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STRYCHNOS SPINOSA LAM: COMPREHENSIVE REVIEW ON ITS MEDICINAL AND NUTRITIONAL USES.

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Abstract

Background: Most of the people living in developing countries rely on local remedies from traditional medicines to take care of their healthcare needs. In recent years, the use of medicinal plants increased considerably. Consequently, studies on medicinal plants are necessary to produce more effective drugs with fewer side-effects. This work aims to compile the dispersal data on *Strychnos spinosa* Lam., a medicinal plant with great therapeutic potential in traditional medicine, on its ethnobotanical uses, chemical compounds, as well as its pharmacological and nutritional effects.
Material and Methods: To achieve the aforementioned aim, electronic databases such as Pubmed, Science Direct, Google scholar, Scopus and SciFinder were scanned.
Results: Literature survey revealed that *S. spinosa* is used in the treatment of microbial infections, malaria, trypanosomiasis, intestinal worms, tuberculosis, infertility, gastrointestinal disorders, snake bite, hypertension, and diabetes mellitus among other ailments. The plant is also used as food material. *S. spinosa* contains many chemical compounds, such as alkaloids, terpenes, sterols, fatty acids, flavonoids, saponin, and others. The fruits are a source of important nutrients such as carbohydrates, sugars, proteins, vitamins and fibres. Experimental studies have shown numerous pharmacological properties, including antimicrobial, antiplasmodial, anti-trypanosomal, anti-leishmanial, anti-nematicidal, anti-inflammatory, anti-oxidant, antidiabetic and other activities.
Conclusion: This review article provides comprehensive information on *S. spinosa* and its various extracts. Due to the promising effects of the plant extracts on various diseases and its nutritional values, there is a need for toxicity studies and clinical trials to assess the effects of its identified bioactive compounds.

Keywords: *Strychnos spinosa*, ethnobotany, pharmacological activities, biological activities, nutrition, phytochemistry.

List of Abbreviations: Cm: Centimeters, IC_{50} : Concentration that inhibits 50% of activity, g: grams, *L.*: *leishmania*, m: meters, *M.*: *Mycobacterium*, mg/mL: milligrams per milliliters, MIC: Minimal Inhibition Concentration, µg/mL: micrograms per milliliters, pg/mL: picograms per milliliters, *P.*: *Plasmodium*, STD: Sexually Transmitted Diseases, *S.*: *Strychnos, T.*: *Trypanosoma, T. b.*: *Trypanosoma brucei.*

Introduction

The use of plants as medicines is widely accepted in the culture and traditions of Africans and people from South America and Asia (Calixto, 2005; Ayyanar and Ignacimuthu 2011). Worldwide, the use of traditional medicines has a long history and encompasses an easily accessible and affordable source of treatment. Nowadays, this practice continues to play a key role in healthcare and many reports estimate that approximately 80% of the people on the globe still rely on traditional medicine for their primary healthcare (WHO 2010; Tittikpina *et al.,* 2018). Various reasons could explain this situation among which are: reduced costs, difficult access to modern medicine, and fewer side-effects (Kumar *et al.,* 2012; Tittikpina *et al.,* 2018). There are several families of plants used in traditional medicine, among which are the Loganiaceae. The Loganiaceae are among plants of wide usages in traditional medicine that are continuously screened for their pharmacological properties. Species of this family belong to genera, such as: *Antonia*, *Gardneria*, *Geniostoma*, *Labordia*, *Logania*, *Mitrasacme*, *Mitreola*, *Neuburgia*, *Norrisia*, *Spigelia*, *Strychnos* and *Usteria* (Gibbons *et al.,* 2012). According to their wide distribution, these plants are used in all parts of the world as remedies, foods and others. One of the largest and most economically important general of the family is *Strychnos,* with more than 200 species (Ohiri *et al.,* 1983, Akoégninou *et al.,* 2006). *Strychnos spinosa* Lam is one of the most documented species in the *Strychnos* genus. *S. spinosa*, "Orange de brousse" in French, means "Wild orange", is a shrub species from savannah ecosystems. This plant is widely utilized by indigenous people in folk medicine and for culinary purposes (Ohiri *et al.,* 1983).

S. spinosa is employed to treat infections and parasitic diseases such as malaria (Asase *et al.,* 2005), trypanosomiasis (Bizimana *et al.,* 2006) and tuberculosis (Molander *et al.,* 2014); and non-communicable diseases such as female sexual disorders, gastrointestinal disorders (Tchacondo *et al.,* 2011) and hypertension (Avakoudjo *et al.,* 2019). The fruits of the plant are mainly consumed by people (Akpavi *et al.,* 2011), and are also transformed to make jam, jelly and processed products (Ngadze *et al.,* 2017), whereas the leaves are turned into vegetable sauce (Guissou *et al.,* 2015). The diverse uses of this plant are linked to its phytochemical compounds such as akagerine, kribine, 11-methoxy-diaboline, stryspinolactone, stryspinoside, strychoside A and B, α-amyrin, β-amyrin, uvaol, lupeol, erythrodiol, ursolic acid (Adesogan and Morah, 1981; Ohiri *et al.,* 1983; Msonthi *et al.,* 1985; Morah, 1993; Hoet *et al.,* 2007); and linalool, geraniol, terpineol, nerolidol, palmitic acid and isopropyl myristate, which have also been detected in the essential oils of its leaves (Hoet *et al.,* 2006). Various biological properties have been demonstrated for *S. spinosa* and its components (Hoet *et al.,* 2007; Bero *et al.,* 2009; Maregesi *et al.,* 2016; Nciki *et al.,* 2016; Mbunde *et al.,* 2019).

Giving the various properties of *S. spinosa*, the aim of this study is to review the complete facts on its medicinal benefits and nutritional values. This review is a compiled survey of information on various aspects of *S. spinosa* including its botany, ethnomedicinal uses, phytochemistry, pharmacological and nutritional properties.

Materials and Methods

The data were obtained by scanning electronic databases such as Pubmed (https://pubmed.ncbi.nlm.nih.gov), Science Direct (https://www.sciencedirect.com), Google scholar (https://schoolar.google.com), Scopus (https://www.scopus.com), and SciFinder (https://scifinder.cas.org) using the following keywords individually, with one another and altogether: *Strychnos spinosa*, ethnobotany, pharmacological activities, biological activities, nutrition, phytochemistry. By doing so, more than 5 000 manuscripts were screened from which 57 were considered for this review: -52 manuscripts contained information related to the ethnobotanical, medicinal, chemical components and nutritional uses of the plant. - 5 manuscripts contained information related to *Strychnos spp* or the Loganiaceae (family *S. spinosa* belongs to). By screening electronic bases, existing unpublished online data on the plant, such as references Brunel *et al.,* (1984), Akoegninou *et al.,* (2006) and Bruneton (2016) could consequently not be accessed. However, it does not retrieve the value of this review which provides most up-to-date information on the aforementioned properties of the plant.

Botanical description of *Strychnos spinosa*: Taxonomy and morphological features

Taxonomy

The Loganiaceae are a family of flowering plants classified in order Gentianales. The family includes up to 12 genera, distributed around the world's tropics: *Antonia*, *Gardneria*, *Geniostoma*, *Labordia*, *Logania*, *Mitrasacme*, *Mitreola*, *Neuburgia*, *Norrisia*, *Spigelia*, *Strychnos* and *Usteria* (Gibbons *et al.,* 2012). The genus *Strychnos* is the largest of the family Loganiaceae. It is pantropical and comprises about 200 species, which may be subdivided into three geographically separated groups: one of around 75 species in Africa, a 73 species group in America and a final one of 44 species in Asia and Australia (Ohiri *et al.,* 1983). Species of *Strychnos* are lianas and shrubby thorny individuals, easily identifiable by their leaves opposite and tree to tree ribs, non-stipulated, with globular fruits looking link oranges. Their seeds and barks contain ordinary violent poisons (Brunel *et al.,* 1984; Akoégninou *et al.,* 2006). In sub-Saharan Africa, *S. spinosa* Lam. is the most common specie, native to the area and found in Northeast tropical Africa (from Somalia to Sudan), in East tropical Africa (from Kenya to Uganda), West-central tropical Africa (from Rwanda to Cameroon), West tropical Africa (from Nigeria to Senegal), South tropical Africa (from Angola to South Africa) and in Western Indian ocean (Madagascar and Mauritius) (USDA 2020).

