


REVIEW

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Ethno-medicinal, phytochemistry, and pharmacological importance of *Hunteria umbellata* (K. Schum.) Hallier f. (Apocynaceae): a useful medicinal plant of sub-Saharan Africa

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Abstract

Background: *Hunteria umbellata* (K. Schum.) Hallier f. (Apocynaceae) is a tropical rainforest tree commonly found in sub-Saharan region of Africa. It is a useful and very popular plant among the locals due to the outstanding anti-diabetic activity of the seeds.

Methods: A comprehensive literature search on articles published on phytochemical analysis and various pharmacological activities of *Hunteria umbellata* was carried out using search engines such as Google Scholar, PubMed and Science Direct.

Results: In this review, it was deduced that *H. umbellata* is employed in folk medicine as an elixir for obesity, fever, leprosy sores, menstrual pain, infertility, yaws, intestinal worms, abdominal discomfort and stomach ache. Due to their durability and immunity against termites, the stems are coveted and desired as timbers in the construction of houses, while the bark has been reportedly exported to Europe for medicinal uses. Pharmacological activities such as fertility enhancing, aphrodisiac, hypoglycemic, anti-inflammatory, has been ascribed to the different morphological organs of *H. umbellata*. Moreover, compounds belonging to important classes of secondary metabolites with biological activities such as triterpenoids, flavonoids, tannins, alkaloids, quinic acids have been identified and characterized from the plant.

Conclusion: From this review, it can be inferred that, numerous and bioactive principles with known biological usefulness are present in the extracts of *H. umbellata* and might be responsible for the observed biological and pharmacological activities.

Keywords: *Hunteria umbellata* (K. Schum.) Hallier f., Phytochemistry, Ethno-medicinal, Pharmacological, Sub-Saharan Africa

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Introduction

The African continent is blessed with about 5000–6000 species of important medicinal plants and flora [1, 2]. Readily availability, cheapness and, presumed efficacy, coupled with ancestral practices and beliefs, have sustained the ceaseless usage of these plants as an elixir in the management of myriads of diseases [3]. Furthermore, some of these medicinal plants contribute to the economy of many countries, up millions of dollars in sales

and export [4–6]. Moreover, there have been increasing pharmacological studies, evaluation, and validation of these plants based on their documented folkloric usage and ethnobotanical surveys [7]. To a large extent, scientific findings have documented many of these plants to elicit arrays of biological activities based on empirical evidence. Furthermore, the mechanism of action and active principles that might be attributed to the observed pharmacological activities have been elucidated. An



Fig. 1 Geographical distribution of *H. umbellate* in Africa

important group of compounds known as secondary metabolites such as alkaloids, flavonoids, terpenoids, and saponins among others has been characterized and identified from many medicinal plants [8, 9]. Some of these compounds have been included in the development of allopathic drugs against some infectious diseases such as malaria and metabolic syndromes [10, 11]. In many third-world nations, developing countries and villages, they still rely largely on herbal preparation as a panacea for many ailments while it accounts for about 30–50% of medicinal consumption in China and some Asian countries [12, 13, 14]. Predominantly found in Sub-Saharan Africa, *Huntera umbellate* is a useful and beneficial medicinal plant, with a plethora of domestic and ethno-medicinal uses.

Botanical description, habitat and distribution of *H. umbellate* in Africa

H. umbellate belongs to the Apocynaceae plant family consisting of 4555 species of trees, shrubs, woody vines, and herbs. It is commonly found in West and Central African countries of Cameroon, Senegal, Ghana, Gabon, Congo, Liberia, Guinea Bissau, Sierra Leone, Ivory Coast, and Nigeria [15]. However, it has also been reported to grow in Angola (Fig. 1). *H. umbellate* is an all-year flowering and fruitful plant which is naturally located in secondary, rain, and gallery forests, 600 m above sea level. It grows as a shrub or small tree up to 15–22 m in height, with a dense leafy crown [16]. The trunk is greyish, which can be serpentine or straight with a diameter of 16 in., while the branches and branchlets have dark brown and pale green colours respectively [17]. The fruits (Fig. 2) are yellowish, with a smooth texture and, can be as large as 31–60 × 40–50 mm in size [18]. The flowers have a strong pleasant smell, consisting of a creamy or pale yellow corolla and pale green sepals [17]. The leaves (Fig. 3) are hard in texture, elliptic or, oblong in shape, with a size of 10–20 cm × 3–10 cm, and petioles which are 8–25 mm long [19]. The peduncle and inflorescence axes in *H. umbellate* may appear swollen due to the exudation of resin from the young buds [17].

Folkloric and ethno-medicinal uses of *H. umbellate*

Vernacularly, the plant is known as “Osu”, “Npokiri” and “Abeere” or “Erin” among the Edo, Igbo and Yoruba people of Nigeria respectively [20, 21]. *H. umbellate* has been documented to possess numerous local and folkloric medicinal uses. The seed and bark, which are prepared as infusions and decoction are effective against fever, leprosy sores, menstrual disturbance, infertility, yaws, intestinal worms, abdominal colic, discomfort, and stomach ache [22–24]. The seeds are used in the local management of Diabetes mellitus by herbalists, while the



