International Journal of Community Research http://www.arpjournals.com
ISSN: 2315 – 6562 **E-ISSN: 2384 - 6828**

CLASSIFICATION, CHEMICAL COMPOSITION AND THERAPEUTIC PROPERTIES OF TERMITE SPECIES- A REVIEW

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ABSTRACT

Constituents from plants, microorganisms and marine species have since long been recognized as important sources of bioactive substances. This has led to the development of a large variety of drugs to treat human diseases such as, among others, a number of antimalarial, anti-cancer, hypoglycemic, cardiovascular, antibiotic, and antineoplastic agents and also holding to their traditional uses. More recently, about 3,106 living and fossil termite species were recognized and classified into 12 families and the amazing biodiversity represented by the myriad of these termites and other insect species has been realized to produce an equally exceptional source of bioactive chemicals with therapeutic potential. Many of these chemical compositions serve as highly effective defensive and predatory chemicals which some of these chemicals possess meaningful pharmacological properties; they represent interesting candidates for new drug discovery and development programs. A few examples are chemical composition with, antibacterial, antifungal, antiviral, cytotoxicity, antigenotoxic or anti-ulcer qualities. This paper is a compilation of the chemical composition of some Termite species assessing its therapeutic properties.

Keywords: Constituents, Termites, Therapeutic potential, Pharmacological properties

Published: 31st July, 2017

INTRODUCTION

Members of the class Insecta are important sources of food and medicine to many animal species including man (DeFoliat, 1992; Adedire and Aiyesanmi, 1992) and are known to constitute more than 76% of the animal kingdom (Yoloye, 1988). Today, approximately 80% of the human population living in developing countries still relies on important part of naturally derived substances, particularly plants with medicinal properties, for its day-to-day health care (Farnsworth, 1984; Cox, 1994). The remaining 20% of individuals in the industrialized parts of the world uses in 25% of cases drugs that have been directly derived from natural products (Farnsworth, 1984; Cox, 1994).

A myriad of breakthrough therapeutics has been developed by following up naturally-derived leads with medicinal properties, not only from plants but also from microorganisms and marine species (Mans, 2016). A few examples are the cardiac glycoside digoxin from the foxglove *Digitalis lantana* L. (Scrophulariaceae) for treating certain heart conditions (Breckenridge, 2006); the muscle relaxant D-tubocurarine derived from the Amazon plants *Strychnos toxifera* L. (Loganiaceae) and *Chondrodendron tomentosum* L. (Menispermaceae) (Bowman, 2006); the antileukemic and antitumor taxol from *Taxus brevifolia* (Mansukhlal *et al*., 1971); the antimalarial artemisinin from *Artemisia annua* (Keat *et al*. 2006); the antibiotic penicillin from the fungus *Penicillium chrysogenum* Thom, 1910 (Trichocomaceae) (Demain and Elander, 1999); the powerful pain killer ziconotide molded on the basis of conotoxin in the venom of the cone snails *Conus geographicus* Linnaeus, 1758, and *Conus magus* Linnaeus, 1758 (Conidae) (McGivern, 2007); and the novel antineoplastic agent trabectedin (Yondelis) originally isolated from the Caribbean sea squirt *Ecteinascidia turbinata* Herdman, 1880 (Perophoridae) (Fayette *et al*., 2005).

However, when compared to plants and marine species, the animal kingdom, particularly the class of the insects (Insecta) represents at least a similar abundance of bioactive compounds with potentially useful therapeutic properties and thus making the use of insects as medicine and food an upsurge of interest (Srivastava *et al*., 2013) and have played a significant role in therapeutic practices (Alvez and Rosa, 2006; Alvez *et al*., 2007; Ferreira *et al*., 2009). The ancient Mayan, Egyptian and Brazilian societies have long since understood the powerful biochemical properties of common insects. In Korea and China, insects of medicinal importance were of significant attraction. Medicinal insects from Australia, Germany, and Mexico and in Native American Indian tribes are also recorded in literatures (Mans *et al*., 2016). Launet (1993) reported traditional medicines as a source of drugs of model medical science.