In Togo according to the Analytical Floras of Togo, nine (9) species of *Strychnos* are represented on the national scale (Brunel *et al.,* 1984). They are more diversified in forest ecosystems where they are represented by slanting and ligneous liana species. Two (2) shrub species are found commonly in savannas ecosystems: *S. spinosa* and *S. innocua*. Throughout the country scale, the most distributed is *S. spinosa*. With the exception of the coastal region, it could be found both in savannas ecosystems and, in open and degraded forest ecosystems (Brunel *et al.,* 1984; Akoégninou *et al.,* 2006).

Morphological features

The target species is a shrubby deciduous plant with a maximum height of 5-6 m with greening white flowers and globular green berry fruits becoming yellow in maturity (Akoégninou *et al.,* 2006). The fruits have a hard pericarp. The global aspect of the tree and the form and the colour of fruits are seemed similar to the orange tree and fruits. Leaves are simple, ovale, glabrous, opposites with axillary spines, slightly curved (Berhaut, 1988). Sometimes there are entirely non-spiny branches. The size of leaves are variable, small 1-2 cm or big 3-8 cm of length and 3-6 cm of large. Flowering is done at the end of the dry season and the beginning of the rainy season during leafing. The green flowers are grouped into an inflorescence in corymb. Fruits are greening berries, spherical with the form and the aspect of an orange, turning into yellow at maturity. The pericarp is hard containing several seeds enrobed by edible pulp (Berhaut, 1988; Akoégninou *et al.,* 2006).

Usages in ethnomedicine

All over the African continent, *Strychnos spinosa* parts are used for various purposes. In different countries located in Sub-Saharan Africa, the roots are generally utilized to treat infections and parasitic diseases, diseases of the digestive tract and as a dewormer as reported in some works (Waterman *et al.,* 2010; Table 1). Hence, when reviewing the different studies performed at national levels on the ethnobotanical uses of *S. spinosa*, numerous studies have reported medicinal activities related to the aforementioned medicinal properties in Ghana, Benin, Burkina Faso, Mali and Kenya where it is also used to treat tuberculosis (Table 1; Asase *et al.,* 2005; Bizimana *et al.,* 2006; Bero *et al.,* 2009; Ibrahim *et al.,* 2014; Molander *et al.,* 2014; Avakoudjo *et al.,* 2019; Novotna *et al.,* 2020). Besides, tuberculosis is most of the time associated with sexually transmitted diseases (STDs). Consequently, other studies in Sub-Saharan Africa have pointed the role of the plant in the cure of STDs. For example, the roots are utilized to treat STDs in Guinea, Mozambique, Zambia and in Tanzania (Ruffo, 1991; Ndubani and Höjer, 1999; Magassouba *et al.,* 2007; Maroyi 2011; Bruschi *et al.,* 2011; Molander *et al.,* 2014; Lawal *et al.,* 2019; Chinsembu *et al.,* 2019; Table 1). By reviewing through the literature, it also came into consideration that anti-infectious and anti-parasitic properties of the plant are not only directed towards humans but also animals. Such properties have been reported in Côte d'Ivoire and Zimbabwe (Koné and Atindehou, 2008; Madzimure *et al.,* 2013). Furthermore, the literature survey pointed out the role of *S spinosa* in the cure of non-communicable diseases in Sudan, Benin, Togo, Nigeria, and South Africa. For instance, in Togo, the roots are used to treat diabetes in mixture with the bulb of *Tacca leontopetaloides* (L.) Kuntze (Dioscoreaceae), by ethnic groups living in the central area (Karou *et al.,* 2011). This is the only mention of antidiabetic properties of *S. spinosa* in Sub-Saharan Africa. On the contrary, the treatment of snakebite with the plant, was mentioned by numerous studies from across the region: in Nigeria, South Africa and Mali (Adesogan and Morah, 1981; Lockett *et al.,* 2000; Molander *et al.,* 2014; Lawal *et al.,* 2019). Finally, various ethnomedicinal uses have also been retained: haemorrhoids, conjunctivitis, eye diseases, diarrhoea, toothache, stomach-ache, hernia, miscarriage prevention, speed of the delivery process, milk production of the new mom, unblocking of respiratory difficulties, etc. (Bero *et al.,* 2009; Molander *et al.,* 2014; Avakoudjo *et al.,* 2019; Novotna *et al.,* 2020; Table 1). In comparison, the ethnobotanical usages of *S. spinosa* are very similar to the ones reported of the species belonging to the genus *Strychnos* in general. For example, *S. innocua* roots, barks and leaves are applied in Mozambique, to induce or to speed the delivery process; to facilitate placenta expulsion and treat madness. Its fruit pulp is eaten in Zambia to treat gonorrhea and its leaves are boiled in Ghana to treat malaria (Asase *et al.,* 2005; Bruschi *et al.,* 2011; Chinsembu *et al.,* 2019). Another example is *S. cocculoides* Baker (another African species) whose roots and fruits are up taken to treat STDs in Zambia; its roots are reduced to ashes to treat lymphogranuloma inguinale and its unripe fruit mixed with tea to treat erectile dysfunction in the same country. Besides, its roots alone are utilized to treat dysmenorrhea, new-born colic, cerebral ischemia, boils on legs, haemorrhage due to injury, and postpartum bleeding in Angola (Chinsembu *et al.,* 2019; Novotna *et al.,* 2020). A third example is *S. panganiensis* Gilg. Its leaves and stem barks are a cure to trypanosomiasis in Tanzania (Ibrahim *et al.,* 2014). A final example is *S. madagascariensis* Poir. Its roots are crushed to treat eye sores in Zimbabwe and its leaves and barks are applied to treat burns, sores, and ringworm in South Africa (Maroyi, 2011; Dlova and Ollengo, 2018). Species of the genus *Strychnos* evolving on other continents are also used for almost the same purposes. For instance, the seeds of *S. potatorum* Linn, common in south-east Asia, are used in the treatment of gonorrhea, leukorrhea, gastropathy, bronchitis, chronic diarrhea, dysentery, renal and vesicle calculi, diabetes, conjunctivitis, scleritis, ulcers, other eye diseases and to clear muddy water (Yadav *et al.,* 2014). Furthermore in South America, *S. brasiliensis* (Spreng.) Mart. roots are uptaken as tonic and febrifuge; *S. erichsonii* M.R. Schomb. ex Progel barks are employed as aphrodisiac; *S. fendleri* Sprague & Sandw barks constitute a treatment to malaria and *S. guianensis* (J.B. Aublet) Martius young shoots are consumed to treat malaria and general debility (Quetin-Leclercq *et al.,* 1990). Those different usages of *S. spinosa* in ethnomedicine are well documented by research made at community, regional, national and sometimes international levels. Most of the ethnobotanical uses are unfortunately not scientifically demonstrated and there are consequently need of research to cover this hole. Fortunately, some of the ethnobotanical uses were subject to further studies to find the reason behind the utilization in some diseases treatment and to refute the use in the case of other ailments.

Table 1: Uses of *Strychnos spinosa* Lam. in ethnomedecine.