Fig. 2 *H. umbellate* seeds

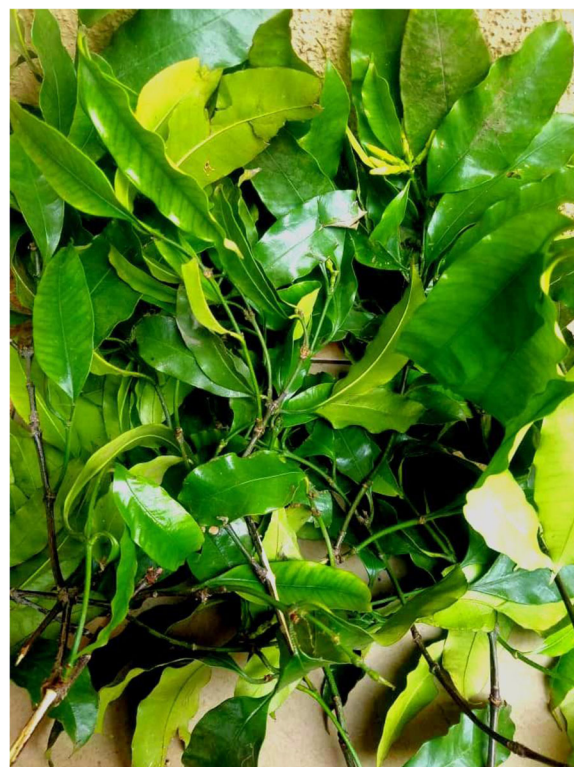


Fig. 3 *H. umbellate* leaves

Table 1 Alkaloids from morphological organs of *H. umbellata*

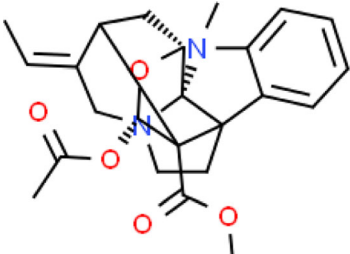
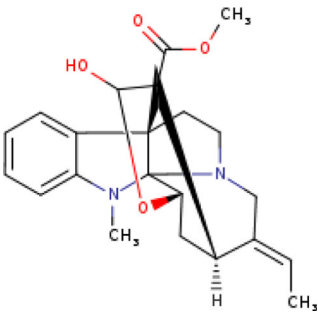
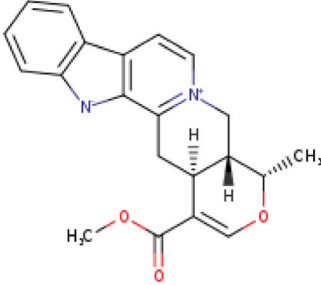
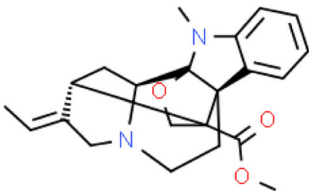
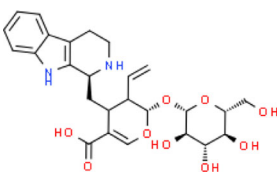
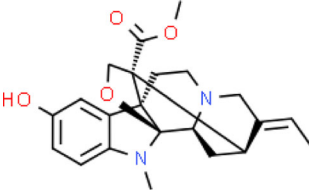
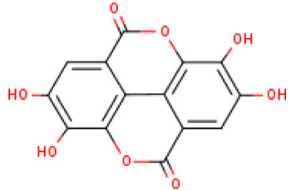
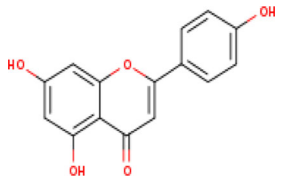
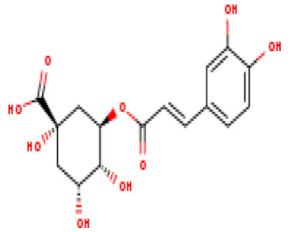
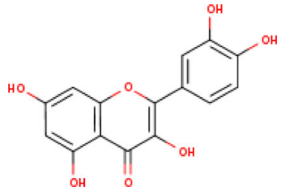
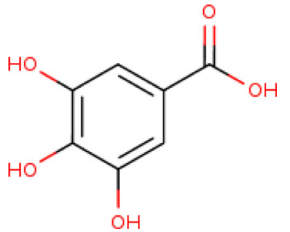
Compound	Structure	Identified organ
Acetylcorymine		Seed
Corymine		Seed
Serpentine alkaloid		Stem bark and leaves
Pseudoakuammigine		Stem bark
Strictosidinic acid		Leaves
Akuammine		Leaves

Table 2 Phenolics from morphological organs of *H. umbellata*

Compound	Structure	Identified organ
Ellagic acid		Seed
Apigenin		Seed
Chlorogenic acid		Seed
Quercetin		Seed
Gallic acid		Seed

leaves and pulp are employed by traditional obstetric and midwives to prevent dystocia and unwanted abortion [20, 21, 25, 26]. The roots are blended and macerated as a bitter tonic in Cameroon and Nigeria, while the wood and stems are durable and considered immune to termites. They are used for making household furniture, carving of small tools, and carpenters planes [17]. The bark is also sold to Europe for different medicinal uses [27].

Phytochemistry of *H. umbellata*

Different classes of compounds (Tables 1, 2, 3 and 4) have been reported to present in the various morphological

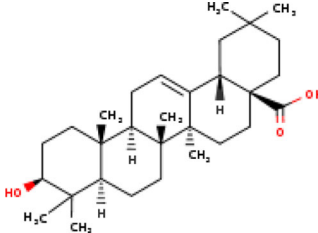
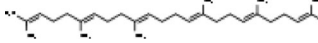
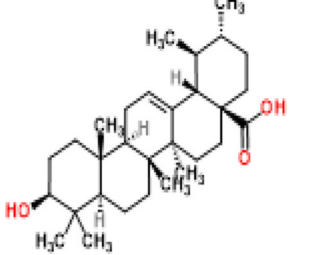
organs of *H. umbellata* and might be responsible for the elicited pharmacological activities (Table 5). Aqueous and methanol extract of the seed, leaves, and stem bark contains alkaloids, anthraquinones, saponins, tannins, reducing sugars, steroidal glycosides, flavonoids, and carbohydrates [47, 48]. Gas chromatography-mass spectrometric (GC-MS) analysis of the methanol seed and leave extracts have identified 21 different compounds which include 2,2'-Benzylidenbis (3-methylbenzofuran), 2-ethylacridine, 2-methoxyresorcinol, 5-methyl-2-phenylindolizine, 6-methoxy-7H-purine, 8,11-octadecadienoic acid, 9-octadecenoic acid (Z), 11-octadecenoic acid, caffeine, benzene methanol, hexadecanoic acid, quinolin-2(1H)-one, urs-12-en-24-oic acid, 1,2-benzisothiazol-3-amine, 1,4-eicosadiene, 1-methyl-3-phenylindole, 10, 13-octadecadienoic acid, 11-octadecenoic acid, dodecanoic acid, hexadecanoic acid and methyl stearate [49]. Many decades ago, Patel and Rowson [50], Bevan et al. [51] revealed that alkaloids such as acetylcorymine, corymine, and isocorymine were isolated from ether extract of *H. umbellata* seeds. Unprecedentedly, ikiridinium, a new indole alkaloid with activity against *Bacillus subtilis* and 4-chloromethylakuammine has been characterized from the seed [52]. Through spectroscopic analysis, it was discovered that solvent fractions of the leaves, and stem bark contains cardiac glycoside, ursolic acid, squalene, oleanolic acid, serpentine, pseudoakuammigine, huntrabirine methochloride, 4-chloromehtylakuammine, strictosidinic acid and akuammine [52–54]. According to reports from pioneer studies, alkaloids such as erinine, ericinine, eripine and umbeliamine have been isolated from the leaves, and root bark of *H. umbellata* [55–57]. According to Adegoke and Alo [58], four water-soluble abereamines alkaloids such as delactonized 8, 11-dihydroxy-14-isopropyl-22-deoxyiso-corymine, 11-hydroxy-14-isopropylisocorymine, 21-hydroxy-14-isopropylisocorymine, 11, 21-dihydroxy-14-isopropyl-22-deoxyisocorymine was characterized from the aqueous seed extract. On the same hand, erinidine, a bisindole alkaloid with hypoglycemic activity has also been isolated from the aqueous extract of the seed [59]. Some flavonoids and phenolic compounds with biological activities, such as chlorogenic acid (1.27 mg/g), gallic acid (0.59 mg/g), ellagic acid (0.61 mg/g), quercetin (2.94 mg/g) and apigenin (0.45 mg/g) in appreciable amounts have been detected and quantified by high-performance liquid chromatography [31, 60]. Furthermore, a new iridolactone- β -glucoside known as segunoside was identified from the stem bark [61].

