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Review

Phytochemical constituents and bioactivities of the extracts of *Cassia nigricans* Vahl: A review

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Cassia **species have been of keen interest in phytochemical and pharmacological research due to their excellent medicinal values. They are rich sources of polyphenols, anthraquinone derivatives, flavonoids and polysaccharides.** ***Cassia nigricans*** **Vahl is an important source of secondary metabolites, notably anthraquinone derivatives. The leaves of** ***C. nigricans*** **Vahl have been reported to contain pharmacologically active substances, including 1,6,8-trihydroxy-3-methyl anthraquinone (emodin), emodic acid, citreorosein, a flavonoid - luteolin, and hydroxyestranic acid, ethyl ester.** ***C. nigricans*** **Vahl is of high therapeutic value in gastro-intestinal disorders, including ulcers and diarrhoea, and skin diseases. It possesses antimicrobial, antiulcer, analgesic, anti-inflammatory, contraceptive, antiplasmodial, insecticidal and larvicidal activities. The plant has the potential to be used in the management of agricultural pests. In conclusion,** ***C. nigricans*** **Vahl contains biologically active compounds that may serve as candidates for new drugs in the treatment and prevention of human and livestock diseases, and pest management.**

Key words: *Cassia nigricans* Vahl, ethnomedicine, chemical constituents, anthraquinones, bioactivities.

INTRODUCTION

Plants have great potential uses, especially as traditional medicine and pharmacopoeial drugs. A large proportion of the world's population depends on traditional medicine because of the scarcity and high costs of orthodox medicine (Tagboto and Townson, 2001; Hudaib et al., 2008). Medicinal plants have provided the modern medicine with numerous plant-derived therapeutic agents (Evans, 2000; Oladunmoye et al., 2009). Many plants contain a variety of phytopharmaceuticals, which have found very important applications in the fields of agri-culture, human and veterinary medicine. Natural products play a dominant role in the development of novel drug leads for the treatment and prevention of diseases (Newman et al., 2003; Gilani and Rahman, 2005). The need to screen plants for pharmaceuticals is particularly urgent in the light of rapid deforestation and the concurrent loss of biodiversity throughout the world. It is very important to have sufficient knowledge regarding herbs not only because of their widespread uses, but also because they have the potentials to cause toxic reactions or interact with other drugs. For example, senna (*Cassia acutifolia)* and germander *(Teucrium polium)* can induce hepatotoxicity (Lynch and Berry, 2007; Sawalha et al., 2008). Although in traditional medicine *Cassia* species have been well known for their laxative and purgative properties and for the treatment of skin diseases (Dalziel, 1956), there is now an increasing body of scientific evidence demonstrating that the plants possess many other beneficial properties.

The aims of the present paper were to review the chemical constituents of *Cassia nigricans* Vahl and their biological activities, and highlight their potentials as candidates for new drugs that may be of value in the treatment and prevention of human and livestock diseases.

GENERAL BOTANICAL DESCRIPTION AND PROPERTIES OF *Cassia* SPECIES

Cassia species belong to the family Caesalpiniaceae. Caesalpiniaceae is often treated as a sub-family, Caesalpinioideae, of the large family Leguminosae. It is closely related to Mimosaceae and Papilionaceae, but can be distinguished by few stamens and five free petals. Caesalpinioideae consist of trees, shrubs and a few woody herbs found in the tropics. Economically, woody Caesalpiniaceae is important for its timber. *Cassia* and *Tamarindus* species are used for medicinal purposes.

Some species of Caesalpiniaceae yield dyes (Hutchinson and Dalziel, 1958; Hutchinson, 1973;

Ghanzanfar, 1989).

All the species of *Cassia* have bright yellow flowers of characteristic shape. The typical flower consists of five similar sepals and petals. *Caesalpinioideae* usually have very small bracteoles, neither resembling nor taking the place of the calyx, which is normally developed and more or less conspicuous. Stamens which are polymorphic are ten in number with the upper 2 - 3 often reduced. Pods could be cylindrical or flattened, dehiscent or indehiscent, with or without septa between seeds, constricted or not between seeds. Leaves are paripinnate. Petiolar glands are present (Hutchinson, 1973; Ghanzanfar, 1989). Examples of *Cassia* species are *C. rotundifolia* Pers., *C. jaegeri* Keay in Bull., *C. nigricans* Vahl, *C. kirkii* Oliv., *C. mimosoides* Linn., *C. mannii* Oliv., *C. aubrevillei* Pellegr. in Bull., *C. sieberiana* DC., *C. arereh* Del., *C. alata* Linn., *C. podocarpa* Guill. and Perr., *C. siamea* Lam., *C. italica* (Mill.) Lam. ex F.W. Andrews, *C. senna* Linn., *C. absus* Linn, C. *singueana* Del., *C. laevigata* Willd., *C. bicapsularis* Linn., *C. tora* Linn., *C. sophera* Linn., *C. occidentalis* Linn. and *C. hirsuta* Linn. Others are *C. auriculata* Linn., *C. fistula* Linn., *C. fruticosa* Mill., *C. ligustrina* Linn., *C. multijuga* Linn., *C. javanica* Linn., *C. nodosa* Buch.-Ham. ex Roxb., *C. roxburghii* DC. and *C. surattensis* Burm. f. (Hutchinson and Dalziel, 1958).

