang, 2014
Toothache	Leaves and roots	DRC, Guinea, and Nigeria	Burkill, 1985; Odugbemi, 2006
Urogenital disorders	Leaves and roots	Cameroon and Nigeria	Burkill, 1985; Focho *et al*., 2009b; Noumi and Ebwelle, 2011; Odugbemi, 2006
Ethnoveterinary medicine (diarrhea, worms, and promote calf growth)	Roots	Cameroon, Ghana, and Nigeria	Offiah *et al*., 2011; Toyang, 2014

1′,3,3′,4′,6′-pentakis-O-(3-methylbutanoyl)-β-D-fructofuranosyl α-D-glucopyranoside, and 1′,2,3′,6,6′-pentakis-O-(3-methylbutanoyl)-β-D-fructofuranosyl α-D-glucopyranoside from the stem bark of *B. guineensis*. Donfack *et al.* (2012) identified vernoguinoside, vernoguinoside A, stigmasterol 3-O-β-D-glucoside, and sitosterol 3-O-β-D-glucoside from the roots of *B. guineensis*. Toyang *et al.* (2013a) identified vernopicrin and vernomelitensin from the leaves of *B. guineensis*. Toyang *et al.* (2013b) identified pentaisovaleryl sucrose from the tubers of *B. guineensis*. Ditchou *et al.* (2019) identified the compounds such as betulinic acid, alphitolic acid, β-sitosterol 3-O-β-D-glucopyranoside, scoparone, and quercetin-3-O-β-galactoside from the roots of *B. guineensis*. Wouamba *et al.* (2020) identified vernoguinamide, physion, erythroglaucin, emodin, hop-17(21)-en-3β-yl acetate, lupeol, betulinic acid, vernoguinoside A, vernoguinoside, β-sitosterol 3-O-β-D-glucoside, stigmasterol 3-O-β-D-glucoside, stigmasterol, β-sitosterol, tetracosanoic acid, tricosanic acid, and arachidic acid glycerol ester from the roots of *B. guineensis*. Similar phytochemical compounds such as alkaloids, carbohydrates, chondrillasterol, flavonoids, free sugars, glaucolides, glycosides, phenols, proanthocyanidin, saponins, steroids, tannins, and terpenoids have been identified from a closely related species *B. adoensis* (Bohlmann *et al.*, 1984; Deeni and Hussain, 1994; Ibrahim and Ogayi, 2012; Inngjerdingen *et al.*, 2012; Mabhiza *et al.*, 2016; Mozirandi *et al.*, 2019; Muhindi *et al.*, 2016; Sanogo *et al.*, 1998; Swamy *et al.*, 2013, 2014). Similarly, *B. lasiopus* yielded the elemanolide-type sesquiterpene lactones, alkaloids, anthraquinones, cardiac glycosides, coumarins, flavonoids, phenolics, reducing sugars, saponins, steroids, tannins, terpenoids, and xanthines (Chhabra *et al.*, 1984; Kimani *et al.*, 2017a, 2017b; Koul *et al.*, 2003; Mutembei *et al.*, 2018; Ochwang'i *et al.*, 2016; Tarwish *et al.*, 2017).

Pharmacological properties of B. guineensis

The following pharmacological activities have been documented from the leaves, roots, and/or tubers of *B. guineensis*, and the phytochemical compounds isolated from the species have anthelmintic, antiangiogenic, antibacterial, antifungal, antioxidant, antiplasmodial, antiproliferative, antitrypanosidal, and clonogenic activities.

Anthelmintic activities

Toyang *et al.* (2012c) evaluated the anthelmintic activities of dichloromethane, methanol, and water extracts from the leaves and tubers of *B. guineensis* using the larval and adult stages of the hookworm *Ancylostoma ceylanicum* and the mouse nematode *Trichuris muris*. The organic extracts of the tubers demonstrated activities, exhibiting 100% killing efficacy against *T. muris* at 2.0 mg/ml in 48 hours. The organic extracts of the leaves exhibited the activities killing 100% of the adult *A. ceylanicum* at 1.0 mg/ml in 24 hours, whereas the aqueous extract of the leaves was active at 2.0 mg/ml in 72 hours, killing 100% of the adult *A. ceylanicum* (Toyang *et al.*, 2012c). Evaluation of the anthelmintic activities of the aqueous extracts of *B. lasiopus* leaves using the *in vitro* anthelmintic assay against the gastrointestinal nematode infective larvae of *Haemonchus, Mecistocirrus, Ostertagia, Trichostrogylus, Cooperia, Bunostomum,* and *Oesophagostomum* species exhibited moderate anthelmintic activities (Njonge *et al.*, 2013).