Important groups of insect chemicals are pheromones and allelochemicals which are signals to pass on information on, for example, impending threats and new food sources (Laurent, 2005; Blum, 1981). Pheromones, for instance, carry information from one individual to (an) other members of the same species and include, among others, sex attractants, intraspecific aggregation signals, alarm substances and trail-marking compounds (Laurent, 2005; Blum, 1981). Allelochemicals on the other hand, travel from one insect to (a) member(s) of (a) different species and include, for instance, defensive signals such as repellents and toxins as well as compounds to locate suitable host plants (Laurent, 2005; Blum, 1981). Many species of insects synthesize their own chemicals, but others derive these substances from the plants they feed on and some of these chemicals after being isolated and identified include alkaloids, bufadienolides, cantharidins, cyanides and cardenolides which are powerful defensive poisons that can restrict movement of attackers (Laurent, 2005; Blum, 1981).

In light of their effectiveness as warning signals and anti-predator defenses, the meaningful pharmacological properties of certain insect chemicals are beneficial against human diseases (Sahayaraj, 2006). Apitoxins such as melittin cause inflammation after bee stings, but these compounds and some of their analogues have been reported to induce immunomodulatory, cytotoxic, and apoptotic effects in various preclinical models (Oršolić, 2012). And cantharidin, the defensive chemical from blister beetles, may represent the lead compound of a promising new class of antineoplastic agents (Ghoneim, 2014). These and many more examples underscore the pharmacological diversity of insect-derived bioactive substances and their potential therapeutic usefulness.

Little is known about how to realize the full potential of insects as a food produce, particularly the edible insect species gathered in rural communities (DeFollart 1992) and developing countries like Nigeria, as their therapeutic values are often neglected. Among such insects are Termites (Isoptera). Termites are among the most successful groups of insects on Earth, colonizing most landmasses except Antarctica. Their colonies range in size from a few hundred individuals to enormous societies with several million individuals. Termites divide labor among castes consisting of sterile male and female "workers" and soldiers". All colonies have fertile males called "Kings" and one or more fertile females called "queens". They feed mostly on dead plant materials and cellulose, generally in the form of wood, leaf litter, soil, or animal dung. They are major detritivores, particularly in the subtropical and tropical regions and their recycling of wood and plant matter is of considerable ecological importance. Each individual termite goes through incomplete metamorphosis that proceeds through egg, nymph and adult stages. Colonies are described as super organisms because the termites form part of a self-regulating entity (Bignell *et al.*, 2010). They are a delicacy in the diet of some human cultures and are used in many traditional medicines. Several hundred species are economically significant as pests that can cause serious damage to buildings, crops, or plantation forests.

CLASSIFICATION OF TERMITE SPECIES

Termites were once classified in a separate order from cockroaches but recent phylogenetic studies indicate that they evolved from close ancestors of cockroaches during the Jurassic or Triassic.

However, the first termites possibly emerged during the Permian or even the carboniferous. As of 2013, about 3,106 living and fossil termite species are recognized and classified into 12 families. The infra order Isoptera is divided into the following clade and family groups, showing the subfamilies in their respective classification (Krishna *et al*., 2013) as shown in Table 1.0.
Information about classification, chemical composition and therapeutic properties of Termites species is segregated and not presented in well documented form. In the present review, information has been compiled with the aim of reporting the chemical composition of the Termites species assessing its therapeutic properties.

MATERIALS AND METHODS

In the present review, information about Insects, Termite species and its classification, chemical composition and therapeutic properties was gathered via searching scientific databases including PubMed, Elsevier, Google Scholar, Springer etc. and other related books either online or offline.