Organ	Diseases	Country	References
Roots	Infections and parasitic diseases, diseases of the digestive tract, dewormer.	Sub-Saharan Africa	Waterman *et al.,* (2010).
Seeds	Emetic action and antidote against snake bite.	Nigeria (Western Africa)	Adesogan and Morah (1981).
Nuts and seeds	Snake bite		Lockett *et al.,* (2000).
Leaves/ Roots/ Twigs	Anti-trypanosomal activity	Mali, Burkina and Benin (Western Africa)	Bizimana *et al.,* (2006).
Leaves, twigs and fruit.	Malaria	Ghana (Western Africa)	Asase *et al.,* (2005).
Root barks	Infectious diseases including sexually transmitted diseases	Guinea (Western Africa)	Magassouba *et al.,* (2007).
Leaves in association with the ones of *Crossopteryx febrifuga* (G. Don) Benth (Rubiaceae).	Dermatitis, loss of fur and skin diseases in livestock (cattle, sheep, goats and poultry).	Côte d'Ivoire (Western Africa)	Koné and Atindehou. (2008).
Cortex	Snake bite	Mali (Western Africa)	Molander *et al.,* (2014).
Plant parts	Urinary infection, haemorrhoids conjunctivitis, eye diseases, diarrhea, tuberculosis, toothache, stomachache, hernia.		Novotna *et al.,* (2020).
Roots + bulbs of *Tacca leontopetaloides* (L.) Kuntze (Dioscoreaceae)	Diabetes	Togo (Western Africa)	Karou *et al.,* (2011).
Roots + roots of *Millettia thonningii* (Schumach.) (Fabaceae)	Female sexual disorders and infertility.		Tchacondo *et al.,* (2011).
Roots + roots of *Entada africana* Guill. & Perr (Fabaceae)	Gastrointestinal disorders		

Plant parts	Stomach-aches, abdominal pains, colic, sterility, abscesses, sleeping sickness and malaria.	Benin (Western Africa)	Bero *et al.,* (2009).
Bark alone Barks + roots	Diarrhea, stomachache, constipation, painful menstrual periods, stimulation of milk production, antibiotic, children's fever, swelling of feet, prevention of paralysis.		Avakoudjo *et al.,* (2019).
Bark + mature fruit	Swelling of foot, prevention of paralysis and children's fever.		
The bark + wild banana	Constipation		
Roots + ingredients	Fever, painful and dirty periods, stomach-aches (with leaves).		
Roots alone	Hypertension, stomach-aches, strengthen the body and slow venom.		
Leaves	Malaria, weariness, fever, unblock respiratory difficulties		
Pulp of the ripe fruit	Foot crevices and facilitate milk production of the new mom.		
Fruit (non-ripe) with one pod of *Aframomum melegueta* K. Schum (Zingiberaceae)	Stomach-aches		
Barks	Stimulate milk production in cows. Added to salt, cure fever and		

	trembling of oxen, diarrhoea and stomachache in livestock.		
Roots bark	Sexually transmitted diseases	South Africa (Southern Africa)	Lawal *et al.,* (2019).
Radix	Snake bite		Molander *et al.,* (2014).
Pulp, seeds	Cattle ticks	Zimbabwe (Southern Africa)	Madzimure *et al.,* (2013).
Root	Abdominal pains, gonorrhoea diarrhoea		Maroyi (2011).
Fruit pericarp	Dysentery	Mozambique (Southern Africa)	Morah (1993).
Roots	Venereal diseases, hernia, speed or induce the delivery process and snake bites.		Bruschi *et al.,* (2011).
Roots	Intestinal worms, gonorrhoea and syphilis.	Tanzania (Eastern Africa)	Ruffo (1991).
Fruits (unripe) Seeds	Emetic, un-retarded growth in children (fruit flesh).	Malawi (Eastern Africa)	Msonthi *et al.,* (1985)
Fruits	Warts (dermatology)	Kenya (Eastern Africa)	Dlova and Ollengo (2018).
Fruits (unripe), roots	Gonorrhoea, lymphogranuloma inguinale	Zambia (Eastern Africa)	Ndubani and Höjer (1999). Chinsembu *et al.,* (2019).
Fruits	Hypertension	Sudan (Northern Africa)	Doka and Yagi (2009).
Crushed Roots	Haemorrhoids	Angola (Central Africa)	Novotna *et al.,* (2020).
Other parts of the plant	Miscarriage prevention, sterility, impotence, cough, tuberculosis, pneumonia, flu, constipation and stomachache		

Pharmacological and biological activities
Antiplasmodial activities

Among the ethnobotanical properties of *S. spinosa* which went through further studies are the anti-infectious ones (Table 2) which includes the plant's utilization to treat malaria. Malaria is a disease caused by four parasites belonging to the genus *Plasmodium* with *P. falciparum* responsible of the most severe cases. The parasite is introduced into the human body by a mosquito, the female *Anopheles mosquitoes* (Philippe *et al.,* 2005; Bero *et al.,* 2009). Consequently to investigate antimalarial properties, plant extracts were evaluated against *Plasmodium falciparum*. Hence, ethyl acetate extract of the stems and boughs were screened against a chloroquine-susceptible strain of *Plasmodium falciparum* (Philippe *et al.,* 2005). No activity was observed with this extract. On the contrary, Bero *et al.,* (2009) by studying the dichloromethane extract of the leaves against chloroquine sensitive and resistant strains of *P. falciparum*, have detected an activity. Indeed, the dichloromethane extract of the leaves was active against both the chloroquine-susceptible and resistant strains of *Plasmodium falciparum* with IC_{50}s of 15.6 ± 3.8 µg/mL and 8.9 ± 2.1 µg/mL respectively (Bero *et al.,* 2009).

The observed antimalarial activity of the leaves confirms the use of the leaves to treat malaria in Ghana and Benin (Asase *et al.,* 2005; Avakoudjo *et al.,* 2019). In addition, the activity of the leaves against *P. falciparum* is high in comparison to IC_{50}s obtained with references such as chloroquine and artemisinin. However, when comparing the activity of the leaves of *S. spinosa* against that of other African *Strychnos* species, it is notable that the IC_{50}s obtained with *S. spinosa* were more interesting. For instance, the ethyl acetate extracts of leaves of *S. cocculoides* and *S. scheffleri* Gilg ex Engl. had respectively an IC_{50} of 20.0±11.9 µg/mL and 21.2 µg/mL against chloroquine sensitive strain of *P falciparum*, higher than the one observed with the leaves of *S. spinosa*. However, some species have also shown activity noteworthier than the one of *S. spinosa*. It is the case of the ethyl acetate extracts of the leaves of *S. henningsii* Gilg with an IC_{50} of 15.9±3.0 µg/mL and of *Strychnos mellodora* S. Moore with an IC_{50} of 13.4 µg/mL (Table 2).

Apart from the parasite *P. falciparum*, *S. spinosa* has been ethnobotanically documented to be active against African trypanosomiasis and leishmaniasis. This activity has also been scientifically proved. On one hand, *Trypanosoma brucei gambiense* and *Trypanosoma brucei rohodeseinse* are the species responsible of the African trypanosomiasis also known as African sleeping sickness or simply sleeping sickness. On the other hand, human leishmaniosis is provoked by various *Leishmania* species: *L. donovani (L. donovani*, *L. infantum* and *L. chagasi*), *L. mexicana* (*L. mexicana*, *L. amazonensis* and *L. venezuelensis*); *L. tropica*; *L. major*; *L. aethiopica* and the sub-genus *viannia* (*L. V. braziliensis*, *L.V. guyanensis*, *L.V. panamensis*, *L. V. peruvian*). The anti-trypansomial and anti-leishmania *in-vitro* testing of the plants were performed following the epidemiological distribution of the parasites (Hoet *et al.,* 2004; Garba *et al.,* 2018; Table 2). Finally, *S. spinosa* was also reportedly active against a third type of parasites, the parasitic nematodes.

Anti-trypanosomial and antinematicidal activities

The methylene chloride extract of the leaves of *S. spinosa* was tested against *T. b. brucei*, *T. b. rhodesiense* and *Leishmania mexicana mexicana* (Table 2). Against the last parasite, a MIC (minimum inhibitory concentration, concentration at which no cell with a normal morphology and/or motility is found in comparison to the control) of 56 - 167 µg/ml was observed but no IC_{50} was determined because only a MIC lower than 19 µg/mL reveals an extract to be active. An interesting IC_{50} was on the contrary observed on *Trypanosoma brucei brucei* and *Trypanosoma brucei rhodesiense* with values respectively of 1.5 ± 0.9 and 16.4 ± 8.8 and µg/mL and a MIC lower than 19 µg/mL. Besides, the extract was active without toxicity on normal mammalian cells in comparison to other tested plants extracts and consequently was the extract of choice (Hoet *et al.,* 2014). Therefore further studies have chemically studied the extract and have identified compounds which might be the cause of the anti-trypanosomial effect (Table 2). Phytosterols and terpenoids compounds were isolated and tested on *T. brucei brucei*. Out of the tested compounds, ursolic acid (terpenoid compound) and 24-hydroperoxy-24-vinylcholesterol (a sterol) were the most active with respective IC_{50}s of 1.0 ± 0.2 and 1.4 ± 0.5 µg/mL (Hoet *et al.,* 2007). Besides, another study has also investigated the anti-trypanosomial activity of the roots of *S. spinosa* on *T. brucei brucei*. Unfortunately, in comparison to the leaves, no interesting MIC was observed *in vitro*.