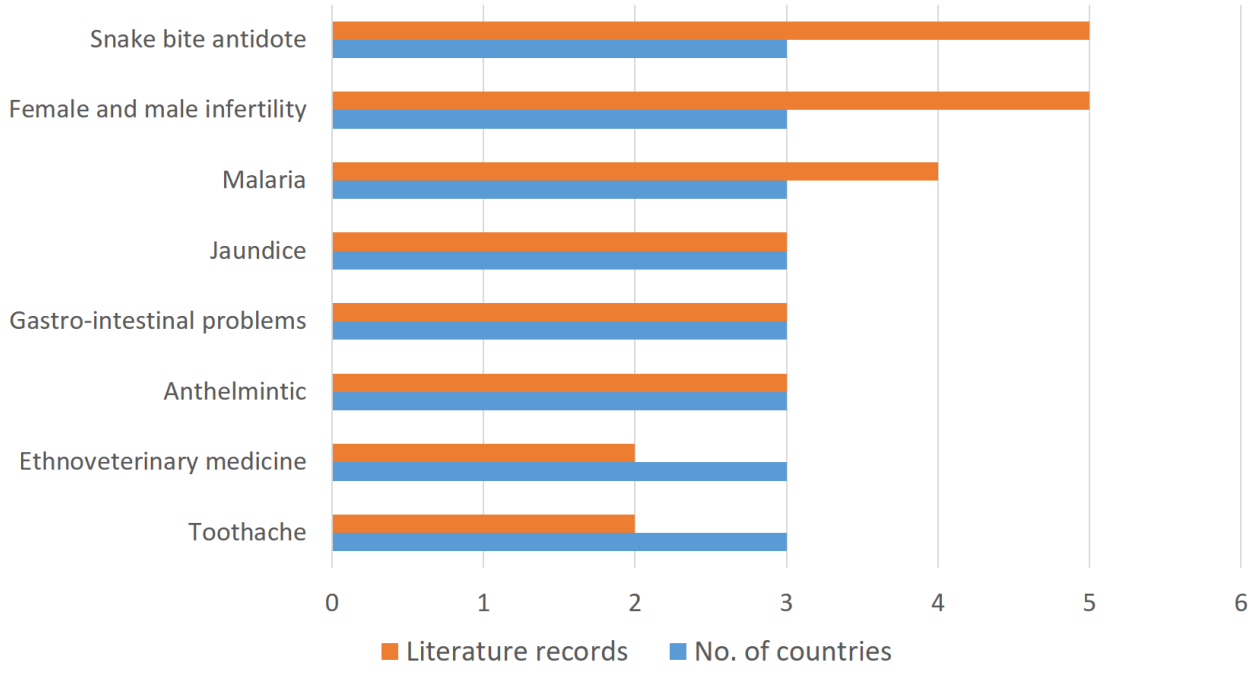

Figure 3. Medicinal applications of *B. guineensis* derived from the literature records.

Antiangiogenic activities

Toyang *et al*. (2012a) evaluated the antiangiogenic activities of aqueous, dichloromethane, and methanol extracts of the tubers of *B. guineensis* and the compound pentaisovaleryl sucrose isolated from the tubers of the species against three prostate cancer cell lines (PC-3, DU-145 and AT3B-1) using the Sprague–Dawley rat ring aorta assay. The methanol and aqueous extracts inhibited the sprout formation in the rat ring aorta assay at 30 and 100 µg/ml (Toyang *et al*., 2012a).