Pharmacological properties of *H. umbellata*

Anti-diabetic and hypoglycemic property

The hypoglycemic activity of water extract of *H. umbellata* seed was evaluated in streptozotocin (50 mg/kg *i.p*)

Table 3 Triterpenoids from morphological organs of *H. umbellata*

Compound	Structure	Identified organ
Oleanolic acid		Stem bark
Squalene		Stem bark
Ursolic acid		Stem bark

induced diabetic rats [28]. The extract at 400, 800, 1000 mg/kg exhibited a significant non-concentration-dependent blood glucose reduction which was stronger than glibenclamide. Moreover, glycogen concentration in the extract-treated diabetic rats was also significantly buoyed thus indicating the glycogen storage enhancing activity of the plant [28]. Pretreatment with aqueous seed extract (20–200 mg/kg) significantly attenuated oral glucose (3 g/kg) and nicotine (50 µg/kg i.p) induced hyperglycemia in rats. It was suggested that the anti-hyperglycemic mechanism of the extract was mediated through intestinal inhibition of glucose uptake [62]. Momodu et al. [29] demonstrated that 250 mg/kg *H. umbellata* aqueous seed extract significantly diminished streptozotocin-induced diabetes with an observed hypoglycemic fasting blood glucose value. A concomitant restoration in the cytoarchitecture of the pancreatic cell was noticed in the treated rats. In a dose (50–200 µg/ml) dependent pattern, *H. umbellata* aqueous seeds extract inhibited 50% hog pancreatic α-amylase (IC_{50} = 221.30 µg/ml) and α-glucosidase (IC_{50} = 184.35 µg/ml) respectively. The enzymes' inhibitory properties of the extract could be attributed to its phenolics and flavonoids constituents [31, 32]. As established by Adeneye et al. [63], butanol fraction (200 mg/kg) of aqueous seed extract exhibited a significant time-dependent hypoglycemic effect in alloxan-induced hyperglycemic rats. The fasting blood glucose concentration (FBG) of 116 mg/dl recorded in the extract-treated

animals was comparable to 114 mg/kg observed in glibenclamide treated. From the same study, a similar blood lowering glucose activity was demonstrated by the alkaloids fraction of the seed extract. Longe and Momoh [44] and Longe et al. [30] demonstrated that 100 and 250 mg/kg methanol seed extract significantly abated buoyed blood glucose in alloxan-induced diabetic male rats. Aqueous seed extract (100–400 mg/kg) significantly reduced blood glucose concentration in high fructose (600 g) diet-fed rats with a tandem decrease in plasma insulin, basal insulin resistance, and leptin reduction [39]. From the same study, an increased adiponectin activity exhibited in the extract-treated animals can be linked to increased insulin sensitivity and fatty acid oxidation which simultaneously can reduce the risk of myocardial infarction and cardiovascular derangement [64–66]. A 14 day oral treatment of alloxan monohydrate (120 mg/kg) induced diabetic rats with 50–200 mg/kg aqueous seed extract revealed an ascending dose-dependent hypoglycemic activity of the seed extract. Furthermore, high circulating plasma insulin, FBG, glycosylated hemoglobin (HbA1c) in response to daily oral fructose (66.7 g/kg), and subcutaneous dexamethasone sodium phosphate (10 mg/kg) load was significantly ameliorated in the extract treatment group [67]. Erini-dine, a light yellow, an amorphous solid alkaloid isolated from the seed extract demonstrated considerable in-vitro α-glucosidase and dipeptidylpeptidase inhibition, but lacked in-vitro aldolase reductase, glycogen

Table 4 Other compounds from morphological organs of *H. umbellata*

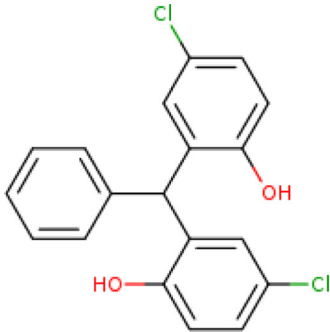
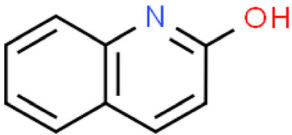
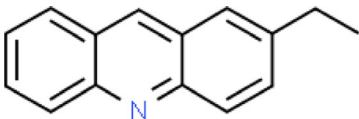
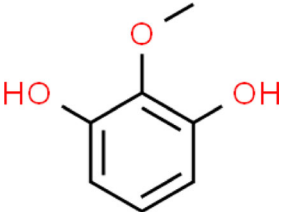
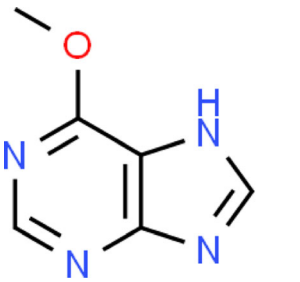

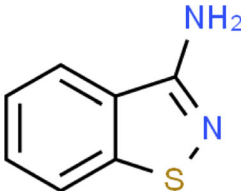
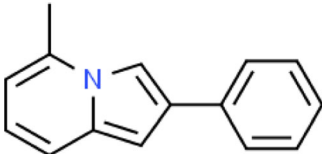
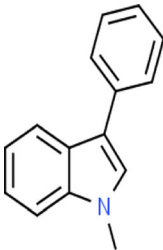
Compound	Structure	Identified organ
2,2'-benzylidenebis		Seed and leaves
Quinolin-2(1H)-one		Seed and leaves
2-Ethylacridine		Seed and leaves
2-methoxyresorcinol		Seed and leaves
6-methoxy-7H-purine		Seed and leaves
Methyl stearate		Seed and leaves
1,2-benzisothiazol-3-amine		Seed and leaves

Table 4 Other compounds from morphological organs of *H. umbellata* (Continued)

Compound	Structure	Identified organ
5-Methyl-2-phenylindolizin		Seed and leaves
1-Methyl-3-phenylindole		Seed and leaves

phosphorylase inhibitory activity and was unable to stimulate insulin release and glucose uptake by HIT-T15 cells and 3 T3-L1 adipocyte respectively. Nonetheless, a significant hypoglycemic effect was observed from the in-vivo studies [59]. *In-silico* study reported that GC-MS identified compound (3-methylbenzofuran) from *H. umbellata* methanol seed extract exhibited strong binding energy to peroxisome proliferator-activated receptor gamma (PPAR- γ). Peroxisome proliferator-activated receptors are key regulators of glucose metabolism. Thus, compounds showing agonistic tendencies are being developed as anti-diabetic agents. With a good molecular docking score of this protein, 3-methylbenzofuran has a promising prospect as an anti-diabetic agent [49].