In point of fact, the dichloromethane extract of the roots has a MIC of 200 µg/mL against *T brucei brucei* and consequently, no *in-vivo* study was performed on it (Aderbauer *et al.,* 2008). The test with the leaves and the roots is based on their ethnobotanical usages respectively in Mali and Benin to treat the sleeping disease (Aderbauer *et al.,* 2008). In Nigeria, the stems barks were reported to be employed to treat human trypanosomiasis and consequently, research was run to prove the barks effects on *T. brucei brucei* in the laboratory. The ethyl acetate extract of the bark was slightly active with an IC_{50} of 75.63 mg/mL (Garba *et al.,* 2018). Those results could help conclude that the leaves of *S. spinosa* might be the most promising part of the plant against *Trypanosoma* spp. It is also important to note that methods used to perform the tests were different.

In the first reported research, the Long Incubation Low Inoculation Test (LILIT) was employed and in the second one, the Long-term Viability Assay (LtVA). But there was no real difference in the two tests as the

LtVA was run similar to the LILIT with just the fact that the trypanosomes were cultivated in the presence of feeder layer bells and the time of incubation was longer. The method of the third described investigation was completely different, it is the Blood Incubation Infectivity Test, slightly modified. This test is primarily utilized to distinguish between *T. brucei brucei* and *T. brucei rhodesiense* and is based on the evaluation of parasitaemia level in the blood of infected mice (Hoet *et al.,* 2004; Bizimana *et al.,* 2006; Aderbauer *et al.,* 2008; Garba *et al.,* 2018).

Apart from *Trypanosoma* spp, *S. spinosa* was revealed to be active against parasitic nematodes (Table 2). Undeniably, the dichloromethane-methanol (1:1) and water extracts of the roots and branches of the plant was evaluated against a levamisole-resistant strain of the nematode *Caenorhabditis elegans*. Only the dichloromethane-methanol extracts were efficacious with 100% activity meaning, 100% of the nematodes in contact with the extract at 1 mg/mL were dead in comparison to the control (Waterman *et al.,* 2010). In a different work, the ethanolic extracts of the leaves and barks of the plant were assessed against the pathogenic worm *Ascaris suum* (from porcine) and their toxicity evaluated using Brine Shrimp Lethality test (BST) on *Artemia salina*. The results confirm the efficacy of the leaves with lethal concentrations ranging from 168.93 to 280.78 mg/mL after 24 h of incubation and from 52.74 to 111.94 mg/mL after 48 h (Maregesi *et al.,* 2016). Paralytic doses (doses of extracts impeaching the movement of nematodes) were also observed with concentrations of 85.56 to 228.84 mg/mL after 24 h of exposition and from 41.84 to 87.77 mg/mL after 48 h with the leaves extract and; 57.95 to 120.4 mg/mL after 48 h with the barks extract. Hence, the leaves of *S. spinosa* were the most active part of the plant. But, in comparison to *S. innocua*, the ethanolic extracts of the leaves of *S. innocua* were more efficient than the ones of *S. spinosa* with lethal doses of 88.27 to 151.79 mg/mL after 24 h of exposition and from 38.73 to 50 mg/mL after 48 h of exposition (Table 2). On the contrary, the stems barks of *S. spinosa* were also more active than the ones of *S. innocua* with paralytic doses of the last one being 68.01 to 144.9 mg/mL (Maregesi *et al.,* 2016; Table 2). Another interesting finding from those various experiments is, for *S. spinosa*, to be active against those different parasites without being toxic to normal human cells.

Apart from being active against human parasites, *S. spinosa* was also used against cattle parasites namely, cattle ticks. Indeed, an exposition of 24 to 48 h to the inner pulp of the fruit and the seeds of unripe fruit extract in the concentration of 5% (w/v: weight of the crushed part/ volume of tap water used), has acaricidal effects on the cattle's fur (Madzimure *et al.,* 2013). This activity shows the wide-range of medicinal effects of *S. spinosa* taking into consideration the fact that other germs and other diseases are also reported. Indeed, in addition to the parasites, other microbes responsible of the infectious diseases *S. spinosa* might treat are bacteria and fungi. Those antimicrobial activities have been documented by various *in-vitro* studies against mycobacteria such as *Mycobacterium spp*; fungi such as *Candida albicans*, *Aspergillus fumigatus* and bacteria such as *Staphylococcus aureus* and *Enterococcus faecalis*.

Antimicrobial activities

Tuberculosis is an infectious disease caused by the complex *Mycobacterium tuberculosis* which is composed of: *M. tuberculosis, M. bovis, M. africanum; M. microti; M. canettii ; M. caprae, M. pinnipedii* and *M. mungi*. M. *tuberculosis* is the cause of at least 99% of pulmonary tuberculosis and at least 90% of all types of tuberculosis. Consequently, to prove the ethnobotanical use of *S. spinosa* to cure the disease, the plant extracts were assessed on *Mycobacterium tuberculosis* (Ballo, 2013; Novotna *et al.,* 2020; Table 2). The dichloromethane extract of roots' barks has a MIC of 125 µg/mL against *Mycobacterium tuberculosis* (Ballo, 2013). Apart from the precedent bacterium, *S. spinosa* is also efficient against other types of bacteria. For instance, to check the use of the plant against stomach-aches and colic, the plant extracts were evaluated on *Escherichia coli*, *Pseudomonas aeruginosa* and *Staphylococcus aureus*. The MICs obtained with the ethanolic, methanolic and aqueous extracts on the two germs were varying from 125 to 500 mg/mL. Unfortunately, obtained MICs, ranging from 125 to 500 mg/mL were not interesting (Ugoh and Bejide, 2013; Avakoudjo *et al.,* 2019; Chinsembu *et al.,* 2019; Tables 1 and 2). In point of fact, MICs of plants extracts are classified to be valuable if MIC $\leq$ 0.1 mg/mL, moderate if 0.1 mg/mL $<$ MIC $\leq$ 0.625 mg/mL and weak if the MIC $>$ 0.625 mg/mL (Kuete, 2010). In opposite to the precedent research, another study on the antibacterial activities of *S. spinosa* extracts against *Bacillus cereus* (ATCC 14579), *Staphylococcus aureus* (ATCC 29213), *Enterococcus faecalis* (ATCC 29212) and *Escherichia coli* (ATCC 25922), has revealed moderate to valuable activities. In the study, the acetone, methanol, dichloromethane/methanol and alkaloids extracts of the leaves were active against the mentioned germs with MICs varying from 0.16 to 1.25 mg/mL. The acetone extract was the most active with the lowest MIC at 0.16 mg/mL against *Enterococcus faecalis* and *Staphylococcus aureus*. Hence, the extract was subjected to fractionation to yield the n-hexane, chloroform, ethyl acetate, butan-1-ol and water fractions. The most potent fraction was the hexane one with MIC at 0.08 mg/mL against *Staphylococcus aureus* and *Escherichia coli* (Isa *et al.,* 2014). The difference observed in the activity of the leaves against *Escherichia coli* in the two aforementioned experiments could be explained by the variation in the place of harvest of the plant, in the solvents of extraction and the method of antibacterial testing (Ugoh and Bejide 2013; Isa *et al.,* 2014). Indeed, the antibacterial activity was evaluated in the first study using the agar well diffusion and macro broth dilution methods which are less sensitive and specific than the broth serial microdilution method used in the second research. By using those methods, if in the first work, no significant anti-fungal activity was found with *S. spinosa*, the second research unveiled interesting antifungal activities against *Candida albicans* (animal isolate), *Cryptococcus neoformans* (animal isolate), *Candida albicans* (ATCC 10231) and *Aspergillus fumigatus* (animal isolate) (Ugoh and Bejide 2013; Isa *et al.,* 2014; Table 2). The most interesting antifungal activities with the extracts were observed against *Aspergillus fumigatus* and *Cryptococcus neoformans* with the best activity being the one of the dichloromethane/methanol extract against *Cryptococcus neoformans* at 0.16 mg/mL. The fractions were active against all fungi except for the butanol and water fractions which were active only on *Cryptococcus neoformans* and *Aspergillus fumigatus*. Surprisingly, the lowest antifungal MIC was observed with the butanol fraction against *Cryptococcus neoformans* at 0.04 mg/mL (Isa *et al.,* 2014). An additional testing of *S. spinosa* leaves against fungi namely *Candida albicans* (ATCC 13803), *Candida albicans* (clinical isolates), *Cryptococcus neoformans* (ATCC 90112) and *Aspergillus niger* (AZN 8240) was performed in Tanzania. Using the micro-dilution method, observations help conclude the ethanol, dichloromethane and petroleum ether extracts to have MICs of 0.313 to 1.25 mg/mL. The dichloromethane was the most active extract with MICs of 0.313 mg/mL, 0.313 mg/mL, 0.469 mg/mL and 0.313 mg/mL respectively against *Candida albicans* (ATCC 13803), *Candida albicans* (clinical isolate), *Cryptococcus neoformans* (ATCC 90112) and *Aspergillus niger* (AZN 8240) (Mbunde *et al.,* 2019).