Antibacterial activities

Donfack *et al*. (2012) evaluated the antibacterial activities of dichloromethane:methanol (1:1) extract of the roots of *B. guineensis* and the compounds such as vernoguinoside, vernoguinoside A, and stigmasterol 3-O-β-D-glucoside isolated from the roots of the species against *Salmonella typhi, Staphylococcus aureus,* and *Shigella flexneri* using the broth microdilution method with ciprofloxacin (1.0–62.5 µg/ml) as a positive control. The extract and compounds exhibited the activities against *S. aureus* and *S. flexneri* with the minimum inhibitory concentration (MIC) and minimum bactericidal concentration (MBC) values ranging from 62.5 to 125.0 µg/ml in comparison to MIC and MBC values of 3.9–7.8 µg/ml exhibited by the positive control (Donfack *et al*., 2012). Toyang *et al*. (2012c) evaluated the antibacterial activities of dichloromethane, methanol, and water extracts of the leaves and tubers of *B. guineensis* against *Acinetobacter baumannii, Escherichia coli, Pseudomonas aeruginosa, Salmonella typhimurium, S. aureus,* and *Staphylococcus epidermidis* using microdilution assay with gentamicin as a positive control. The extracts exhibited weak activities against *A. baumannii, S. aureus,* and *S. epidermidis* with MIC values ranging from 750.0 to 1,000.0 µg/ml (Toyang *et al*., 2012c). Ditchou *et al*. (2019) evaluated the antibacterial activities of the compounds such as betulinic acid, alphitolic acid, β-sitosterol 3-O-β-D-glucopyranoside, scoparone, and quercetin-3-O-β-galactoside isolated from the roots of *B. guineensis* against *Aerococcus viridans, E. coli, Klebsiella pneumoniae, Neisseria gonorrhoeae, P. aeruginosa, Salmonella choleraesuis, Proteus mirabilis, S. aureus,* and *Enterococcus faecalis* using the microdilution method with ciprofloxacin and gentamicin as the positive controls. The compounds exhibited weak activities against *A. viridans, S. choleraesuis, S. aureus,* and *E. faecalis* with MIC and MBC values ranging from 312.5 to 2,500.0 µg/ml and 625.0 to 5,000.0 µg/ml, respectively (Ditchou *et al*., 2019). Wouamba *et al.* (2020) evaluated the antibacterial activities of the crude extract, ethyl acetate, and n-butanol fractions of the roots of *B. guineensis* and the compounds such as vernoguinamide, physion, erythroglaucin, emodin, hop-17(21)-en-3β-yl acetate, lupeol, betulinic acid, vernoguinoside A, vernoguinoside, β-sitosterol 3-O-β-D-glucoside, stigmasterol 3-O-β-D-glucoside, stigmasterol, β-sitosterol, tetracosanoic acid, tricosanic acid, and arachidic acid glycerol ester isolated from the roots of the species against *E. coli, Salmonella enterica,* and *S. flexneri* using the broth microdilution method with ciprofloxacin (7.8 µg/ml) as a positive control. The ethyl acetate and n-butanol fractions and the compounds exhibited activities against the tested pathogens with MIC values ranging from 31 to >500.0 µg/ml in comparison to MIC value of 0.07 µg/ml exhibited by the positive control (Wouamba *et al*., 2020).

Similar results were obtained by several researchers who evaluated the antibacterial activities of aqueous and organic extracts of *B. adoensis* and compounds isolated from the species against both Gram-negative and Gram-positive bacteria (Kisangau *et al*., 2007; Chitemerere and Mukanganyama, 2011; Ibrahim and Ogayi, 2012; Mutuku *et al*., 2013; Mozirandi and Mukanganyama, 2017). The leaf and stem extracts of *B. lasiopus* also exhibited the antibacterial activities against both Gram-negative and Gram-positive bacteria (Kareru *et al*., 2008; Mutembei *et al*., 2018; Rachuonyo *et al*., 2016a, 2016b, 2016c, 2016d, 2016e).

Antifungal activities

Donfack *et al*. (2012) evaluated the antifungal activities of dichloromethane:methanol (1:1) extract of the roots of *B. guineensis* and the compounds such as vernoguinoside, vernoguinoside A, and stigmasterol 3-O-β-D-glucoside isolated from the roots of the species against *Candida albicans, Candida parapsilosis,* and *Cryptococcus neoformans* using the broth microdilution method with nystatin (1.0–62.5 µg/ml) as a positive control. The extract and compounds exhibited the activities against tested pathogens with MIC and minimum fungicidal concentration (MFC) values ranging from 7.8 to 125.0 µg/ml in comparison to MIC and MFC values of 1.9–15.6 µg/ml exhibited by the positive control (Donfack *et al*., 2012). Toyang *et al*. (2012c) evaluated the antifungal activities of dichloromethane, methanol, and water extracts of the leaves and tubers of *B. guineensis* against *Aspergillus fumigatus, C. albicans, C. neoformans,* and *Trichophyton mentagrophytes* using microdilution assay with fluconazole and amphotericin B as the positive controls. The extracts exhibited weak activities against the tested pathogens with MIC values ranging from 200.0 to 1,000.0 µg/ml (Toyang *et al*., 2012c). Ditchou *et al*. (2019) evaluated the antifungal activities of the compounds such as betulinic acid, alphitolic acid, β-sitosterol 3-O-β-D-glucopyranoside, scoparone, and quercetin-3-O-β-galactoside isolated from the roots of *B. guineensis* against *C. albicans* using the microdilution method. Only compounds, such as alphitolic acid and β-sitosterol 3-O-β-D-glucopyranoside, exhibited the activities with the zone of inhibition of 7.0 mm (Ditchou *et al*., 2019). The crude leaf and stem extracts of a closely related species, *B. lasiopus*, exhibited the activities against *C. albicans, Microsporum canis,* and *T. mentagrophytes* (Rachuonyo *et al*., 2016a, 2016f; Vlietinck *et al*., 1995).