Anti-oxidant property

The anti-oxidant potential of morphological organs of *H. umbellata* using different scientific approaches has

been documented [33], reported the stem bark aqueous extract (0.05–1.0 $\mu\text{g/ml}$) to exhibit strong dose-dependent 1, 1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging activity ($\text{IC}_{50} = 0.47 \mu\text{g/ml}$) which compared favorably with ascorbic acid (0.39 $\mu\text{g/ml}$). Significant ferric reducing anti-oxidant power (FRAP) and high phenolic content (124.19 gallic acid equivalent/ gram) were also observed. Also observed in the same study, stem extract (150–300 mg/kg) prevented hydroxylamine oxidation by superoxide radicals, increased catalase, and GSH-Px expression in the serum, liver, and heart homogenate. According to Momodu et al. [29], a significant elevation in the serum SOD, CAT and decreased thiobarbituric acid reactive species (TBARS) activity of rats treated with seed and leaf extract (250 mg/kg), suggest the potential of the plant to confer protection against reactive oxygen species (ROS) and oxidative stress. Obboh et al. [31] reported that 0.8, 0.255 and 0.2 mg/ml of the

Table 5 Summary of pharmacological properties of *H. umbellata*

Pharmacological Activities	Organ used	Extract	References
Anti-diabetic, Hypoglycemic	Seed	Aqueous, Methanol	[28–30]
Anti-oxidant	Stem bark, Leaf, Seed	Aqueous, Butanol,	[29, 31–33]
Anti-microbial	Seed	Ethanol, Methanol, Aqueous	[28, 34, 35]
Anti-inflammatory	Fruit	Aqueous, Butanol	[36, 37]
Analgesic and Antipyretic	Seed, Stem bark, Fruit	Aqueous	[38]
Effect on weight	Seed	Aqueous	[39, 40]
Anti-hyperlipidemic	Seed	Aqueous	[37, 41]
Sexual, Aphrodisiac and Oxytocic	Seed	Aqueous	[31, 36, 42]
Toxicological	Seed, Fruit, Stem bark	Aqueous	[35, 37, 39]
Cytotoxic and Anti-carcinogenic	Leaf	Methanol	[43]
Anxiolytic and Anti-angiogenic	Seed	Aqueous	[42]
Hematopoietic	Seed	Aqueous, Methanol	[41, 44, 45]
Nutritional	Seed	Essential oil	[46]

aqueous seed extract elicited hydroxyl radical (50%), DPPH (75%) scavenging and Fe^{2+} (40%) chelating activity respectively. According to Oboh et al. [32], the seed extract showed 3-ethylbenzthiazoline-6-sulphonic acid radical scavenging (11.60 μmol Trolox equivalent anti-oxidant/g) capacity. Moreover, the extract at 160 $\mu\text{g}/\text{ml}$ significantly attenuated sodium nitroprusside (SNP) and Fe^{2+} induced malondialdehyde (MDA) production by 40% and 85% respectively in rat penile tissue. Sixty days exposure of 36 males Wistar rats to aqueous seed extracts (100, 200, 400 mg/kg) revealed a considerable increase in testicular anti-oxidants profile. The highest level of SOD (06.25 U/mg protein), CAT (22.74 U/mg protein), glutathione (0.69 $\mu\text{M}/\text{g}$ tissue), glutathione reductase (217 nM/min/mg protein), and glutathione peroxidase (GSH-Px) (144 nM/mg protein) was observed at the highest extract concentration which was significant to the untreated group but not significant ($p > 0.05$) from Vitamin C exposed animals [42]. A significant increase in non-enzymatic and enzymatic anti-oxidants parameters was observed in high fructose-fed rats treated with *H. umbellata* aqueous seed extract (100–400 mg/kg) as against the untreated animals. The lowest level of tissue lipid peroxidation and oxidation indices such as malondialdehyde (3.28 nmol/mg), conjugated dienes (17.63 nmol/mg), lipid peroxides (12.34 nmol/mg), protein carbonyl (2.33 nmol/mg), fragmented DNA (2.51%) and the highest expression of anti-oxidants indices; SOD (48 nmol/min/mg/protein), catalase (40 nmol/min/mg/protein), glutathione reductase (38 nmol/min/mg/protein), and glucose-6-phosphate dehydrogenase (28 nmol/min/mg/protein) was observed at 400 mg/kg of the extract dosage group [39]. In the submission of Adeneye et al. [36], butanol fraction, alkaloid fractions, and aqueous extract of the seed at a concentration of 0.2–1.0 mg/ml elicited dose-dependent in-vitro anti-oxidant. A DPPH radical scavenging activities of (83%, 75%, 90%), nitric oxide (IC_{50} = 96.00 $\mu\text{g}/\text{ml}$, 24.00 $\mu\text{g}/\text{ml}$, 46.70 $\mu\text{g}/\text{ml}$) and superoxide anion inhibition (IC_{50} = 170.50 $\mu\text{g}/\text{ml}$, 112.00 $\mu\text{g}/\text{ml}$, 85.00 $\mu\text{g}/\text{ml}$) was demonstrated by the crude extract, butanol and alkaloids fractions respectively. The crude extract and butanol fraction exhibited a proanthocyanidins (38.90 and 53.67 catechin equivalent/mg), flavonoids (0.50 and 11.78 mg rutin equivalent /mg) and phenol (39.68 and 97.12 mg rutin equivalent/mg) content respectively [36]. Twenty-eight days treatments with aqueous seed extract, considerable elevated hepatic CAT, GSH, SOD, and lowered lipid peroxidation of alloxan-induced diabetic rats. The highest concentration of CAT (38.30 U/mg protein) and GSH (0.43 mg/g protein) was noticed in 250 mg/kg extract-treated rats while 100 mg/kg extract fed animals showed the highest values of SOD (7.0 U/mg protein) and lowest MDA (6.10 mg/protein) [30].

Anti-microbial property

Employing the agar well diffusion method, 50% aqueous leaf and seed extract in-significantly inhibited methicillin-resistant *Staphylococcus aureus* (MRSA) with zones of 10 mm and 6.30 mm respectively [34]. *H. umbellata* seed ethanol and methanol extracts (400 mg/ml) demonstrated 10 and 19 mm, 30 and 17 mm, 21 and 0 mm, 20 and 15 mm, 19 and 0 mm zones of inhibition on *Bacillus sp*, *Streptococcus sp*, *Lactobacillus sp*, *Shigella sp*, and *Proteus vulgaris* respectively. Minimum bactericidal concentration (MBC) of 40 and 50 mg/ml of ethanol seed extract was demonstrated on *Bacillus sp* and *Streptococcus sp* respectively [35]. The activity index of the ethanol extract versus commercial antibiotics (nalidixic acid and ciprofloxacin), revealed the plant extract as a potential candidate against food pathogens [35]. Aqueous seed extract (25–200 mg/ml) exhibited a dose-dependent anti-microbial activity against gram-positive (*Staphylococcus aureus*, *Escherichia coli*) gram-negative (*Pseudomonas aeruginosa* and *Bacillus subtilis*) bacteria [28]. The anti-fungi potential was also observed tandemly in *Candida albicans*, *Penicillium notatum*, and *Aspergillus niger* [28]. The highest bacteria inhibition zone of 22 mm at 200 mg/ml was detected for *Bacillus subtilis* and 19 mm for fungi (*Candida albicans*). Nonetheless, very low and insignificant inhibitory activities of the aqueous fruit pulp extract were observed against *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Escherichia coli*, and *Pseudomonas aeruginosa* [28]. The antagonistic effect of methanol stem and seed extracts (15–150 $\mu\text{g}/\text{ml}$) on two clinical bacteria isolates (*Escherichia coli* and *Staphylococcus aureus*) was determined by Chimechefulma et al. [53]. Minimum inhibition of both microorganisms by stem bark and leaves extract respectively was detected at 50 and 150 mg/ml. In a separate study, Ajala et al. [61] submitted that ikirydinium, an isolated alkaloid from the seed extract exhibited an IC_{50} of (0.6 μg) against *Bacillus subtilis* ATCC 6051. Dismayingly, no significant inhibition was observed on the growth of *Candida albicans* (ATCC 90028), *Escherichia coli* ATCC 11775, *Staphylococcus aureus* ATCC 9144 and ATCC 25923, and *Bacillus subtilis* ATCC 6633.