CHEMICAL COMPOSITION AND THERAPEUTIC PROPERTIES:

Termites and the substances extracted from them have been used as medicinal resources by human cultures all over the world. Termite products have a

Table 1A: The Termite species divided into the following clade and family groups, showing the subfamilies in their respective classification (Krishna *et al*., 2013)

S/No.	Hierarchy	-	Examples
1.0	Kingdom	Animalia	animals
2.0	Phylum	Arthropoda	Arthropods
3.0	Subphylum	Hexapoda	-
4.0	Class	Insecta	Insects
5.0	Order	Blattodea	-
6.0	Infraorder	Isoptera	-
7.1	Family	Cratomastotermitidae	*Cratomastotermes wolfschwenningeri*
7.2	Family	Mastotermitidae	*Mastotermes darwiniensis*
	Parvorder	Euisoptera	-
7.3	Family	Termopsidae	*Termopsis bremii*
7.4	Family	Archotermopsidae	*Archotermopsis wroughtoni*
7.5	Family	Hodotermitidae	*Microhodotermes viator*
7.6	Family	Stolotermitidae	
7.6.1	Subfamily	Stolotermitinae	*Stolotermes brunneicornis*
7.6.2	Subfamily	Porotermitinae	*Porotermes adamsoni*
7.7	Family	Kalotermitidae	*Kalotermes flavicollis*
	Nanorder	Neoisoptera	-

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Table 1B: The Termite species divided into the following clade and family groups, showing the subfamilies in their respective classification (Krishna *et al*., 2013)

7.8	Family	Archeorhinotermitidae	*Archeorhinotermes rossi*
7.9	Family	Stylotermitidae	*Stylotermes fletcheri*
7.10	Family	Rhinotermitidae	
7.10.1	Subfamily	Coptotermitinae	*Coptotermes formosanus*
7.10.2	Subfamily	Heterotermitinae	*Heterotermes platycephalus*
7.10.3	Subfamily	Prorhinoterminae	*Prorhinotermes spp*
7.10.4	Subfamily	Psammotermitinae	*Psammotermes allocerus*
7.10.5	Subfamily	Rhinotermitinae	*Rhinotermes sp.*
7.10.6	Subfamily	Termitogetoninae	*Termitogeton umblicautus*
7.11	Family	Serritermitidae	*Serritermes serrifer*
7.12	Family	Termitidae	
7.12.1	Subfamily	Sphaerotermitinae	*Sphaerotermes sphaerothorax*
7.12.2	Subfamily	Macrotermitinae	*Macrotermes spp.*
7.12.3	Subfamily	Foraminitermitinae	*Foraminitermes tubifrons*
7.12.4	Subfamily	Apicotermitinae	*Disjunctitermes insularis*
7.12.5	Subfamily	Syntermitinae	*Syntermes sp.*
7.12.6	Subfamily	Nasutitermitinae	*Nasutitermes spp.*
7.12.7	Subfamily	Cubitermitinae	*Cabitermes sp*
7.12.8	Subfamily	Termitinae	*Discuspiditermes sp.*

long use in several traditional medicinal systems, for instance, as a paste consisting of a mixture of macerated termites and parts of the mound (Srivastava *et al*., 2009; Chakravorty *et al*., 2011).

In several traditional African medicinal systems, the paste is boiled and topically applied to prevent infection of external wounds, and ingested to treat internal hemorrhages (Chakravorty *et al*., 2011). And in Indian Ayurveda, the boiled paste is used as a remedy for ulcers, rheumatic diseases, anemia, pain, and a declining health (Srivastava *et al*., 2009; Chakravorty *et al*., 2011).

The whole of Soldier termites locally known as Mbwiidi in Zaire are used to revive someone who's fallen into a syncope/blackout/fainting fit. Interestingly, termites are also used as a medical device in certain African countries. In order to insert a drug substance subcutaneously, a termite is allowed to bite into the area of the patient's skin coated with the substance, thus effectively injecting it under the skin (Srivastava *et al*., 2009). Thus, the chemical composition of some species of Termite and their therapeutic properties is discussed below.

***Nasutitermes* spp (Isoptera: Termitidae):**

The defensive secretion of the frontal gland from termite soldiers is a mixture of monoterpenes, sesquiterpenes and diterpenes, the latter being the most representative. Analyses of the dichloromethane extract from soldiers of the Brazilian termite, *Nasutitermes macrocephalus* (Silvestri, 1903) (Isoptera, Nasutitermitinae), described for the first time, allowed to identify the presence of two monoterpenes (alpha-pinene and limonene) and two sesquiterpenes (beta-trans-caryophyllene and gamma-selinene) by GC-EIMS, and the isolation of one