C. nigricans Vahl, also known as *Chamaecrista nigricans* (Vahl) Greene, is called *Jiwo Tsamiya* or *Shuwakan Gargari* in Hausa. The plant is a woody annual herb, or undershrub, between 1.22 and 1.52 m high with small yellow flowers. It is widespread in tropical Africa, including Nigeria, Arabia and India, especially in cultivated or old clearings by roadside and open grassy areas. It has brown, hairy pubescent stems, containing pith.

The leaf of *C. nigricans* Vahl has 10 - 18 pairs of symmetrical oblong leaflets. Each leaflet is about 15 - 26 mm long and 5 - 6 mm broad. The midrib is central. The rhachis and petiole are about 7 cm long. The petiole has an ellipsoidal gland about 2 mm long. The leaf base is rounded and apiculate. Racemes are solitary or paired with one raceme axillary and the other supra-axillary. The pod is flattened, and with oblong (25 - 40 mm) valves curling on dehiscence. The seeds inside are ten in number (Dalziel, 1948; Irvine, 1961) (Plate 1).

Cassia species have been of keen interest in phytochemical and pharmacological research due to their excellent medicinal values. They are well known in folk medicine for their laxative and purgative uses (Dalziel, 1948; Abo et al., 1999; Hennebelle et al., 2009). Besides, they have been found to exhibit anti-inflammatory (Chidume et al., 2001), antioxidant (Yen et al., 1998; Yen and Chuang, 2000), hypoglycaemic (Bhakta et al., 1997; Jalalpure et al., 2004), antiplasmodial (Iwalewa et al., 1990, 1997), larvicidal (Yang et al., 2003), antimutagenic (Silva et al., 2008; Yadav et al., 2010) and anticancer activities (Prasanna et al., 2009; Yadav et al., 2010). They are also widely used for the treatment of wounds (Bhakta et al., 1998), skin diseases such as ringworm, scabies and eczema, gastro-intestinal disorders like ulcers (Dalziel, 1948; Benjamin, 1980; Abo et al., 1999; Elujoba et al., 1999; Jacob et al., 2002), and jaundice (Pieme et al., 2006).

Plate 1. *C. nigricans* Vahl shrub growing in the wild.

The phytochemical studies of the medicinal plants have provided some biochemical basis for their ethnopharmacological uses in the treatment and prevention of various diseases and disorders (Edeoga et al., 2005; Krishnaiah et al., 2009; Okigbo et al., 2009). The medicinal properties of *Cassia* species are due to their contents of hydroxyanthraquinone derivatives.

The genus *Cassia,* with *C. acutifolia* Del *or C. angustifolia* Vahl as the official species, is generally accepted in the British pharmacopoeia to consist of members possessing strong purgative activities (Dziedzic and Hudson, 1984). Of the thirty three species growing in Nigeria, only a few have been investigated for laxative properties, although they are also described to have other medicinal and local uses by traditional healers (Elujoba et al., 1999; Abo et al., 2000).

The properties and applications of all *Cassia* species are similar, though they differ from those of Indian senna (*C. angustifolia* Vahl) or *Alexandria senna* (C. *acutifolia* Del.) in that they possess the active components at lower concentrations (Obiorah, 1982; Ayim, 1986; Kinjo et al., 1994; Pamplona-Roger, 1999). The presence of

anthraxquinones (I) seems to be closely linked to the plant's physiological processes, and the most frequent substitution pattern is that of emodin (II) It was discovered that in *Cassia senna* seedling, chrysophanol (III) was the first anthraquinone formed, then aloe-emodin (IV) appeared, and finally rhein (V) (Figure 1). During fruit development, the amounts of aloe-emodin glycoside and rhein glycoside fall markedly and sennosides (Figure 1, VI) accumulate in the pericarp (Fairbairn and Shrestha, 1967; Trease and Evans, 1989).

Abo and Adeyemi (2002) showed a significant seasonal variation in the concentration of anthraquinone content. Anthraquinones attained peak levels during the months of October to March, corresponding to the dry season in the northern part of Nigeria; and a significant decrease occurred during the rainy season (April - September).