Anti-inflammatory property

In a 9 weeks study, the palliative effect of the aqueous seed extract (100–400 mg/kg) against pro-inflammatory mediators expression was observed in a high fructose diet-induced metabolic syndrome model. Compared to the untreated groups, a significant reduction in the activity of tumor necrosis factor- α (13.72 ng/ml), interleukin-6 (4.03 ng/ml), and interleukin-8 (4.53 ng/ml) were observed at 400 mg/kg extract-treated groups [39]. The anti-inflammatory mechanism of action of aqueous fruit pulp extract was reported by [37]. The plant was

hypothesized to block the release of inflammatory mediators such as prostaglandins and histamine. The extract at 250 mg/kg and 500 mg/kg attenuated xylene and carrageenan-induced ear and paw edema which compared favourably with dexamethasone and indomethacin [37]. A more effective (6.00 mm) ameliorative activity of the extract (500 mg/kg) on dextran induced paw edema which was significant ($p < 0.01$) to the control (7.6 mm) and stronger than diphenhydramine (6.5 mm), treated animals after 6 h was observed. However, an insignificant formalin-induced arthritis abating potential of the extract was noticed [37]. A notable reduction in formalin (0.2 ml of 2%), and carrageenan (0.1 ml of 0.5%) induced paw swelling was caused by administration of 50 mg/kg alkaloid and butanol fractions [36].

Analgesic and antipyretic property

Employing different experimental procedures, [38] evaluated the analgesic potential and activity of the seed (50–200 mg/kg) in aqueous extract pretreated rats. It was revealed that the treated rats had significant tolerance to cold (0–1 °C) and hot water (55 °C). The highest reduction (76%) in the rate of writhes in 200 mg/kg extract-treated mice in response to acetic acid injection was also noticed. Furthermore, a considerable decrease in formalin-induced biphasic nociceptive responses (frequency in paw licking and biting) in extract-treated rats was observed. The extract at the highest dose (200 mg/kg) was significant to the un-treated group and compared favourably with aspirin (100 mg/kg) and morphine (10 mg/kg). Sixty minutes pretreatment with stem bark extract (150, 300, 600 mg/kg) significantly reduced the frequency of abdominal constriction in response to intraperitoneal administration of 0.6% acetic acid (10 ml/kg) at all extract doses. The 150 mg/kg extract group demonstrated 68.2% inhibition which is higher than the acetylsalicylic acid (66.9%) treated group. An observable increased reaction time of the extract-treated groups to hot plate test was exhibited 300 and 600 mg/kg [33]. The percentage (79.9 and 72.3%) reduction paw licking interval in response formalin (to 20 µl of 1%) was highest at 150 mg/kg and 300 mg/kg respectively. The study thus suggests that the extract's antinociceptive action might be through modulation of the dopaminergic system [33]. Within 30 min of the experiment, the induction of writhes by acetic acid was significantly less pronounced in fruit pulp aqueous extract (250 and 500 mg/kg) and aspirin-treated mice relatively to normal saline-treated mice [68]. Fever reducing activity of the fruit pulp aqueous extract (250–500 mg/kg) was observed in *E.coli* induced pyrexia rabbits [28]. Relatively to aspirin, a statistically significant and reduced basal rectal temperature, 90 min post extract treatment was noticed [68].

Effect on weight

A significant dose-dependent weight-reducing effect was observed in rats pretreated with alkaloids fractions (25 and 50 mg/kg) of *H. umbellate* seed for 14 days before intraperitoneal triton WR-1339 (200 mg/kg *i.p*) exposure [40]. The lowest percentage weight increase of 12.08% and 15.85% was noticed in 50 and 25 mg/kg alkaloid fractions treated groups respectively, while triton only induced group showed the highest weight increase (21.42%). In another 14 days study, the impact of alkaloid fractions on weight increase was evaluated. The smallest but significant average body weight of 144 g amounting to a 10.45% increase was noticed in the 50 mg/kg treated group while the simvastatin (10 mg/kg) and 25 mg/kg alkaloid treated group of rats showed 13.47% and 16.67% weight increase respectively [40]. In the same period, the control group of animals on normal rat chow, without the extract or simvastatin exhibited a weight increase from 127.30 g – 161.80 g equating to 27.12% [40]. As established by Adeneye et al. [42], a 60-day study with 6 experimental groups revealed that the set of animals treated with 100, 200 and 400 mg/kg aqueous seed extract exhibited a dose-dependent weight reduction of 280 g, 279.20 g, and 243.70 g respectively vis-à-vis Vitamin C (20 mg/kg), distilled water (10 ml/kg), clomiphene (0.3 mg/kg) treated groups with average body weights of 307.80 g, 290 g, and 315.30 g respectively. Ajiboye et al. [39] reported that abdominal circumference which was hitherto increased in rats on high fructose diet for 9 weeks was dose-dependently reduced after 3 weeks of administration of aqueous seed extract (100, 200, and 400 mg/kg). Respective mean abdominal sizes of 12.5 cm, 15 cm, 19 cm, and 27 cm were recorded in 400, 200, 100 mg/kg extract group and untreated rats respectively. A body mass index (BMI) of 0.9 g/cm³ significantly higher than 0.65 g/cm³ and 0.60 g/cm³ of metformin and 400 mg/kg seed extract groups respectively was calculated in the high fructose diet animals [39]. Body mass index is the measure of body fat and risk of obesity based on weight (kg) to height (m²) ratio. The low BMI of the extract-treated group thus implicates *H. umbellate* seed as a potential anti-obesity agent. Worth noting, an opposing effect on weight gain was also dose-dependently demonstrated by all extract doses (100, 200, and 400 mg/kg) but the highest activity of 16% weight gain by the 400 mg/kg extract was statistically significant to the 65% weight gain observed in the untreated high fructose dieted animals [39]. Weight loss has been associated with alloxan-induced diabetes models in rats due to the loss of muscle adipose tissue protein and fatty acids [69–71]. This phenomenon was considerably ameliorated by 100 and 250 mg/kg methanol seed extract. A 150 g average weight documented in glibenclamide treated diabetic animals was similar to 170 g and 155 g

mean weights that were recorded in 250 and 100 mg/kg extract treated groups. However, the above results were statistically significant and higher than 90 g average weight of the diabetic untreated animals [30]. Vis-à-vis the control animals, 28 days of oral consumption of aqueous seed extract showed that the animals on all extract dose exhibited lower weight increment [72]. In ascending order, 200, 400 and 800 mg/kg extract exhibited 5.30%, 6.25%, and 14% weight increase which were nonetheless lower than 16% documented for the control animals. However, no observable changes in the weight of the liver, kidney, spleen, and heart were noticed [72].