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rippertane and six trinervitane diterpenes by RP-HPLC. The chemical structures of the purified compounds were elucidated by interpretation of their spectroscopic data (1D and 2D NMR, EIMS, HRESIMS, and specific optical rotation) and the complete unequivocal assignment of the 3α -hydroxy-trinervita-1(15),8(19)-dien-2-one (6) was included in this paper, to complement the lack of information in the literature. Antibacterial, antifungal and cytotoxicity against cancer cell lines activities were evaluated. In particular, the compounds 2α, 3β-dihydroxytrinervita-l (15),8(19)-diene (2) and 3α-hydroxy-15-rippertene (7) exhibited the better activities against the clinically isolated Gram-positive bacterium methicillin-resistant *Staphylococcus aureus* BMB 9393, both with a MIC value of 31.2 μ/mL. This is the first description of a rippertane diterpene (7) as an antibacterial agent (de la Cruz *et al*., 2013).

In another study, the chemical composition and variability of the defensive secretion in *Nasutitermes corniger* (Motschulsky, 1885) was analyzed in an urban area of Brazil of semiarid region. Eighteen compounds were identified by gas chromatography-mass spectrometry. Cluster analysis classified the populations into two main groups: group I, seasonal forest, with α-pinene, β-pinene, 2-hexanol and 3-hexanol as major compounds, whereas group II, Caatinga, showed a lower percentage for α-pinene, β-pinene and limonene. It is suggested that climatic factors, geographical distance, and likely genetic differences between populations influence the chemical composition of the secretion of soldiers resulting in the possible formation of two ecotypes (Mello *et al*., 2016).

Methanol extracts of soldiers of *N. guayanae* and *N. surinamensis* have been shown to contain complex mixtures of diterpenes and monoterpenes. Eighteen diterpenes have been isolated and identified where twelve of them are previously known nasute termite diterpenes, while six are new trinervitene diterpenes. 2α,9β -dihydroxy-3β, 8β -oxido-1(15)-trinervitene has been isolated from *N. guayanae*, while 3α,14α-diacetoxy-2β-hydroxy-1(15),8(19)9-trinervitatriene; 14α -acetoxy-2β, 3α-dihydroxy-1(15), 8(19)9-trinervitatriene; 2β,3α-diacetoxy-11β,14α-dihydroxy-1(15), 8(19)-trinervitadiene; 9α,14α -diacetoxy-2β,3α -dihydroxy-1(15), 8(19)-trinervitadiene and 2β,9α,14α -triacetoxy-3α-hydroxy-1(15), 8(19)-trinervitadiene have been isolated from *N. surinamensis*. Their structures were determined on the basis of their spectroscopic properties (Laurent *et al*., 2005). Also, from the soldier of *N. canaliculatus*, a novel 10-oxygenated secotrinervitane diterpene, 3α, 10α-diacetoxy-7,16-secotrinervita-7,11,15(17)-triene(4) was isolated and identified (Rabemanantsoa *et al*., 1996).

***Macrotermes* spp (Isoptera: Termitidae):**

The biochemical properties and nutritional content of four castes (queen, worker, soldier and winged (alate)) of *Macrotermes subhyalinus* (Rambur) were evaluated to determine the Protein digestibility and anti-nutrient contents used as food for human and animal consumption. Physico-chemical properties of the oil of each caste were also determined to reveal the potential uses of the oil and its stability in storage using standard to analytical methods. The queen was the most easily digestible (84.72%) of the castes while the soldier was the least with a digestibility value 81.10%. The queen was significantly more digestible than the other castes. In general, all the four castes have low anti-nutrient (oxalate, phytate and tannin) values. Among the castes, worker has significantly higher anti-nutrient levels than the other castes. In general, worker and soldier have relatively higher digestibility values and significantly higher anti-nutrient contents as well as relatively higher values for most of the physico-chemical parameters tested, suggesting that they are the least edible caste. Overall, the results showed that all four castes of *M. subhyalinus* have very low levels of anti-nutrients tested for, are easily digested and produce edible oil. These findings confirm that all four castes of *M. subhyalinus*, and possibly other termite species, are safe for human and animal consumption, and therefore recommended for inclusion in human foods and livestock feeds (Ajayi, 2012). More so, the chemical analysis of *Macrotermes nigeriensis* was analyzed. The concentrations of proximate, minerals, vitamins and fatty acids of the termite were determined using standard methods. The following major nutrients were identified: proteins (20.94 ±