The concentration of aglycone rose slightly during the rainy season, apparently, due to interconversion of some glycosides to the aglycones. The free aglycone content, found to be considerably lower than glycoside content, is desirable for optimum laxative activity and reduced toxicity (Abo and Adeyemi, 2002). Based on the findings of Abo and Adeyemi (2002), the season of harvest is a crucial factor in the determination of optimum drug development from the leaves of *C. nigricans* Vahl.

ETHNOMEDICAL USES OF *C. nigricans* Vahl

Cassia nigricans Vahl has some traditional medicinal applications in Africa including Nigeria, especially in the northern part of the country. Its roots and leaves are used in Senegal and Guinea-Bissau as antiperiodic agent and a substitute for quinine. The pulverized leaves added to food improve appetite and act as a febrifuge, and a decoction prepared from the leaves of the plant is used as a wash and fumigation in fever. An infusion is given for the treatment of sore throat.

The root Infusion is administered as a purgative and vermifuge in Senegal, Guinea-Conakry and Chad (Dalziel, 1948; Irvine, 1961). The leaves of *C. nigricans* Vahl are claimed to possess analgesic, antiulcer and antioedema activities, and they are beneficial in the treatment of gastro-intestinal disorders (Dalziel, 1948; Akah and Nwabie, 1993). A pinch of the ground leaves is taken with water for the treatment of peptic ulcers (Akah et al*.,* 1998b). *C. nigricans* Vahl is used in Ghana to control insect pests of stored grains and legumes (Belmain et al., 2001).

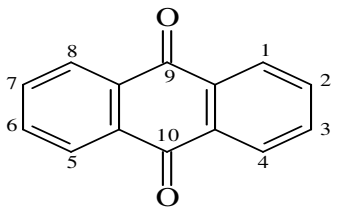
PHYTOCHEMICAL CONSTITUENTS ISOLATED FROM *C. nigricans* Vahl

Phytochemicals are natural bioactive compounds found in plants, including the medicinal plants, fruits, vegetables, flowers, leaves, roots and fibres, and they act as a defence system against diseases, or more accurately protect plants against diseases (Krishnaiah et al., 2009). The therapeutic potentials, including antioxidant, antimicrobial and anticarcinogenic properties of higher plants are due to the presence of secondary metabolites (Canigueral et al., 2008; Kaur and Arora, 2009). The medicinal values of these plants lie in bioactive phytochemical constituents that produce definite physiological actions on the human and animal body. Some of the most important bioactive phytochemical constituents are the glycosides, alkaloids, flavonoids, tannins, steroids, terpenoids, essential oils and phenolic compounds (Harbone, 1984; Edeoga et al., 2005; Okwu, 2005). Species of *Cassia* are rich sources of polyphenols, anthraquinone derivatives (Tiwari and Yadava, 1971; Yen et al., 1998; Bahorun et al., 2005; Georges et al., 2008), flavonoids (Singh et al., 1980) and polysaccharides (Singh, 1982). These biologically active chemical substances, known as secondary metabolites in medicinal plants, form the foundations of modern prescription drugs (Sofowora, 1993).

Anthraquinone or anthracene glycosides are the glycolsides in which the aglycones are anthracene derivatives, and they occur as the pharmacologically active constituents of several cathartics. Most anthraquinones are simply polyhydroxy or methoxy derivatives with or without one carbon side chain (-CH_3, - CH_2OH, - CHO, - COOH), which invariably occupies a *β*-position of the anthraxquinone. Dimers are quite common. The most frequent substitution pattern is that of emodin, chrysophanol (1,8-dihydroxyl-3-methylanthraquinone), and its derivatives frequently coexist with emodin and related metabolites (Verhaeren et al., 1983; Trease and Evans, 1989).

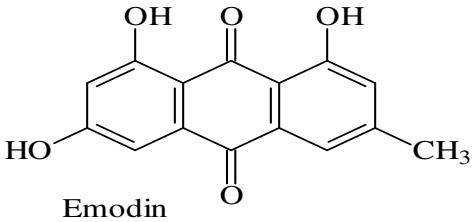
In recent decades, there are many reports on the use of medicinal plants. From the studies, it was discovered that the exact amount of active chemical constituents are frequently unknown. In general, one or two markers of pharmacologically active components in herbs and or herbal mixtures are currently employed for: (1) evaluating the quality and authenticity of herbal medicine; (2) Identification of the single herb or herbal mixtures; and (3) assessing the quantitative herbal composition of a herbal product. It was discovered that multiple constituents are usually responsible for the therapeutic effects of the plants.