Anti-hyperlipidemic property

As observed by Adeneye and crooks [42], elevated levels of serum triacylglyceride (TG), total cholesterol (TC), low and very-low-density lipoprotein cholesterol (LDL-C and VLDL-C) in rats exposed to a single dose of 200 mg/kg triton WR-1339 (*i.p*) were considerably reduced by oral infusion of seed alkaloid fractions (25 and 50 mg/kg). Serum TG, TC, LDL-C, VLDL-C values of 161.50 mg/dl, 129.70 mg/dl, 70.83 mg/dl, 33.83 mg/dl were respectively reduced significantly ($p < 0.01$) to 134.30 mg/dl, 115.00 mg/dl, 35.50 mg/dl and 19.17 mg/dl after 14 days consecutive treatment with 50 mg/kg of the alkaloid fractions. Conversely, the value of high-density lipoprotein cholesterol (HDL-C) was significantly ($p < 0.001$) increased from 25.00 mg/dl to 60.33 mg/dl after alkaloid therapy. Besides, a significantly reduced value for the predictor of cardiovascular disease such as atherogenic index (AI) and cardiovascular risk index (CRI) of 0.4 and 1.8 was observed in the alkaloids treated animals compared to 3.0 and 5.0 of hyperlipidemic untreated rats [40]. This development might be due to the increased activity of HDL-C which is referred to as good cholesterol. HDL-C is involved in reverse cholesterol transport from peripheral tissue to the liver, which can subsequently redistribute cholesterol to other tissues or excreted from the body by the gallbladder [73]. CCL₄ exposure has been implicated in the aetiology of dyslipidemia by triggering increased entry of acetate into liver cells, thereby leading to a rise in fatty acids and triglycerides production. Ogunlana et al. [41], thus submitted that deranged value of 0.91 mmol/L for plasma HDL-C in response to CCL₄ (2 ml/kg *i.p*) injection, was up-regulated to 2.17 mmol/L and 1.33 mmol/L, while TG was reduced to 0.63 mmol/L after 28 days medication with 500 mg/kg *H. umbellata* aqueous seed extract. As extensively disclosed by Ajiboye et al. [37], a remarkable difference in the blood TC, TG, HDL-C, LDL-C, and VLDL values of high fructose diet untreated rats versus 3 weeks aqueous seed extract (100, 200, 400 mg/kg) treatment was discerned. Treatment regimen with 400 mg/kg extract exhibited the most potent anti-

dyslipidemic activity by reducing elevated TC, cholesterol, TG, LDL-C and VLDL-C values from 60.31 mg/dl, 3.17 mg/dl, 78.53 mg/dl, 28.77 mg/dl, 17.71 mg/dl to 49.97 mg/dl, 1.35 mg/dl, 58.02 mg/dl, 12.15 mg/dl, 11.60 mg/dl respectively. Besides, coronary artery index, AI, and cardiac index were also reduced. Be that as it may, HDL-C value was conversely and consequentially buoyed from 15.83 mg/dl to 26.02 mg/dl post extract treatment [37]. Adeneye and Adeyemi [62] also concluded that hypertriglyceridemia noticed in serum triglycerol (419.80 mg/dl) of fructose-induced insulin-resistant rats was dose-dependently reversed to 193.30 mg/dl, 124.50 mg/dl, 82.30 mg/dl by 50, 100, and 200 mg/kg extract treatment. On the same hand, hypercholesterolemia was outstandingly attenuated from 461.50 mg/dl to 237.80 mg/dl, 136.80 mg/dl, and 82.30 mg/dl by the extract doses independently [62]. As documented by Longe and Momoh [41], the methanol seed extract at 250 mg/kg elicited stronger total cholesterol, plasma triacylglyceride, LDL-C reducing and a formidable HDL-C increasing activity than glibenclamide in alloxan exposed treated animals. The activity of the extract at all doses was significantly better than control (untreated animals).

Sexual, aphrodisiac and oxytocic property

H. umbellata has been reported to improve sexual activities and related enzyme markers in male rats [31]. The aqueous seed extract (50 and 100 mg/kg) administered orally for 28 days was observed to increase mounting prevalence, copulation, and intromission urge in the male rats. Moreover, a decrease in post-ejaculatory, climbing, and intromission latency was observed. These are relevant feelings, indexes, and a sense of sexual performance and gratification. Biochemical analysis revealed that the extract at 100 mg/kg elicited the highest decrease in arginase activity (0.22 $\mu\text{mol}/\text{min}/\text{mg}$ protein) of the penile tissue homogenate in comparison with 0.39 and 0.58 observed in the viagra (5 mg/kg) treated and control animals respectively [31]. The 50 mg/kg extract dosage significantly ($p < 0.05$) reduced serum arginase activity (0.19 $\mu\text{mol}/\text{min}/\text{mg}$ protein), which was lower than the 0.22 $\mu\text{mol}/\text{min}/\text{mg}$ protein and 0.39 $\mu\text{mol}/\text{min}/\text{mg}$ protein exhibited by 100 mg/kg extract and sildenafil citrate (5 ml/kg) treated groups respectively. Conversely, penile nitric oxide activity was significantly raised by 50% in 100 mg/kg extract-treated animals relative to the control group [31]. Reduced arginase and increased nitric oxide play a vital biochemical role in initiating, maintaining an erection, and preventing erectile dysfunction [74]. Thus, the observed activity by the extracts hence validates the folkloric and ethno-medicinal usage as an aphrodisiac. In a bid to analyze the erectogenic potential of *H. umbellata* seed on popular enzymes implicated in male erectile dysfunction, phosphodiesterase 5

(PDE5), and arginase inhibitory activity of the aqueous seed extract was investigated [32]. It was disclosed that the extract in a dose (50–250 µg/ml) dependent manner inhibited these enzymes. The highest inhibitory activity of 23% and 78% of phosphodiesterase (IC_{50} 539.72 µg/ml) and arginase (IC_{50} 41.53 µg/ml) respectively was demonstrated by 250 µg/ml. In a 60-day study, Adeneye et al. [36] comprehensively evaluated the male fertility enhancing the ability of the aqueous extract (100–400 mg/kg) of the seed. Radioimmunoassay analysis revealed that serum testosterone activity of 4.70 ng/ml and 6.39 ng/ml exhibited by 200 and 400 mg/kg extract fed animals was significantly higher than 2.53 ng/ml and 2.59 ng/ml observed in control and Vitamin C treated animals. The same trend was discerned in the serum immunoradiometric assay of luteinizing hormone (LH) and follicle-stimulating hormone (FSH) [36]. Although clomiphene (0.3 mg/kg) had the strongest activity in up-regulating the pro-fertility hormones in male rats, however, the 400 mg/kg extract-treated group manifested a higher LH and FSH activity of 1.42 ng/ml and 3.25 ng/ml respectively, which was better than 0.64 ng/ml and 2.29 ng/ml in Vitamin C (20 mg/kg) and control animals. Conversely, the concentration of prolactin and estrogen which has been reported to interfere negatively with the function of the testicles, testosterone, and sperm production was significantly diminished by the extract at 400 mg/kg [36]. Compared to the control, the average weight of the testes was slightly bigger in the extract fed groups. A significantly ($p < 0.05$) improved gonadosomatic and sexual developmental indices (GSI) was reported in the quintessence groups. Also, analysis of semen showed that the most elevated sperm quantity (47.38 total sperm/g cauda epi $\times 10^7$) and percentage sperm motility (87.17%) was found in the 400 mg/kg extract group. Juxtaposing with the control group value of 22.97%, significantly diminished dead sperm cells of 16.83% was exhibited at the highest concentration of extract treatment [36]. Corroborative, 7.67% of abnormal sperm cells found in the 400 mg/kg were statistically smaller than 10.86% and 14.03% displayed by ascorbic acid and clomiphene medicated groups respectively [36]. The oxytocic activity of the pulp extract (10 mg/kg) was assessed in the uterus of non-pregnant rats. As reported by [48], there was a 77.60% uterine contraction in response to the extract administration, and a subsequent significantly ($p < 0.05$) augmented and potentiated tonic response was noted when the extract was in synergy with oxytocin [48].