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0.08%), carbohydrates (20.74 ± 0.00%) and lipids (34.23 ± 0.83%); the minerals included potassium (3360.00 mg/kg), sodium (1120.00 mg/kg), iron (9.56 mg/kg) and zinc (0.97 mg/kg); the vitamins were ascorbic acid (17.76 ± 1.60 mg/100g), niacin (2.74 ± 0.02 mg/100g) and riboflavin (1.56 ± 0.02 mg/100g); and the fatty acids were oleic acid (52.45 ± 0.58%), palmitic acid (31.39 ± 0.92%) and linoleic acid (7.57 ± 0.16%). The high fat content of the termite was made up mainly of unsaturated fatty acids (60.64%), consisting of 53.07% monounsaturated and 7.57% of polyunsaturated fatty acids (Igwe *et al*., 2011).

The Antibacterial activities of 90% alcohol extracts of *Macrotermes estherae* (Desneux) and *Microtermes obes* Holmgren including their mounds and nearby soil extracts were collected and assayed against various bacterial strains. The test organisms showed activity and their mound extracts because they inhibited all the bacterial strains studied (Solavan *et al*., 2007b). The microbial activities of microorganisms obtained from the gut of *Macrotermes michaelseni* were investigated. Seventeen isolates were examined for their abilities to produce substances with antibiotic activities when grown in pure culture. All isolates formed measurable antibiotic activities against *Escherichia coli*, *Staphylococcus aureas and Citrobacter freundii*. The isolates did not form inhibition zones against *Candida albicans*, *Shigella* species and *Salmonella paratyphi* (Aswani *et al*., 2015).

Prorhinotermes spp (Isoptera: Rhinotermitidae):

The chemical composition of the frontal gland secretion in soldiers, intercastes and swarming imagoes of *Prorhinotermes simplex* using GC-MS was evaluated and isolated. In the soldiers, two groups of chemicals were observed to form the secretion: nitroolefins and sesquiterpene (*Z*,*E*)-α-farnesene. Major Nitro compound is (*E*)-1-nitropentadec-1-ene; (*E*)-1-nitroheptadec-1-ene and 1-nitrotridec-1-ene occur in much lower amounts; 1-nitrotetradec-1-ene, 1-nitrohexadec-1-ene, nitropentadecadiene, and nitrohepta- decadiene are present in trace amounts. In swarming imagoes, nitro compounds fraction contains only (*E*)-1-nitropentadec-1-ene and (*E*)-1-nitroheptadec-1-ene. Rich mixture of sesquiterpenes (21 identified, about 10 unidentified) was found in both sexes. No sexual differences in composition of secretion were found except for the ratio between sesquiterpenes and nitro compounds. In functional dealate reproductives (kings and queens), no compounds present in alates were detected. In spite of the presence of a secretion inside the frontal gland reservoir of presoldiers, no compounds other than cuticular hydrocarbons were detected using GC-MS. The composition of the frontal gland secretion of artificial intercastes strongly resembles that of swarming imagoes. Except nitro compounds, it is rich in sesquiterpenes, of which 10 (same as in imagoes) were found to occur in the secretion (Jan *et al*., 2007).

Pseudacanthotermes spiniger (heterometabole insect, Isoptera):

Two novel antimicrobial peptides, which was proposed to name termicin and spinigerin, was isolated from the fungus-growing termite *Pseudacanthotermes spiniger* (heterometabole insect, Isoptera). Termicin is a 36-amino acid residue antifungal peptide, with six cysteines arranged in a disulfide array similar to that of insect defensins. In contrast to most insect defensins, termicin is C-terminally amidated. Spinigerin consists of 25 amino acids and is devoid of cysteines. It is active against bacteria and fungi. Termicin and spinigerin show no obvious sequence similarities with other peptides. Termicin is constitutively present in hemocyte granules and in salivary glands. The presence of termicin and spinigerin in unchallenged termites contrasts with observations in evolutionary recent insects or insects undergoing complete metamorphosis, in which antimicrobial peptides are induced in the fat body and released into the hemolymph after septic injury (Lamberty *et al*. 2001; Da Silva *et al*., 2003; Ramos-Elorduy, 2005).