These multiple constituents may act synergistically and could hardly be separated into active parts. Moreover, the herbal constituents may vary depending on the harvest seasons, plant origins, drying processes and other factors (Walker, 2004; Silva et al., 2008). For example, senna extracts widely used in the treatment of intestinal constipation are complex mixtures, with several active constituents, such as dianthrone glycosides (sennosides A, B, C and D), free anthraquinone (aloe-emodin, chrysophanol, rhein) and anthraquinone glycosides. Among these constituents, sennosides A and B are present in higher concentrations than the other constituents of these



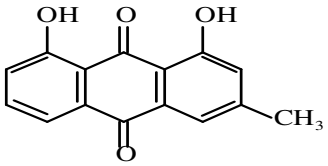
I

Anthraquinone



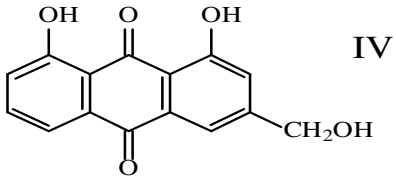
II

Emodin
1,6,8-trihydroxy-3-methylanthraquinone



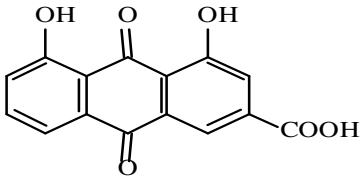
III

Chrysophanol
1,8-dihydroxy-3-methylanthraquinone



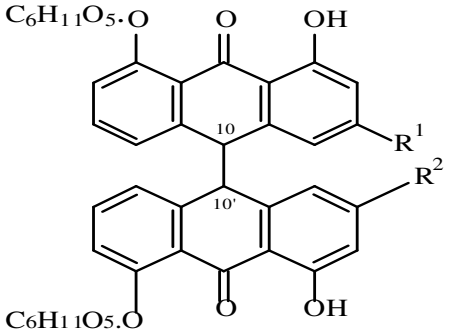
IV

Aloe-emodin
1,8-Dihydroxy-3-hydroxymethylanthraquinone



V

Rhein
1,8-Dihydroxy-3-carboxylic acid anthraquinone



VI

	R^1	R^2	10-10'
Sennoside A	COOH	COOH	trans
" B	COOH	COOH	meso

Figure 1. Chemical structures of main anthraquinones isolated from *Cassia* species.

extracts (Sun and Su, 2002). Other substances commonly found in a number of plant extracts are the antioxidants (Lee et al., 2003).

They act as radical scavengers inhibiting lipid peroxidation and other free-radical-mediated processes, and protect humans against several diseases attributed to free - radical reactions such as Parkinson's disease, atherosclerosis and cancer (Mates et al*.,* 1999; Emerit et al., 2004; Silva et al*.,* 2008).

The preliminary phytochemical screening of the extracts of the leaves of *C. nigricans* Vahl revealed the presence of carbohydrates, reducing sugars, anthracene derivatives, flavanoids, steroids, tannins, saponins, cardiac glycosides and alkaloids (Ikhiri et al., 1992;

Table 1. Active compounds isolated from *C. nigricans* and their bioactivities.

Part of *C. nigricans*	Active constituents	Bioactivities	References
Whole plant	Emodin	Antiplasmodial activity (malaria) *in vitro* and *in vivo* – rats	Obodozie et al., 2004
Leaves	Emodin	Antimicrobial activity	Ayo et al., 2007
Leaves	Emodin	Insecticidal activity against adult white fly (*Bemisa abachi*), and mosquito larvicidal activity against *Anopheles gambiaea*	Georges et al., 2008
Leaves	Citreorosein	Mosquito larvicidal activity against *Anopheles gambiaea*	Georges et al., 2008
Leaves	Emodic acid	Mosquito larvicidal activity against *Anopheles gambiaea*	Georges et al., 2008
Leaves	Luteolin	Not determined yet	Georges et al., 2008
Leaves	Hydroxyestranic acid, ethyl ester	Antimicrobial activity	Ayo et al., 2009c

Chidume et al., 2001; Nwafor and Okwuasaba, 2001; Ayo and Amupitan, 2007).

Cassia nigricans Vahl is known to be an important source of secondary metabolites, notably anthraquinone derivatives. In a detailed study on the extracts of *C. nigricans* Vahl leaves, an active constituent 1, 6, 8-trihydroxy-3-methylanthraquinone (emodin) was isolated (Obodozie et al., 2004; Ayo et al., 2007; Georges et al., 2008). Bioassay-guided isolation of *C. nigricans* Vahl leaf extract yielded anthraquinones, emodic acid, citreorosein and a flavonoid, luteolin (Georges et al., 2008). Ayo et al. (2009c) also isolated a steroidal ester; hydroxyestranic acid, ethyl ester, from the methanol extract of the leaves, possessing potent antimicrobial activity (Table 1). The chemical structures of these isolated compounds are shown in Figure 2. Besides anthraquinones, luteolin and the steroidal ester, β-sitosterol acetate, heptadecanoic acid, 14-methyl ester; and a toxic principle, bis 2-ethylhexyl phthalate were identified in the methanol extract of the leaves of *C. nigricans* Vahl (Ayo et al., 2009b).