Toxicological property

The hepatoprotective activity of water extract of the seed was evaluated in-vivo against carbon tetrachloride (CCl_4) (2 ml/kg *i.p*) induced toxicity in rats [35]. It was

documented that the concentration of important liver toxicity biomarkers such as alkaline phosphatase, alanine aminotransferase, aspartate aminotransferase, total protein was increased in CCl_4 induced untreated animals. However, 28 days of oral exposure of the rats to 500 mg/kg of the extract significantly reduced the values of alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), total protein to 678 U/L, 42.40 U/L, 25.70 U/L and 6.88 (g/dl) respectively. The result suggests that the extract prevented haloaklylation and lipid peroxidation of the liver tissue [35]. Short term toxicity study in rabbits depicts that, the seed alcohol and water extracts did not elicit liver toxicity [39]. This was inferred from the insignificant changes in the values of liver function markers viz. ALP, AST, ALT, total bilirubin, and conjugated bilirubin of the extract-treated animals [39]. The result of the tissue histology showed no observable distortion in the architectural integrity of the liver vis-à-vis the control group [41]. In another 21 days study, Ajiboye et al. [39] established that a near-normal liver histo-architecture was found in high fructose-induced metabolic syndrome rats, treated with aqueous seed extract (400 mg/kg). A full lustre appearance, sparkling eyes, and normal fecal droppings are the few physical parameters that corroborated the biochemical and physiological wellness of the extract fed animals [75]. Morphometric analysis and histology revealed that the aqueous seed and leaves extract (250 mg/kg) reversed streptozotocin-induced uneven distribution, distortion, vacuolation of pancreatic islet cell in rats [29]. Congruently, 14 days of oral pretreatment with 25 and 50 mg/kg alkaloid fraction of *H. umbellata* markedly improved the histological lesions of fatty hepatic degeneration induced by triton WR-1339 (200 mg/kg *i.p*) [71]. The possibility of the fruit pulp to elicit sub-acute toxicity was evaluated by Igbe et al. [37]. The aqueous extracts (200, 400, and 800 mg/kg) was administered for 28 days in both sexes of animals. The effect of the extract on all doses on biochemical and serum electrolytes indices vis-à-vis the control was insignificant. At the highest dose of 800 mg/kg, parameters such as creatinine, urea, bicarbonate, total protein, ALP, AST, total albumin, ALT, glucose, conjugated bilirubin in the female and male animals measured (0.29 and 0.31 mg/dl), (27.10 and 27.00 mg/dl), (26.20 and 24.20 mMol/L), (6.60 and 5.60 mg/dl), (18.40 and 17.80 mg/dl), (134 and 135 IU/L), (0.22 and 0.20 mg/dl), (45.50 and 48.30 IU/L), (102.12 and 100.44 mg/dl) (0.12 and 0.11 mg/dl) respectively [72]. Further histological assessment of the kidney, liver, and lungs revealed a protective effect of 800 mg/kg extract on the tissues. The data from the study concluded that sub-acute administration of aqueous fruit pulp extract is nontoxic, and no observable changes in the values of hematological parameters such as

hemoglobin, hematocrit, red blood cells, white blood cells, platelets, mean platelet volume, granulocytes count, monocytes/eosinophil, lymphocytes, mean corpuscular volume, mean corpuscular hemoglobin concentration, red cell distribution width was detected [37]. Nonetheless, Edosuyi et al. [33] observed an increased platelet aggregation, suggesting that prolonged usage of the aqueous stem bark extract might be a risk factor for thrombotic complications. In 28 days sub-acute toxicity study, the aqueous stem bark extract (150, 300, and 600 mg/kg) was observed to be toxic [33]. Histological examination revealed changes such as irregular glomeruli in the kidneys and the architectural configuration were not observed in control but seen in the heart, liver at 300 and 600 mg/kg water extract-treated animals. Alveolar hemorrhage and edema mild vascular congestion observed in the lungs and spleen respectively were not present in the control animals. A significantly increased creatinine value in 300 and 600 mg/kg extract exposed rat which was significantly greater than control animals is suggestive of damaged functioning nephrons [33]. Increased mean corpuscular hemoglobin, reduced lymphocyte and red blood cells observed in the study are characteristic of macrocytic anemia. The extract significantly increased the activity of aspartate aminotransferase at 300 and 600 mg/kg which corroborated the mild liver inflammation observed in the histopathology diagnosis [33]. Contrastingly, a 24-h acute toxicity study by Igbe et al. [28] established that no adverse effect on hematological parameters such as white blood cell count and hematocrit values or mortality was detected in all aqueous seed extract (10, 12.5, 15 and 17.5 g/kg) treated group. As reported by Longe et al. [30], extensive treatment of alloxan-induced diabetic rats with methanol seed extract (100 and 250 mg/kg), revealed that the extract at 100 mg/kg conferred a more potent hepatic protection in the diabetic rats. Comparatively, elevated values of AST, ALT, ALP, and total bilirubin were abrogated in the untreated animals from 15.60 U/L, 14.10 U/L, 92.10 U/L, and 0.76 mg/dl to 10.10 U/L, 11.10 U/L, 78.10 U/L and 0.59 mg/dl in the treated rats [30]. As demonstrated Edosuyi et al. [67], 14 days acute toxicity examination of 1000, 2000, 4000, and 8000 mg/kg stem bark water extract showed zero mortality of the treated mice. Toxicity signs and allergic reactions such as convulsion, diarrhea, Curtis anserina, sedation, horripilation, increased urination, and tremors were not exhibited by any animals in the different dosage groups. Intraperitoneal administration of the aqueous seed extract was analyzed for acute toxicity using Weibull and Probit mathematical tests. The result suggests that the mean lethal dose of extract was 1660 mg/kg and 1614 mg/kg respectively for the two mathematical models [76]. Dismayingly, a very high mortality rate of 80 and 100%

was observed at 1.8 and 2.0 g/kg extract-treated animals. Probit scores of 3.04, 5.25, 5.84, and 6.90 were recorded at 1.4 g/kg, 1.6 g/kg, 1.8 g/kg 2.0 g/kg extract dose respectively, indicating the slight toxicity of the extract considering the route of administration [76]. On the other hand, an acute oral toxicity study in Swiss albino mice showed no mortality after 24 h of exposure to aqueous seed extract (1, 5, 10, and 15 g/kg), and no signs of delayed toxicity were exhibited 2 weeks post-treatment [37].