Odontotermes formosanus Shiraki (Isoptera: Termitidae):

Termicin, a defensin-like antimicrobial peptide of termites that has strong antifungal activity was identified from *Odontotermes formosanus*. Fifty-six different termicin mRNAs encoding 46 different

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peptides were amplified and identified from *Odontotermes formosanus*, a species that inhabits environments with a large variety of microbial fauna (Xu *et al*., 2012).

Solavan *et al*., (2007b) investigated the antibacterial ability of *Odontotermes formosanus* Shiraki with other termite species mostly used by South Indians for treating diseases associated with microorganisms. The antibacterial activity of 90% alcohol extract of *Odontotermes formosanus* Shiraki including its mounds and nearby soil extract were collected and assayed against various bacterial strains. The antibacterial activity was higher in *Odontotermes formosanus* Shiraki at 12.6 ± 0.5 mm and its mound extracts at 14.3 ± 1.1 mm against *E. coli* BL21. In another study, it was shown that *Odontotermes formosanus* exhibited anti- ulcer effect and used to treat asthma (Solavan *et al*., 2004, 2006). Wilsanand (2005) reported that *Odontotermes formosanus* contains analgesic properties and as such can be effective for treating pain, rheumatism. The antigenotoxic potential of the termite, *Odontotermes formosanus* Shiraki supplemented food on acephate and endosulfan induced toxicity in the Swiss albino mice (*Mus musculus*) was evaluated. Dietary supplementation with termite to male and female mice treated with acephate and endosulfan significantly decreased the percentage of chromosomal aberration and micronuclei in the bone marrow cells than in pesticide treated F0 and F1 generations ($P < 0.01$). The chromosomal aberrations induced by acephate and endosulfan included minute, gap, inversion, ring, pulverization and tetraploids. The experimental groups treated with acephate/endosulfan and supplemented with termite food did not show critical genotoxic aberration markers like pulverization and ploidy suggesting a strong antigenotoxic effect of the termite components. Dietary supplementation with termite to male and female mice treated with acephate and endosulfan significantly decreased the percentage of chromosomal aberration compared to pesticide treated in F0 and F1 generations ($P < 0.01$) suggesting an antigenotoxic role of the termite components (Solavan *et al*., 2007a).

Microcerotermes exiguous

Alves and Alves (2011) reported that *Microcerotermes exiguus* contains antiviral properties and as such effective for treating cold, cough, hoarseness, asthma, catarrh, bronchitis, influenza, flu, whooping cough, sore throat, sinusitis and tonsillitis.

***Reticulitermes* spp. (Isoptera: Rhinotermitidae):** Thirty-eight different termicin (a defensin-like antimicrobial peptide of termites that has strong antifungal activity) mRNAs encoding 21 different peptides were amplified and identified from *Reticulitermes chinensis* (Xu *et al*., 2012).

The antibacterial activities of Proteinaceous Compounds in Crude Extract from the Eastern Subterranean Termite, *Reticulitermes flavipes* Kollar was assessed against a common Gram-positive soil bacterium *Bacillus subtili*. Activities of the crude extract, heat-treated extract, and size-fractionated extracts against *B. subtilis* were determined using the inhibition zone assay in comparison to Ampicillin (positive control) and Tris-NaCl buffer (negative control). The activity against *B. subtilis* was evidenced in all but the heat-treated solutions, indicating the presence of antibacterial activities, the existence of multiple active compounds in the crude extracts, and the protein nature of the active compounds (Yuan *et al*., 2014). Yuan *et al*., (2016) also investigated the antimicrobial production by *Reticulitermes flavipes*, against a panel of bacteria including three multidrug resistant (MDR) and four non-MDR human pathogens and it was determined that the crude extract of naïve termites had a broad-spectrum activity against the non-MDR bacteria but it was ineffective against the three MDR pathogens *Pseudomonas aeruginosa*, methicillin-resistant *Staphylococcus aureus* (MRSA), and *Acinetobacter baumannii*. Heat or trypsin treatment resulted in a complete loss of activity suggesting that antibacterial activity was proteinaceous in nature. Further investigation demonstrated that hemolymph, not the hindgut, was the primary source of antibiotic activity. This suggested that the termite produces these antibacterial activities and not the hindgut microbiota. Two-dimensional gel electrophoretic analyses of 493 hemolymph protein spots indicated