TOXICITY OF *C. nigricans* Vahl

Cassia species have shown marked toxicity to both man and animals, despite their medicinal uses. Their fatalities to pigs, sheep and cattle as well as human deaths from overdoses of herbal remedies involving *Cassia* species have been reported (Nwude and Parsons, 1977). Toxicity or other major activity is commonly associated with the aglycone moiety of compounds isolated from the plant. Most *Cassia* species containing anthraquinones are toxic in high doses. Some species containing cyanogenic glycosides are hydrolysed after consumption to yield hydrocyanic acid. Hydrocyanic acid is a potent cellular asphyxiant; smaller amount causes a short period of stimulation with excitement and convulsion followed by depression and death (Lewis and Elvin-Lewis, 1977; Nwude and Parsons, 1977).

The brine shrimp (*Artemia salina*) lethality bioassay of the petroleum ether, ethyl acetate, methanol and chloroform extracts of the leaves of *C. nigricans* Vahl showed that the extracts were cytotoxic. The chloroform extract showed the strongest cytotoxic activity (median lethal concentration, LC_{50} = 26.91 µg/ml), and petroleum ether was the least cytotoxic (LC_{50} = 149.5 µg/ml) (Ayo and Amupitan, 2007). Acute toxicity study of extract of the leaves of *C. nigricans* Vahl was investigated in mice using the intraperitoneal route. The median lethal dose (LD_{50}) values were found to be 210 ± 4.5 mg/kg (Chidume et al., 2001) and 245 ± 28 mg/kg (Akah et al., 1998a).

The results showed that *C. nigricans* Vahl was moderately toxic. *Cassia nigricans* Vahl leaves were fed with standard rat diet at the concentration of 1% and 5% (w/w) to rats over a 6-week period to assess the potential toxicity of the plant. At the concentration of 1%, normal dietary intake and weight gain were recorded, and no neurotoxic and adverse neurobehavioural effects were observed in the rats. When *C. nigricans* Vahl was incorporated into the diet of the rats at 5% level, significant reductions in growth rate, weights of the liver and the kidneys were obtained, and cell hyperplasia was observed in the liver (Belmain et al., 2001). Further studies through long-term bioassays are required to determine the chronic toxicity of the plant on other body organs and systems, and involving other animal species.

PHARMACOLOGICAL ACTIVITIES OF *C. nigricans* Vahl

Antifeedant activity

C nigricans Vahl at the concentrations of 0.5, 1 and 5% w/w was tested against four common storage pests (*Rhyzopertha dominica*, *Callosobruchus maculatus*, *Sitophilus zeamais* and *Prostephanus truncatus*). The