Antioxidant activities

Evans *et al*. (2015) evaluated the antioxidant activities of 80% methanol extracts of the leaves of *B. guineensis* using ferric reducing antioxidant power (FRAP) and 2,2′-azino-bis(3-ethylbenzothiazoline-6-sulfonic acid (ABTS) assays with ascorbic acid and trolox as the positive controls. The extract exhibited activities with FRAP value of 23.9 mg of TE/g of dry extract in comparison to 45.0 and 47.5 mg of TE/g of dry extract exhibited by the two positive controls. In the ABTS assay, the extract exhibited the activities with the percentage of inhibition of 67.0% and half-maximal inhibitory concentration (IC_{50}) value of 13.1 µg/ml in comparison to the IC_{50} values of 4.1 and 4.9 µg/ml exhibited by the

positive controls (Evans *et al*., 2015). Similarly, the aqueous and organic extracts of the leaves and roots of *B. adoensis* exhibited the antioxidant activities when evaluated using ABTS, FRAP, hydroxyl radicals, nitric oxide, and superoxide radicals scavenging ability assays (Mautsa and Mukanganyama, 2017; Nethengwe *et al*., 2012; Stangeland *et al*., 2010; Vasincu *et al*., 2014).

Antiplasmodial activity

Toyang *et al*. (2013b) evaluated the antiplasmodial activities of dichloromethane, methanol, and water extracts of the leaves and tubers of *B. guineensis* and the compounds such as vernopicrin, vernomelitensin, and pentaisovaleryl sucrose isolated from the leaves and tubers of the species against chloroquine-sensitive and chloroquine-resistant *Plasmodium falciparum* using an SYBR Green I-based DNA detection method with artesunate and chloroquine as the positive controls. The extracts and compounds exhibited activities with IC_{50} values ranging from 0.5 to 30.0 µg/ml in comparison to IC_{50} values of 0.002–0.07 µg/ml exhibited by the positive controls (Toyang *et al*., 2013b). The aqueous and organic extracts of the leaves of *B. adoensis* also exhibited antiplasmodial activities (Nethengwe *et al*., 2012; Obbo *et al*., 2019; Stangeland *et al*., 2010; Zemicheal and Mekonnen, 2018). The aqueous and organic extracts of *B. lasiopus* leaves as well as compounds isolated from the species exhibited antiplasmodial activities against chloroquine-sensitive and resistant *P. falciparum* (Irungu *et al*., 2007; Kimani *et al*., 2017b; Muregi *et al*., 2003; Muthaura *et al*., 2015; Njenga *et al*., 2015). The leaf, root, and stem bark extracts of *B. lasiopus* exhibited *in vivo* antimalarial activities in mice against a chloroquine-tolerant *Plasmodium berghei* (Muregi *et al*., 2007).