The activities reported in those different research works are very close to the ones revealed in a different analysis on *S. spinosa* fruits from South Africa. MICs of the dicloromethane-methanol extract of the fruits against various Gram positive, Gram negative, fungi and dermatophytes have shown MICs varying from 40 to 4000 µg/mL (Table 2; Nciki *et al.,* 2016). The most interesting activity was observed against *Brevibacterium agri* (ATCC 51663), *Staphylococcus epidermidis* (ATCC 2223), *Tricophyton mentagrophytes* ATCC 9533, *Pseudomonas aeruginosa* ATCC 27853 and *Candida albicans* (ATCC 10231), respectively, at 40 µg/mL, 250 µg/mL, 250 µg/mL and 500 µg/mL. In contrast to the earlier mentioned research where leaves were not efficient against *Candida albicans*, the fruits of *Strychnos spinosa* were potent against this yeast in the present study with a MIC at 500 µg/mL. Besides, when comparing the activity against *Staphylococcus* spp., when the leaves were very active against *Staphylococcus aureus*, the fruits were oppositely not efficient, with MICs at 4000 µg/mL, 2000 µg/mL and 4000 µg/mL accordingly against gentamycin and methicillin-resistant *Staphylococcus aureus* (GMRSA) ATCC 33592, methicillin-resistant *Staphylococcus aureus* (MRSA) ATCC 43300 and *Staphylococcus aureus* ATCC 25925 (Nciki *et al.,* 2016; Table 2). In general, when comparing the antimicrobial activities of *Strychnos spinosa* leaves with that of another *Strychnos* species namely *S. madagascariensis,* on the same germs, it is noticeable that the dichloromethane-methanol leaves of *S. spinosa* were more active than the ones of *S. madagascariensis* whose obtained MICs were belonging to the interval [130 - 4000 µg/mL]. However, it is worthy pointing the fact that *S. madagascariensis* leaves were more efficient against *Pseudomonas aeruginosa* ATCC 27853, *Tricophyton mentagrophytes* ATCC 9533, *Microsporum canis* ATCC 36299 and *Candida albicans* (ATCC 10231) with according MICs of 250, 130, 1000, and 250 µg/mL where *S. spinosa* leaves had respectively MICs of 500, 250, 500 and 500 µg/mL. The reviewed antimicrobial activities are due to the capacity of the plant extracts and their compounds to disrupt membranes of bacteria and fungi, modifying the flux happening through their membranes in and out their cells and leading to their immobility and or death (Tittikpina *et al.,* 2019a).

When anti-infectious diseases activities seem to be the most important part of the medicinal activities of *S. spinosa*, other medicinal properties such as anti-inflammatory, anti-oxidant, inhibition of α-glucosidase enzyme and inhibition of hyaluronidase and phospholipase activities have also been investigated pharmacologically. Those properties are in relation with the ethnomedicinal uses of the plant in case of painful periods, swelling of foot, foot crevice, diabetes and snake bite (Karou *et al.,* 2011; Molander *et al.,* 2014; Avakoudjo *et al.,* 2019; Novotna *et al.,* 2020).

Anti-inflammatory, antioxidant and other activities

Strychnos spinosa was investigated for the anti-inflammatory role of acetone, methanol and dichloromethane-methanol extracts of its leaves (harvested in Nigeria) by using a COX-inhibitor screening kit Cayman (MI, USA) to investigate its inhibition effects on the pro-inflammatory enzymes COX-1 and COX-2. The methanol and dichloromethane extracts selectively inhibited COX-2 with IC_{50} ranging from 14.47 to 15.51 pg/mL. The acetone extract did not inhibit neither COX-1 or COX-2 but the fractions coming from its liquid partition with other solvents were active on COX-1. Indeed, the butanol, hexane and water fractions present IC_{50}s corresponding respectively to 14.66, 15.25 and 14.93 pg/mL against COX-1 (Isa *et al.,* 2018). Concerning their role in inflammation, when COX-1 is constitutive of the cell and is produced under all physiological conditions, COX-2 is not constitutive of the cell and its production is induced by inflammatory stimuli. Hence COX-2 is the target of pro-inflammatory drugs (Choi *et al.,* 2009; Table 2). Consequently, a prospective anti-inflammatory drug out of *S. spinosa* leaves should consider its dichlormethane and methanol extracts and make sure it does not inhibits COX-1 which is also implied in the protection of stomach and intestinal lining (fight against stomach acidity and ulcers). Besides, the anti-inflammatory activity of roots' barks (harvested in South Africa) acetone extract against 15-lipoxygenase (15-LOX), xanthine oxidase (XO) and inducible nitric oxide (NO) production in lipopolysaccharide (LPS) stimulated RAW264.7 macrophage cells, has also been investigated (Lawal *et al.,* 2019). It has shown the extract to show no significant inhibition of 15-lipoxygenase (15-LOX) and xanthine oxidase (XO). However, an interesting result was obtained on the inhibition of inducible nitric oxide (NO) production in lipopolysaccharide (LPS) stimulated RAW264.7 macrophage cells with an IC_{50} at 41.4 ± 7.3 µg/mL. The inhibition of nitric oxide is of interest in case of inflammation because this enzyme gives an anti-inflammatory response under physiological conditions which, under abnormal situation, could be unusually high (Sharma *et al.,* 2007; Lawal *et al.,* 2019; Table 2). Those results justify the use of roots to treat swelling of the foot, aches, hypertension and related disease (Avakoudjo *et al.,* 2019; Novotna *et al.,* 2020). As anti-inflammatory activities are closely related to anti-oxidant ones, the preceding research has also investigated the anti-oxidant activity of the same extract through the determination of the free radical and nitric oxide scavenging capacity by using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) and nitric oxide inhibition assays. No significant anti-oxidant activity was revealed as the IC_{50}s obtained were respectively greater than 167 µg/mL and 700 µg/mL (Lawal *et al.,* 2019; Table 2). In contrast, a different study by assessing the anti-oxidant effects of leaves (harvested in Nigeria) extracts and fractions, found good results. The method used was the same as in the precedent research but was based only on the determination of the free radical scavenging capacity by using the 1,1-diphenyl-2-picrylhydrazyl (DPPH) and 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonique acid (ABTS).