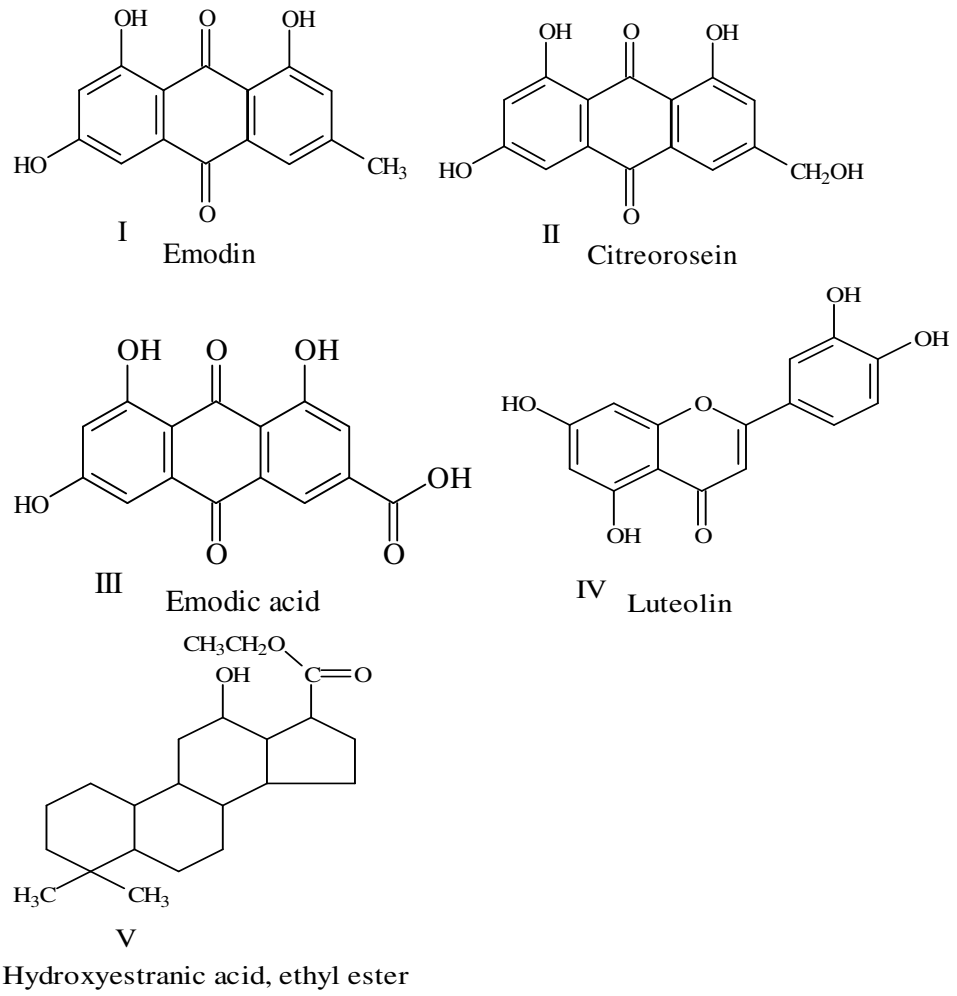


Figure 2. Chemical structures of bioactive compounds isolated from *C. nigricans* Vahl.

leaf powder was found to control all the pests of stored grains by exhibiting feeding deterrent activity. The efficacy of the plant as an antifeedant rose with increase in concentration, and the highest concentration of 5% gave the best control (Belmain et al., 2001). The methanol extract of the leaves of *C. nigricans* Vahl showed potent antifeedant activity, indicating that the extract contains classes of compounds that are of value in the control of the destructive effect of the insect pests on stored grains (Georges et al., 2008). Although plant-based antifeedants leave minimal residues following application, especially when fed at low concentrations (Belmain et al., 2001; Georges et al., 2008), potential bioaccumulation and chronic toxicity associated with the plant powder of *C. nigricans* Vahl require investigation.

Pest management and insecticidal activities

Despite several methods currently used for the control of mosquitoes, the spread of malaria and other parasite diseases constitutes major problems in developing and under developing countries. Resistant and environmental damages caused by synthetic pesticides have necessitated research for new, alternative pest management strategy. Preparations derived from plants are traditionally used as insecticides and are of great potential value in pest control (Ismann, 2006). Hexane and ethyl acetate extracts of *C. nigrican*s Vahl have been demonstrated to exhibit 100% mortality on 4th instar mosquito (*Ochlerotatus triseriatus)* larvae. *C. nigricans* Vahl extracts exhibited 30 - 50% mortality on white flies (*Bemisia tabaci*). Methanol extract of *C. nigricans* Vahl showed 100% mortality on mosquito larvae. Similar effect was observed on ethyl acetate extract of the plant (Georges et al., 2008). *C. nigricans* Vahl thus contains compounds that may be of value in the development of environmentally safe pest-management agents.

Emodin, emodic acid and citreorosein principles were isolated as insecticidal principles in *C. nigricans* Vahl.

Emodin demonstrated larvicidal activity at 24 h. It exhibited potent toxicity on white flies (*Bemisia tabaci*) at 25, 12.5, and 6.25 µg/l, which showed 83, 79 and 51% mortalities, respectively; while the methanol extract of *C. nigricans* Vahl showed 100% mortality on mosquito larvae. Furthermore, emodin was shown to possess about 85% mortality on mosquito larvae of *Anopheles gambiaea,* and adult white flies (*Bemisia tabaci*) that cause wide damage to food crops such as tomatoes, onions, cabbage, okra, melons, cotton and French beans (Georges et al., 2008). Georges et al. (2008) further demonstrated that emodin or emodin-rich extracts of *C. nigricans* Vahl are potential candidates for the development of pest management agents that are natural and friendly to the environment in the control of mosquito larvae and white flies. Further studies are required to determine the chronic toxicity effects on animals of the potential residues left on food crops treated with the plant extracts or active compounds after storage.

Antiplasmodial activity

The antiplasmodial activity against chloroquine-resistant strain of *Plasmodium falciparun* strain K1 was investigated *in vitro*. The main antiplasmodial principle, emodin, was isolated from the whole plant of *C. nigricans* Vahl (Obodozie et al., 2004). Emodin isolated from *C. nigricans* Vahl showed potential therapeutic effects in the treatment of malaria in patients who have developed resistance against the conventional drug, chloroquine. The findings of Obodozie et al. (2004) thus, for the first time, demonstrated that emodin isolated from *C. nigricans* Vahl possesses antiplasmodial activity, which supports the use of this plant in African traditional medicine to treat malaria. The extracts of *C. nigricans* Vahl may be beneficial in the treatment and prevention of other blood protozoal diseases in the tropics, which are currently known to be resistant to the conventional drugs. This requires investigation.