Cytotoxic and anti-carcinogenic property

As reported by Engel et al. [43], *H. umbellate* methanol leave extract (10 g/ml) showed a 6% proliferative effect on breast cancer cell line BT-20. However, no in-vitro effect on breast cell line MCF-7, osteocarcinoma cell lines MG-63 and Saos-2 were demonstrated.

Anxiolytic and anti-angiogenic property

The efficacy of *H. umbellate* aqueous seed extract to reduce and relieve anxiety in rats using the open field and dark-light box tests was carried out by Adeneye et al. [42]. It was recorded that the animal given 100 mg/kg extract spent more time in the compartment and less time in the dark compartment which was significant ($p < 0.05$) than the control animals. Moreover, extract-treated animals showed more confidence by expressing less aversion for open spaces. The extract treated animals exhibited significantly ($p < 0.05$) enthusiastic, explorative, less anxious tendency by entering into more squares, and this was more significant than the control animals. Adeneye et al. [42] credited the observed anti-anxiogenic activity to phytochemical compounds contained in the plant extract.

Hematopoietic property

The potential of aqueous seed extract (50, 100, 200 mg/kg) to improve hematological profile in rats was evaluated by Adeneye et al. [45]. In the 28 days study, 200 mg/kg extract-treated rats recorded the highest immuno-stimulatory and positive increase in some blood parameters. Significant ($p < 0.05$) increase in hemoglobin (Hb) (15.2 g/dl), pack cell volume (PCV) (47.9%), platelet count ($764.30 \times 10^3 \mu\text{l}$), total leucocyte count ($18.5 \times 10^3 \mu\text{l}$) and lymphocyte differential (90.6%) were noticed. Furthermore, it was observed that co-administration of cyclophosphamide (30 mg/kg *i.p*) and aqueous seed extract significantly increased red blood cell (RBC), Hb, PCV in rats. A non-significant increase in mean corpuscular volume (MCV) and mean corpuscular hemoglobin concentration (MCHC) was also noticed [45]. Cyclophosphamide is a known anti-cancer drug, albeit deleterious effect on proliferating tissues such as the bone marrow, thereby indirectly lowering the

formation and division of blood cells [77, 78]. Based on the elicited activity, it was concluded that the seed extract can be handy in preventing drug-induced anemia [45]. Corroborative, it was extrapolated from 14 days experiment by Longe and Momoh [44] and Longe et al. [41] that methanol seed extract exhibited significant hematopoietic effect by increasing RBC, PCV, and Hb values in diabetic rats.

Nutritional property

Nutritional analysis of dried seeds of *H. umbellata* showed that it contained important dietary nutrients and molecules [46]. Proximate composition of the dried seed revealed the presence of moisture (9.57%), crude protein (13.65%), crude fiber (26.79%), crude fat (14.97%), and carbohydrate (43.28%). Important micro and macro elements such as calcium (76 mg/100 g), magnesium (180 mg/100 g), potassium (1130 mg/100 g), sodium (87.50 mg/100 g), iron (60 mg/kg), and manganese (5 mg/100 g) were identified from the elemental analysis, while, ascorbic acid was present in a trace amount of 0.15 mg/g. The availability of inorganic elements such as carbon (52.10%), nitrogen (7.14%), and oxygen (34.3%) was also confirmed [69]. As established by Badejo et al. [79], soxhlet extracted oils from dehulled seeds of *H. umbellata* had low acid (5.61–23.00 mgKOH/g) and peroxide values (4.00–7.20 Meq/kg), which were also comparable with palm kernel oil [80]. The observed physicochemical parameters indicated the high stability and low rancidity susceptibility of the oils over a long period of time [79].

Non-pharmacological activity

Alamneme et al. [81] extensively reported that sulfuric (H_2SO_4) and hydrochloric acid (HCl) extracts (0.1–0.5% v/v) of *H. umbellata* seed husk inhibited steel rod (Fe = 98.3%, C = 0.133%, P = 0.0061%, Mn = 0.82%, Cr = 0.08%) corrosion. There was a significant reduction in the loss of the metal mass in presence of the extracts compared to the control. Moreover, scanning electron micrograph (SEM) and surface morphology observation indicated that mild steel immersed in the acid media in the absence of the extracts showed corrosion pits and a high degree of localized corrosion attack. Adsorption spectroscopy depicts that the amount of Fe^{2+} dissolved in the electrolyte was inversely proportional to extract concentration. This further suggests that the mechanism of corrosion inhibition of *H. umbellata* was through adsorption of the extract molecules and formation of protective film on the metal surface, consequently leading to a reduction in the rate of metal dissolution. However, HCl extracts showed better activity than the H_2SO_4 counterpart. Fourier transform infrared spectroscopy (FTIS) of the extracts and corrosion by-products showed the presence of oxygen and nitrogen atoms in the

functional groups which mimic the structures and features of known anti-rust agents [82].

Clinical studies

There is a dearth of literature on clinical studies on the biological and pharmacological activity of morphological organs of *H. umbellata*. Notwithstanding, the anti-diabetic efficacy of *H. umbellata* aqueous seed extract was observed in 5 patients with Type 1 diabetes mellitus. An average fasting blood sugar (FBS) of 180 mg/dl was recorded in the first week of the experiment. It was deduced that treatment with 1 oz. shot of the extract, twice per day for 21 days attenuated the average FBS to 88 mg/dl in diabetic patients. The researchers inferred from the result that the extract is twice potent as metformin (500 mg) in the treatment of diabetes mellitus. Data interpretation from the study concluded that metformin cures diabetes mellitus in 8 weeks, while *H. umbellata* aqueous seed extract attains a more effective result in about 3 weeks. Biometric analysis of the study concluded that the extract was better than metformin by a factor of 2.67 [83].

Conclusion

From the review, it can be inferred that numerous and bioactive principles with known biological usefulness are present in the extracts of *H. umbellata*. There is no paucity of scientific information on the plant as seen from the arrays of documented and reported pharmacological activity elicited by the plant, which can be attributed to many of these active compounds acting singly or synergistically. Amongst the morphological organs, it was deduced that the aqueous extract of the seed is non-toxic, with potent and widest range of biological activities. On the other hand, the stem extracts were noted to be more toxic and caution should be taken in its consumption. Conclusively, more clinical research and studies should be carried out to explore the seed for its arrays of biological potential, especially the hypoglycemic activity.

Abbreviations

GC-MS: Gas Chromatography Mass Spectrophotometry; FBG: Fast Blood Glucose; PPAR- γ : Proliferator-Activated Receptor Gamma; FRAP: Ferric Reducing Anti-oxidant Power; TBARS: Thiobarbituric Acid Reactive Species; MBC: Minimum Bactericidal Concentration

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Authors' contributions

OSO and OSF conceived the idea, OSF and PIA outlined the content, PIA and OSF searched the internet. AZA and OSF wrote the manuscript, OSF and DOA edited the manuscript. All authors read and approved the final manuscript for submission. All authors reviewed and approved the final manuscript.

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Competing interests

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