All the extracts and fractions were active with IC_{50}s ranging from 33.66 to 249.82 µg/mL. The methanol extract presented the best activity with IC_{50}s of 36.56 µg/mL and 62.74 µg/mL respectively with DPPH and ABTS. And, the most active fraction was the water fraction with respectively IC_{50}s of 33.66 µg/mL and 65.2 µg/mL. All those anti-oxidant activities were higher and least appealing than that of common antioxidant, ascorbic acid (4.65 and 2.26 µg/mL) and Trolox (9.71 and 16.46 µg/mL) (Isa *et al.,* 2014). Finally, apart from anti-inflammatory and anti-oxidant activities, *S. spinosa* was also researched for its anti-diabetic and anti-snake bite activities. Antidiabetic properties were studied by investigating the inhibition effects of the leaves aqueous ethanol (70%) extract against an isolated digestive enzyme (showed α- glucosidase) linked to type 2 diabetes mellitus. The treatment of snake bite was investigated by the inhibition effect on hyaluronidase, phospholipase A2 and protease coming from two types of snakes (*Bitis arietans* and *Naja nigricollis*) of the water and ethanol extracts of the cortex and radix (Molander *et al.,* 2014; Adinortey *et al.,* 2018). An interesting inhibition potential of α-glucosidase was realized at an IC_{50} of 129.4±0.094 µg/mL (more interesting in comparison to acarbose, a reference antidiabetic 196.9±0.036 µg/mL). This activity needs further and deeper investigation especially *in-vivo* ones to establish the complete antidiabetic potential of the plant (Aditorney *et al.,* 2018). Concerning the use to treat snake bite, the most significant activity was observed with the ethanol extract of the radix which inhibited the hyaluronidase of *Naja nigricollis* at 29% only at a concentration of 5 mg/mL. At the same concentration, all the other extracts on the other targets had a percentage of inhibition comprised between -11 (no inhibition at all) and 15. This result does not confirm the use of the plant to treat snake bite and is very far from the one obtained with the aqueous extract of the folium of *Strychnos innocua* Delile which had 102% and 109% of inhibition respectively on the hyaluronidase of *Bitis arietans* and *Naja nigricollis* (Molander *et al.,* 2014; Table 2).

Table 2: Biological/pharmacological activities of extracts from *Strychnos spinosa* Lam. parts. µg/mL: micrograms per milliliters; mg/mL: milligrames per milliliters; MIC: Minimal Inhibition Concentration, IC_{50} : Concentration that inhibits 50% of activity.

Organ	**Pharmacological / biological activity**	**References**
Stem and bough	Anti-plasmodial activity (no activity)	Philippe *et al.,* (2005).
Leaves	Anti-plasmodial activity: against chloroquine sensitive strain of *Plasmodium falciparum* (IC_{50}: 15.6±3.8 µg/mL) and chloroquine resistant strain of *Plasmodium falciparum* (IC_{50}: 8.9±2.1)	Bero *et al.,* (2009).
Branch	100% activity (100% of dead in comparison to the control) against a levamisole-resistant strain of the nematode *Caenorhabditis elegans*.	Waterman *et al.,* (2010).
Root	100% activity (100% of dead in comparison to the control) against a levamisole-resistant strain of the nematode *Caenorhabditis elegans*.	Waterman *et al.,* (2010).
Leaves and barks	*Ascaris suum goeze* (pathogenic worm) lethal doses ranging from 168.93 to 280.78 mg/mL after 24h and from 52.74 to 111.94 mg/mL after 48h.	Maregesi *et al.,* (2016).
Inner pulp of the fruit and the seeds of unripe fruit	Acaricidal effects on cattle ticks after a 24 to 48h of exposition to fruit extract in the concentration of 5% (w/v: weight of the crushed part/ volume of tap water used).	Madzimure *et al.,* (2013)
Leaves	Extracts: *Trypanosoma brucei brucei* (IC_{50}): 1.5 ± 0.9 µg/mL *Trypanosoma brucei rhodesiense* (IC_{50}): 16.4 ± 8.8 µg/mL. *Leishmania mexicana mexicana* (MIC): 56-167 µg/ml. Compounds: Ursolic acid (IC_{50}): 1.0 ± 0.2 µg/mL . 24-hydroperoxy-24-vinylcholesterol (IC_{50}): 1.4 ± 0.5 µg/mL.	Hoet *et al.,* (2004); Hoet *et al.,* (2007).
Roots	Anti-trypanosomial activity: MIC=200 µg/mL against *Trypanosoma brucei brucei*.	Aderbauer *et al.,* (2008)
Stem bark	IC_{50} of 75.63 mg/mL on *Trypanosoma brucei brucei*.	Garba *et al.,* (2018).
Leaves	MICs against fungi (*Candida albicans*, *Aspergillus fumigatus*, *Cryptococcus neoformans*) and bacteria (*Staphylococcus aureus*, *Enterococcus faecalis*, *Escherichia coli*) from 0.16 mg/mL to 1.25 mg/mL for extracts and from 0.04 to 1.25 mg/mL for fractions.	Isa *et al.,* (2014).

Fruits	MICs against *Staphylococcus aureus* ATCC 25925, methicillin-resistant *Staphylococcus aureus* (MRSA) ATCC 43300, gentamycin and methicillin-resistant *S. aureus* (GMRSA) ATCC 33592, *S. epidermidis* ATCC 2223, *Propionibacterium acnes* ATCC 11827, *Brevibacterium agri* ATCC 51663 and *B. linens* DSM 20425, *Pseudomonas aeruginosa* ATCC 27853, *Escherichia coli* ATCC 25922, *Tricophyton mentagrophytes* ATCC 9533, *Microsporum canis* ATCC 36299 and *Candida albicans* (ATCC 10231) varying from 40 to 4000 mg/mL.	Nciki *et al.,* (2016).
Leaves	Antifungal activity with MICS from 0.313 to 2.5 mg/mL; 0.313 to 2.5 mg/mL; 0;469 to 1.25 mg/mL and 0.313 to 3.75 mg/mL respectively on *Candida albicans* clinical, *Candida albicans* ATCC13803, *Candida neoformans* ATCC 90112, *Aspergillus niger* AZ 8240.	Mbunde *et al.,* (2019).
Roots barks	MIC: 125 µg/mL against *Mycobacterium tuberculosis*.	Ballo (2013).
Leaves, stem barks	Antimicrobial activity against *Escherichia coli* and *Pseudomonas aeruginosa* with MICs ranging from 125 to 500 mg/mL.	Ugoh and Bejide (2013).
Leaves	Inhibition of α-glucosidase enzyme (whose inhibition has been reported as a novel strategy to delay the absorption of glucose after meals) with inhibition of 79% with IC_{50} of 129.4±0.094 µg/mL.	Adinortey (2018).
Leaves	Anti-oxidant activity was evaluated using DPPH and ABTS radical scavenging activity with IC_{50} from 33.66 µg/mL to 314.30 µg/mL.	Isa *et al.,* (2014).
Root bark	Anti-oxidant activity of the acetone extract: DPPH assay (>167); NO scavenging (>500)	Lawal *et al.,* (2019).
Root bark	Anti-inflammatory activities of the acetone extract: 15-LOX inhibition (>83); XO inhibition (>167); IC_{50} value in µg/mL of inhibition of NO in RAW 264.7 cells (41.4 ± 7.3).	Lawal *et al.,* (2019).
Leaves	Anti-inflammatory activity was evaluated by the inhibition of COX enzymes activity, IC_{50} obtained was ranging from 14.7 pg/mL to 15.51 pg/mL.	Isa *et al.,* (2018).
Radix and cortex	Inhibition of hyaluronidase and phospholipase A2 ranging: 3 to 6%	Molander *et al.,* (2014).