Antiulcer activity

The leaves of *C. nigricans* Vahl are much used medically to treat peptic ulcer. The aqueous and methanol extracts of the leaves were found to possess significant antiulcerogenic properties, apparently mediated via the inhibition of histaminergic receptors (Akah et al., 1998a; Chidume et al., 2001). The water extracts protected rats from aspirin-induced ulcerogenesis and retarded intestinal transit, increased the pH and reduced both the volume and acidity of gastric secretion (Akah et al., 1998a). Thus, the findings support the use of the plant in folklore medicine in the treatment of peptic ulcer (Akah et al*.,* 1998b).

The most important constituents of the plant associated with antiulcer activity are the flavanoids. Flavanoids have a wide spectrum of pharmacological activities including antiulcer effects. They have been found to offer 63% protection against immobilisation-induced ulcers and 52% against phenylbutazone-induced ulcers. Some other constituents of the plant evaluated for antiulcer activity include antraquinones, alkaloids, terpenes, steroids, polysaccharides, polycyclic phenols, soprenoids hydroleucodine, sesquiterpenes, pectins, sulphonic acids, glycolipids and amines (Akah et al., 1998a; Yen and Chuang, 2000; Nanasombat and Teckchuen, 2009). The methanol extract of *C. nigricans* Vahl leaves protected the gastric mucosal damage induced by combined cold stress and aspirin (Chidume et al., 2001). The stomach of rats treated with the extract was covered with a relatively thick layer of mucus. Therefore, Chidume et al. (2001) suggested that the extract may exert its effects by forming a cytoprotective barrier which is beneficial in peptic ulcer.

Oral administration of the methanol extract of *C. nigricans* Vahl leaves inhibited dose-dependently the ulcerogenic effect of indomethacin by reducing the ulcer index from 11.1 in control animals to 1.9 using the higher dose of 1,000 mg/kg orally, while the preventive ratio decreased dose-dependently by 23.42 - 82.88% (Nwafor and Okwuasaba, 2001). The extract significantly and dose-dependently protected rats from ethanol-induced ulcer, and the lowest dose (250 mg/kg orally) was more effective than propranonol (40 mg/kg, orally), a non-selective β-adrenergic blocker. The water extract of *C. nigricans* Vahl leaves reduced significantly aspirin-induced ulcer index in a dose-dependent fashion (Akah et al., 1998a). Nwafor and Okwuasaba (2001) further suggested that the antiulcerogenic activity of the extract may be due to its ability to mobilize the prostaglandins in gastric mucosa by increasing its microcirculation. The fact that the phytochemical analysis of the extract revealed the presence of saponin and flavonoids suggests that the compounds, established to protect the integrity of the mucous membrane, may be involved in preventing ulcer development in the gastric mucosa.

Anti-inflammatory, analgesic and antinociceptive activities

The methanol extract of *C. nigricans* Vahl leaves showed a significant anti-inflammatory effect against egg-albumen induced inflammation in rats in a remarkable dose-dependent fashion. Pain threshold increased significantly following intraperitoneal administration of the extract in mice, and the maximum effect was observed 60 minutes following the administration. The analgesic effect of extract of the leaves of the plant is, apparently, due to interference in the stimulation of peritoneal receptors. The methanol extract has been shown to reduce significantly the number of acetic acid-induced writhes in

mice, thus revealing antinociceptive properties (Chidume et al., 2001).

Contraceptive activity

The methanol extract of the leaves of *C. nigricans* Vahl showed significant contraceptive activity in mice and rats. The extract dose-dependently (0.5 - 1.0 g/kg) prevented the animals from conception for 1 - 4 gestational periods. It inhibited foetal implantation, confirmed by laparotomy on day 10 of pregnancy. The pups obtained from the rodents administered with the extract showed significant changes in weight and length compared to controls. The extract exhibited anticonceptive effect, apparently, due to its anti-implantation, oestrogenic and/or direct effects on the uterus (Nwafor and Okwuasaba, 2001).