Antiproliferative activities

Toyang *et al*. (2012a) evaluated the antiproliferative activities of aqueous, dichloromethane, and methanol extracts of the tubers of *B. guineensis* and the compound such as pentaisovaleryl sucrose isolated from the tubers of the species against three prostate cancer cell lines (PC-3, DU-145 and AT3B-1) using the 4-[3-(4-iodophenyl)-2-(4-nitrophenyl)-2H-5-tetrazolio]-1,3-benzene disulfonate (WST-1) assay. The extracts and the compound exhibited the activities with IC_{50} values ranging from 4.2 to >100.0 µg/ml (Toyang *et al*., 2012a). Toyang *et al*. (2013a) evaluated the antiproliferative activities of acetone extracts of the leaves of *B. guineensis* and the compounds such as vernopicrin and vernomelitensin isolated from the leaves of the species against 10 cancer cell lines (breast: MDA-MB-231, breast: MCF-7, colon: HCT-116, leukemia: HL-60, lung: A549, melanoma: A375, ovarian: OVCAR3, pancreas: Mia-paca, prostate: PC-3, and prostate: DU145) using the WST-1 assay. The extract exhibited the activities with IC_{50} values ranging from 4.0 to 26.0 µg/ml against the 10 cell lines, whereas the compounds exhibited IC_{50} values ranging from 0.1 to 2.0 µM (Toyang *et al*., 2013a). Toyang *et al*. (2013c) evaluated the antiproliferative activities of dichloromethane extracts and the compound pentaisovaleryl sucrose isolated from the tubers of *B. guineensis* using *in vivo* antiprostate tumor assay in nude mice, *in vitro* using the WST-1 assay against nine cancer cell lines (breast: MDA-MB231, breast: MCF-7, colon: HCT-116, leukemia: HL-60, lung: A549, melanoma: A375, ovarian: OVCAR3, pancreatic: Mia-Paca, and prostate cancer: CAPAN-1). The prostate cancer (PC-3) xenograft tumors treated with the extract showed the activities by decreasing the tumor size, whereas the compound also demonstrated activities by exhibiting IC_{50} values ranging from 5.0 to 14.1 µM (Toyang *et al*., 2013c). Toyang (2014) evaluated the antiproliferative activities of dichloromethane extracts of the root tubers of *B. guineensis* against the prostate cancer line (PC-3) using trypan blue cell viability assay. The extract inhibited greater than 50% of cell viability at the concentrations of <40.0 µg/ml (Toyang, 2014).

Antitrypanosidal activities

Tchinda *et al*. (2002) evaluated the antitrypanosidal activities of the compounds such as vernoguinosterol and vernoguinoside peracetate isolated from the stem bark of *B. guineensis* against the four strains of bloodstream trypomastigotes *Trypanosoma brucei rhodesiense* using the Alamar Blue assay. The compounds exhibited the inhibitory activities with IC_{50} values ranging from 3. to 5.0 µg/ml (Tchinda *et al*., 2002). Kimani *et al*. (2017a, 2017b) evaluated the *in vitro* antitrypanosomal activities of the aqueous and organic of the aerial parts of *B. lasiopus* and phytochemical compounds isolated from the species using Almar Blue and resazurin assay. Both the extract and the compounds exhibited the activities with the IC_{50} values ranging from 0.2 to 65.8 µg/ml for the extracts and 0.07–9.8 µM for the compounds (Kimani *et al*., 2017a, 2017b).

Clonogenic activities

Toyang *et al*. (2012a) evaluated the clonogenic activities of aqueous, dichloromethane, and methanol extracts of the tubers of *B. guineensis* and the compound pentaisovaleryl sucrose isolated from the tubers of the species against the prostate cancer cell lines (PC-3) using the clonogenic assay. The extracts and the compound exhibited dose-dependent activities by inhibiting the colony formation by PC-3 cells (Toyang *et al*., 2012a). Toyang *et al*. (2013a) evaluated the clonogenic activities of acetone extracts of the leaves of *B. guineensis* and the compounds such as vernopicrin and vernomelitensin isolated from the leaves of the species against 10 cancer cell lines (breast: MDA-MB-231, breast: MCF-7, colon: HCT-116, leukemia: HL-60, lung: A549, melanoma: A375, ovarian: OVCAR3, pancreas: Mia-paca, prostate: PC-3, and prostate: DU145) using the clonogenic assay. The extract and the compounds exhibited dose-dependent activities inhibiting the colony formation with an IC_{50} value of <0.5 µM (Toyang *et al*., 2013a).

CONCLUSION

Research conducted so far revealed that compounds such as alphitolic acid, arachidic acid, betulinic acid, emodin, erythroglaucin, hop-17(21)-en-3β-yl acetate, lupeol, pentaisovaleryl sucrose, physion, quercetin-3-O-β-galactoside, scoparone, β-sitosterol 3-O-β-D-glucopyranoside, stigmasterol, stigmasterol 3-O-β-D-glucoside, tetracosanoic acid, tricosanic acid, vernoguinamide, vernoguinoside, vernoguinoside A, vernoguinosterol, vernoguinoside peracetate, vernopicrin, and vernomelitensin isolated from *B. guineensis* have antiangiogenic, antibacterial, antifungal, antitrypanosidal, and clonogenic activities. Therefore, the future research on *B. guineensis* should focus on the possible biochemical mechanisms of both the crude extracts and identified phytochemical compounds including

the toxicological, *in vivo*, and clinical studies to corroborate the traditional medical applications of the species.

CONFLICT OF INTEREST

The author declares that he has no conflict of interest.

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