Phytochemistry

Alkaloids are the predominant compounds of the *Strychnos* species. Some of these alkaloids present interesting pharmacological potentialities and have allowed the development of hemi-synthetic derivatives that were used in anaesthesiology, for example, the bisindoles bisammoniums of the alkuronium type. Formerly, many of the plant species were used as arrow poisons in the Indo-Malaysia region or test poisons in Africa. In Africa, various works have given information on more than 170 alkaloids present in the 75 species of the genus *Strychnos*, belonging to the sub-Saharan African region (Ohiri *et al.,* 1983). Most of the species are undocumented in regards to their phytochemistry and it is unfortunately the case of *S. spinosa*. However, some terpenoid alkaloids have been deciphered in leaves and stems barks of this plant using spectroscopic means namely nuclear magnetic resonance (NMR) and mass spectrometry combined with extraction and various liquid chromatographic techniques to isolate pure compounds: akagerine, 10-hydroxy-akagerine, kribine, 11-methoxy-diaboline (Ohiri *et al.,* 1983). Using the same means, other types of terpenes have also been found in the fruits and leaves: stryspinolactone (monoterpen secoiridoid), kingiside aglycone, α-amyrin, β-amyrin, uvaol, lupeol, erythrodiol, ursolic acid (pentacyclic triterpens) (Adesogan and Morah, 1981; Msonthi *et al.,* 1985; Morah, 1993; Hoet *et al.,* 2007; Figures 1 and 2). Concerning secoiridoids, NMR and mass spectrometry led to detect in the plant branches, three new secoiridoid glucosides namely stryspinoside, strychoside A and strychoside B alongside other compounds such as: loganin, secologanin, sweroside, secoxyloganin, secologanin, dimethyl acetal, secologanoside, secologanoside 7-methyl ester, secologanoside dimethyl ester, secologanic acid, vogeloside, 14 epi-vogeloside, 14 (5S)-5-carboxystrictosidine, astragalin and nicotiflorin (Itoh *et al.,* 2005, Figures 1 and 2). Besides, using Gas Chromatography coupled to Flame-Ionization-Detection (GC-FID) and to mass spectrometry (GC-MS) after the regular extraction and liquid-liquid fractionation, some compounds mainly terpenes and fatty acids such as linalool, geraniol, terpineol, nerolidol, palmitic acid and isopropyl myristate, have also been detected in the essential oils coming from the leaves (Hoet *et al.,* 2006; Figures 1 and 2). Furthermore, using NMR and mass spectrometry, phytosterols have also been unveiled in fruits: clerosterol, β-sitosterol, stigmastanol, stigmasterol and saringosterol (Morah, 1993; Hoet *et al.,* 2007 ; Ibrahim *et al.,* 2014; Figures 1 and 2). Finally, a saponin (Triploside A) and a lignan (Lirioresinol B) were also identified in the branches (Adesogan and Morah, 1981; Itoh *et al.,* 2005). The main compounds unveiled in *S. spinosa* are terpenes (more than 60%), followed by sterols, fatty acids and flavonoids. It could explain the fact that compounds such as nonacosane and nonaconasol which are terpenes precursors have also been unveiled in some extracts. The chemical composition of *S. spinosa* also explains, the predominant activity of non-polar extracts on biological and pharmacological targets. Indeed as reported in the precedent lines, hexane, dichloromethane, mixture of dichloromethane and methanol were most of the time the type of extracts which exhibited interesting biological and or pharmacological activities.

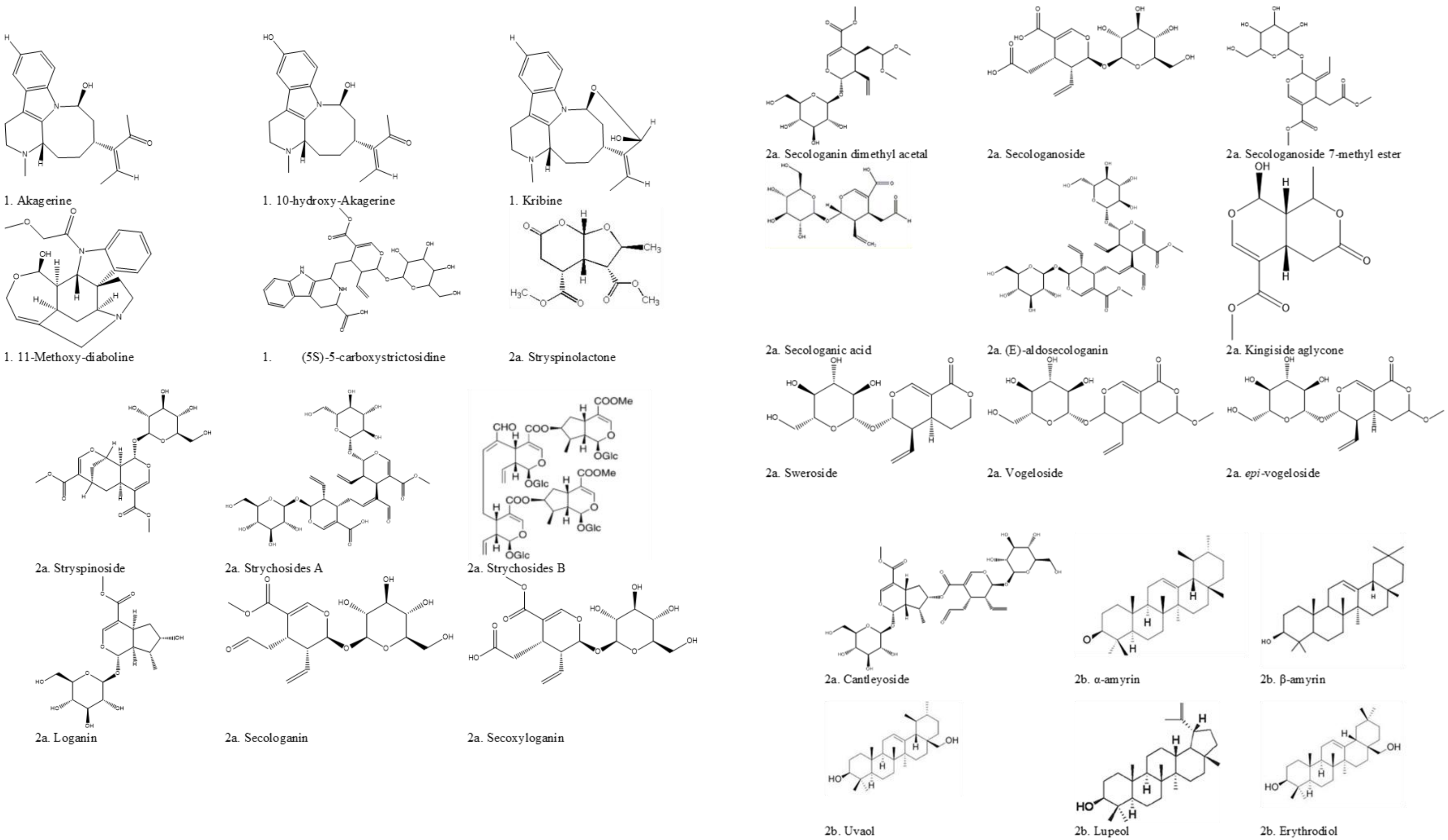
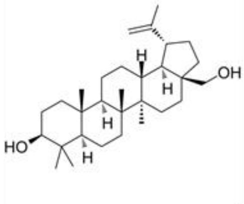
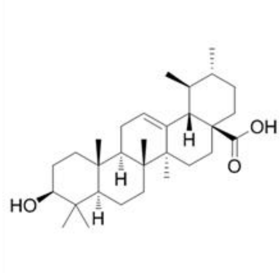


Figure 1: Chemical compounds identified in *Strychnos spinosa* leaves, stems barks, fruits and branches (Part 1).

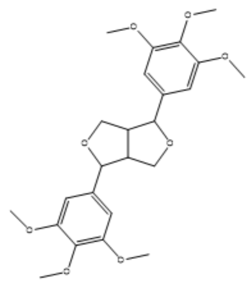
1. Terpenoid alkaloids, 2a: monoterpenes, 2b: pentacycliques triterpenes.