Effect on contractile activity of the smooth muscle

The methanol extract of *C. nigricans* Vahl leaves dose-dependently reduced the amplitude of spontaneous contraction of the smooth muscles of the rabbit jejunum. It also inhibited the gastro-intestinal propulsion (Chidume et al., 2001). Thus, *C. nigricans* Vahl is a potent inhibitor of intestinal motility. It has been suggested that the mechanism of inhibition is mediated via the histaminergic receptor (Chidume et al., 2001). Nwafor and Okwuasaba (2001) showed that the methanol extract of *C. nigricans* Vahl leaves inhibited significantly the intestinal propulsion, and this inhibition was decreased by the α_2-adrenergic blocker, yohimbine and also reduced by an anticholinergic drug, atropine. Similarly, the extract increased castor oil-induced diarrhoea in rats, and its reduction was enhanced by yohimbine.

Antimicrobial activity

The antimicrobial activity of crude extracts (petroleum ether, ethyl acetate, chloroform and methanol) of *C. nigricans* Vahl leaves was investigated against S*taphylococcus aureus, Streptococcus pyogenes, Corynebacterium pyogenes, Salmonella typhi, Escherichia coli* and *Pseudomonas aeruginosa* using agar diffusion technique. The results showed that the extracts were effective against all the test micro-organisms, an exception was the petroleum extract which showed no inhibition. The minimum inhibitory concentration of the extracts of chloroform and methanol was found to be 2×10^4 µg/ml (Ayo and Amupitan, 2004).

Emodin isolated from the ethyl acetate of the leaves of *C. nigricans* Vahl was tested against common pathogenic microorganisms. The results demonstrated that emodin significantly inhibited the growth of all the microorganisms (Ayo et al., 2007). The antimicrobial activity of the steroidal ester, hydroxyestranic acid, ethyl ester, isolated from methanol extract of the leaves was investigated against *S. aureus, S. pyogenes, Bacillus subtilis, C. pyogenes, S. typhi, E. coli, P. aeruginosa, Candida albicans, Neisseria gonorrhoea* and *Klebsiella pneumoniae* using agar diffusion technique. The results showed that the compound was effective against all test organisms, and the minimum inhibitory concentration was found to be 2×10^3 µg/ml (Ayo et al., 2009c). The results of the studies confirmed the use of *C. nigricans* Vahl in traditional medicine in the treatment of wounds, and that the plant is a potential source of wide spectrum antibiotics.

Antioxidant activity

Cassia species have been found to contain polyphenol compounds, such as anthraquinones, flavonoids, steroids and tannins, which exhibited strong antioxidant activity (Yen et al., 1998; Kumaran and Karunakaran, 2007). Methanol extract of the leaves of *C. nigricans* Vahl was investigated for antioxidant activity, using 1,1-diphenyl-2-picrylhydrazyl (DPPH) free-radical scavenging activity (Ayo et al., 2009a). The mechanism of the DPPH free-radical scavenging activity is based on the ability of an antioxidant to react with DPPH, which is a stable free radical, and convert it to a stable diamagnetic molecule, 1,1-diphenyl-2-picrylhydrazine. The degree of decolourization of the purple coloured solution of DPPH is used as an indication of the scavenging potential of the antioxidant compound (Mensor et al., 2001; Sharma et al., 2007). The results of the study showed that the extract possesses antioxidant activity as evidenced by its DPPH free-radical scavenging activity. The free-radical scavenging activity of the antioxidants contained in the extracts may be partly responsible for the mechanism underlying the prophylactic and therapeutic effects exerted by the bioactive compounds isolated from the plant (Ayo et al., 2009a). This requires further investigation.

CONCLUDING REMARKS

The available information in the literature on the bioactivities of the active constituents of the extracts of *C. nigricans* Vahl shows that the plant contains compounds with strong pharmacological activities of potential clinical relevance. There is an increasing body of evidence that *C. nigricans* Vahl is an important potential source of new pharmacological agents that may be beneficial in the prophylaxis and therapy of many infectious and parasitic diseases of man and livestock. Although some pharmacological activities of the plant extracts have been demonstrated, there is paucity of information on the effects of the bioactive constituents on the body systems,

including the cardiovascular, haematologic, respiratory, reproductive, endocrine and nervous parameters. The evaluation of effects of the bioactive constituents of the extracts and their interactions in the body systems may reveal some side-effects of the extracts. The knowledge of the side-effects is necessary, if the isolated compounds are to be administered on a long-term basis to patients suffering from chronic diseases. Besides, some beneficial effects of the extracts still need to be explored and investigated on experimental basis.

In the overall, the studies on *C. nigricans* Vahl extracts have shown very promising results, and further elucidation of the pharmacological role of the active constituents has become imperative. There is the need to explore the role of the plant as potential agents for grain storage and pest management, especially in the tropics where colossal post-harvest losses of grains occur on a yearly basis. Further investigations are required in order to isolate more new compounds from the plant extracts, and to test their bioactivities with the aim of increasing the drug arsenal currently used in the treatment and prophylaxis of human and animal diseases.

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