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that a total of 38 and 65 proteins were differentially expressed at least 2.5-fold upon being fed with *P. aeruginosa* and MRSA, respectively which provide the first evidence of constitutive and inducible activities produced by *R. flavipes* against human bacterial pathogens.

Termite-associated microorganisms:

Padilla *et al*., (2015) evaluated some extracts from termite-associated bacteria in vitro antiviral activity against bovine viral diarrhea virus (BVDV). They identified 2 bacterial strains as active, with 98% of inhibition (IP). They also identified that a 100% methanol fraction contain the compound(s) responsible for antiviral activity with SI of 262.41. The study present new information for antiviral research of *Streptomyces chartreusis* compounds isolated from termite mounds against BVDV and for the treatment of HCV infection.
Six new eremophilane-type sesquiterpenes, namely, nigriterpenes A-F (1-6) and one new phenolic compound, named 2-hydroxymethyl-3-pentylphenol (7), along with fomannoxin alcohol, 3-butyl-7-hydroxypthalide, scytalone and fomannoxin were isolated from the ethyl acetate extracts of the fermented broths of termite nest-derived medicinal fungus *Xylaria nigripes*, which has long been used as a traditional Chinese medicine for treating insomnia and depression. Their structures were elucidated on the basis of spectroscopic data analysis and compared with literature. All the pure isolates were evaluated against lipopolysaccharide-induced inducible nitric oxide synthase (iNOS), cyclo-oxygenase-2 (COX-2) expression, and NO production in murine brain microglial BV-2 cells. Of the compounds tested, nigriterpene C (3) and fomannoxin alcohol exerted significant inhibitory effects on two induced enzymes and NO production without any significant cellular toxicity which indicated that the potential anti-inflammatory effects of nigriterpene C (3) and fomannoxin alcohol on murine brain microglial BV-2 cells may provide a rationale for the traditional medicinal uses of *X. nigripes* for treating insomnia and depression (Jung-chung *et al*., 2017).

CONCLUSION

The therapeutic potential of Termite species, either recording traditional medical practices or employing them and their products at the laboratory and/or clinical level has been investigated. Thus, Termites seem to constitute an almost inexhaustible source for pharmacological research. More studies are needed on the chemical composition of termites to discover which biologically active compounds are actually present within insect bodies as many species of termite are yet to be utilized or studied. More so, the conversion of the therapeutic potential of these medicinal insects into contemporary efficacious medicinal applications will require a collaborative effort of governments, holders of traditional knowledge, scientists, and pharmaceutical companies as these medicinal insects face a number of unprecedented obstacles which when overcome will lead to the full exploration of the valuable compounds represented by this largely unexplored source of bioactive substances and the development of structurally novel and mechanistically unique drugs to more effectively manage human diseases and malnutrition. In addition, their use needs to be at a sustainable level to avoid overexploitation.

DISCLOSURE/CONFLICT OF INTEREST STATEMENT

The authors of this paper have no financial or personal relationship with other people or organizations that could inappropriately influence or bias the content of the paper. It is to specifically state that "No Competing interests are at stake and there is No Conflict of Interest" with other people or organizations that could inappropriately influence or bias the content of the paper. The manuscript has not been published previously by any of the authors and/or is not under consideration for publication in another journal at the time of submission.

ACKNOWLEDGEMENT:

The authors are sincerely grateful to all our colleagues who played various noteworthy roles towards the success of the publication. Their suggestions were quite useful.

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AUTHORS'S CONTRIBUTIONS

Abu, T., Njoku-Onu, K.A and Augustine, E. U was involved in several stages of this academic effort, especially the literature search, manuscript drafting and draft revisions.

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