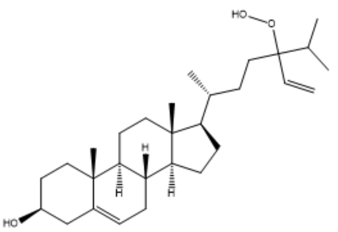
2b. Betulin



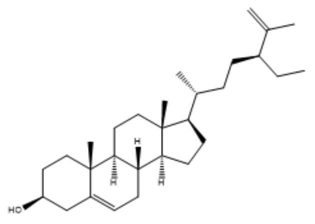
2b. Ursolic acid



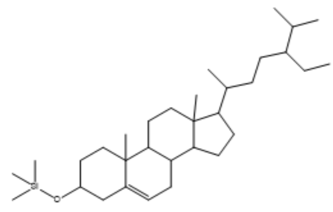
3. Lirioresinol B



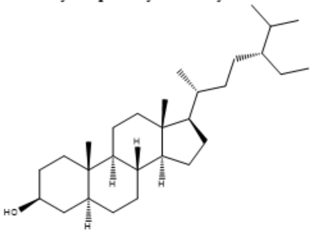
4. 24-hydroperoxy-24-vinylcholesterol



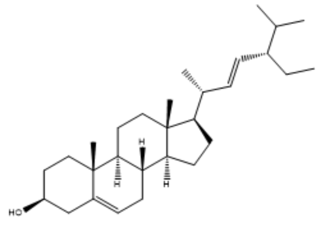
4. Clerosterol



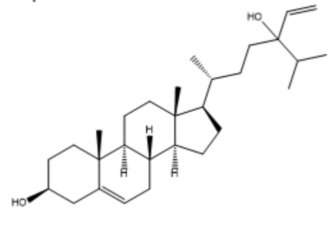
4. β-sitosterol



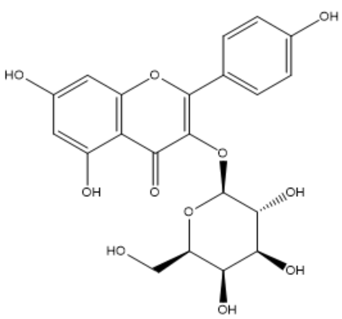
4. Stigmastanol



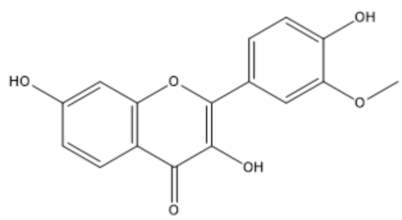
4. Stigmasterol



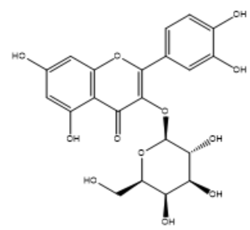
4. Saringosterol



5. Trifolin



5. Geraldol



5. Hyperin

Figure 2: Chemical compounds identified in *Strychnos spinosa* leaves, stems barks, fruits and branches (Part 2).
2b: Pentacyclic triterpenes, 3. Lignan, 4. Sterols, 5. Flavonoids.

Uses as food and nutritional values

Strychnos spinosa is a spontaneous plant used in alimentation in many African countries including Togo. In this country, the plant is one of the most threatened food plants used by ethno-cultural groups (Akpavi *et al.,* 2011). In general, in Togo and various African countries, fruits are the main part used as food (Folega *et al.,* 2011). For example, in South Africa, the fruits are consumed by various ethnic groups. Besides, fruits are processed to make jam, jelly and other products and, are presented to be one product with a potential to be developed into new food or beverage products with high nutritional values in South Africa and Zimbabwe (Van Wyk, 2011; Ngadze *et al.,* 2017; Nitcheu Ngemakwe *et al.,* 2017; Mashile *et al.,* 2019). This situation is the same in some countries like Nigeria and Botswana where fruits are, in addition, used to fight famine in rural areas and are presented to be a good candidate for introduction in the crop systems. In other areas, the plant is not only used for food but also for various purposes ranging from medical to commercial ones (Lockett *et al.,* 2000; Legwaila *et al.,* 2011). For example, in Burkina Faso, the plant is used for its edible fruits, vegetable sauce (made out of its leaves), construction and firewood (with its stems and branches), medicine, commerce (fruits, leaves, trunk), field trees and conservation (Metus and Lykke, 2003; Guissou *et al.,* 2015). The reason behind the plant's fruit consumption is their nutritional values. In point of fact, the fruits are rich in carbohydrates including sugars, fats, proteins, vitamins, fibres and are also a valuable source of energy. For example, the amount of fibres belongs to the ranges 16 to 24% (Table 3). In comparison to the daily recommended intake for adults which is 25 g to 30 g per day, the consumption of a fruit (weighing 145-383 g) could provide the amount more than needed to meet daily needs. With minerals and vitamins, the objective of meeting the daily intake could also be attained with manganese (Mn, daily recommended intake for adults and elderly respectively: 2.5 to 2.8 mg and 1.8 to 2.3 mg); magnesium (Mg, daily recommended intake for adults and elderly respectively: 360-420 mg and 320-350 mg) and vitamin C (daily recommended intake for adults and elderly respectively: 75 – 90 mg and 45 mg) (Table 3; Saka and Msonthi, 1994; Lockett *et al.,* 2000; Amarteifeio and Mosase 2006; Tittikpina *et al.,* 2019b). Besides, the fruits could be used to supplement the intake of proteins, carbohydrates and types of minerals such as phosphorus (P), calcium (Ca), iron (Fe), potassium (K), sodium (Na), copper (Cu) and zinc (Zn) by other foods in the alimentation of adults and children (Lockett *et al.,* 2000; Sitrit *et al.,* 2003; Legwaila *et al.,* 2011; Guissou *et al.,* 2015; Table 3). Three types of sugars are present in fruits: fructose, sucrose and glucose. Their concentration varies respectively from 44 to 86 mg/g; 15.3 à 27.9 mg/g and 2.5 à 14.5 mg/g. This variation is influenced by the ripeness of fruits and the age of the trees bearing them. The level of citric, malic and succinic acids also varies accordingly and respectively from 9.6 to 13.5 mg/g, from 5.4 to 11.1 mg/g and 0 to 2.9 mg/g (Sitrit *et al.,* 2003; Table 3). The fruits of *S. spinosa* are valuable for the people using them not only for its nutritional values but also, for the profit they could make by turning them into various processed foods. Consequently, *S. spinosa* could help fight malnutrition, famine in African countries especially rural areas and, increase the quality of life of farmers by providing them with an additional source of revenue.

Table 3: Nutritional values of *Strychnos spinosa* Lam fruits % : percentage (100g of fruit) ; P: phosphorus, Ca: calcium, Mg: Magnesium, Fe : Iron, K : potassium, Na : sodium, Cu: copper, Mn: Manganese, Zn : zinc ; Vit C : vitamin C; -: Not available.

References	Dry matter (%)	Ash (%)	Crude protein (%)	Fat (%)	Fibre (%)	Total carbohydrate (%)	Energy value (kJ/100 g)	Minerals (µg/g)									vitamins
								P	Ca	Mg	Fe	K	Na	Cu	Mn	Zn	Vit C
Saka and Msonthi (1994)	22.1	4.1	5.4	31.2	17.6	42.1	1923	1081	149	430	136	19683	253	-	-	-	-
Lockett et al. (2000)	10.77	2.58	11.7	1.94	23.96	59.82	-	1680	1300	1410	43.9	-	-	2.4	27.4	10.8	-
Amarteifeio and Mosase (2006)	19.7	4.6	3.3	-	16.7	-	-	660	560	490	1.1	1370	21.7	-	-	2.2	880

Conclusion

The results of several studies have shown that *S. spinosa* is an important medicinal plant, with many bioactive constituents. The plant has shown a wide range of biological properties and proved *in vitro* to be effective in the treatment of various illnesses such as microbial and parasitic infections, hypertension, diabetes mellitus, snakebite, and inflammatory diseases. Besides, the data reported confirmed that *S. spinosa*, namely its fruits is a rich source of important nutrients that can be beneficial to human health. The presence of carbohydrates, sugars and minerals in the plant shows the high energy content that could be utilized as a source of crude materials for pharmaceutical and nutraceutical industries. Because of its multiple compounds and pharmacological properties, it is necessary to conduct further studies to justify other ethnomedicinal uses not yet studied like diarrhoea, female sexual disorders, infertility and stimulation of lactation, and also revealed other unknown useful properties of this plant. Literature review observed that no toxicity and clinical trials have been performed so far. Therefore, the new challenge is the investigation for the therapeutic potentials *in vivo* and the safety of this plant, and clinical trials on the isolated molecules, considering the lack of published data in these aspects.

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