Chapter

Pharmacological Potentials of Ginger

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Abstract

Zingiber officinale, belonging to the family Zingiberaceae, is a popular spice and herb used as delicacy and to manage numerous diseases such as diabetes, hypertension, cancer, ulcer, diarrhea, cold, cough, spasm, vomiting, etc. in folk medicine from China, India, and Arabia Peninsula to other continents of the world including Africa (Nigeria, Egypt, and so on). Though this review is aimed at summarizing the pharmacological potentials of this well-endowed spice, interestingly, we found out that these reported ethnobotanical uses are attributed to a number of inherent chemical constituents including gingerol, 6-, 8-, 10-gingerol, 6-shogaol, 6-hydroshogaol, oleoresin, etc., eliciting various pharmacological effects, not limited to antioxidant, antitumor/anticancer, anti-inflammatory, antihyperglycemic, antihypertensive, anticholesterolemic, antibiotic/antimicrobial, neuroprotective, antiulcer/gastroprotective, antiemetic, hepatoprotective, and antiplatelet aggregation, safety profiles established through a number of studies (in vitro, in vivo, and cell lines), though some of these potentials are yet to be explored. Sadly, even few of these established effects are yet to be experimented in clinical trials, and only until these are intensified would there be prospect toward drug development for preventive and curative treatments. In conclusion, we are able to highlight and sum up the therapeutic implications of ginger and its related derivatives in the management of ailments confronting humanity.

Keywords: ginger, spice, pharmacological potentials, gingerol, 6-, 8-, 10-gingerol, 6-shogaol, 6-hydroshogaol, oleoresin

1. Introduction

Ginger (*Zingiber officinale* Roscoe) is a well-known herbal spice believed to have originated from either India [1] or Southeast Asia [2]. It is a sterile plant, thus reproduced by rhizomes, not by seeds [3], and grows well in tropical and subtropical regions of the world [4]. It is used for culinary purposes, as a seasoning or condiment and as a therapeutic agent [5]. It is known to be an effective spasmolytic, antipyretic, antiemetic, antioxidant, antiulcer, analgesic, hypotensive, antidiabetic, and anti-inflammatory agent [6, 7] containing scented essential oils and spicy oleoresins [8]. Ginger has long been in use therapeutically and currently still validated as a potent medicinal spice for the treatment of various ailments. Indigenously, it has been used against colds [9], sore throats [10], and *Staphylococcus aureus* [11] and tested effectively against cancer cells [12]. Ginger can be used as a dietary

supplement and as additives in the production of various snacks and merchantable products [13]. Additionally, it is considered a safe herbal drug [14], as the spices have been categorized to be generally regarded as safe: "GRAS."

2. Botanical description, occurrence, and distribution

Zingiber officinale (Roscoe), ginger of the family Zingiberaceae, is an herbaceous (available as rhizomes) perennial plant growing as tall as 90 cm. The leaves, lanceolate, appear to be simple, alternate, distichous, narrow, long possessing sheathing bases with 2–3 cm broad, while the rhizomes (7–15 cm long and 1–1.5 cm broad) are aromatic, thick lobed with pale yellow coloration. The flowers are small, have calyx that are lofty, have sepals very united, are three toothed, and split open on a side with three subequal corolla forming an oblong to lanceolate connate segment with green coloration [15, 16]. Ginger give rise to numerous lateral clump shoot which on maturation appeared dry. Ginger originate from Southeast Asia predominately in India but now well distributed or cultivated in China, Bangladesh, Australia, and Nigeria [17].

3. Ethnobotanical uses

Ginger had been used medicinally since time immemorial with documented use from Sanskrit, Chinese, Greek, Arabic, and Roman ethnomedicine book. However, in the ninth century, Europe recognized the indigenous use of this wonderful spice, and England followed suit in the tenth century. Ginger is used in folkloric medicine for indigestion, high blood pressure, arthritis, intestinal and throat infections, vomiting, nausea, lung diseases, cold, cough, pain, swellings, etc. [15, 17, 18]. Other nutritional uses are found in condiment, beer, wine, and so on [18].

4. Phytochemistry of ginger

Ginger, a spice of diverse health benefits, has been found to be rich in nonnutritive and biologically active compounds known as phytochemicals [19, 20], which have been linked to its health functions. The nutritional and therapeutic values have been recognized in its nutraceutical benefits linked to the presence of certain phytochemicals contained in it. The use of ginger as a nutraceutical agent is not only attributed to its health-augmenting benefits but also to its availability, affordability, and safety.

More than 400 compounds have been found in the chemical analyses of ginger [21]. These compounds includes alkaloids; saponins; flavonoids; steroids; tannins; carbohydrates; glycosides; proteins; amino acids; dietary fiber; ash; phytosterols; vitamins A, B, and C; minerals; and terpenoids [22–24] while detected to be devoid of acid compounds and reducing sugars [23].

The main components of the ginger rhizome are in the order carbohydrates, lipids, terpenes, and phenolic compounds [25]. The terpenes and the phenolic compounds make up the two foremost classes of phytochemicals in ginger [26]. Phenolic compounds of ginger are also referred to as its nonvolatile components, which have been incriminated in its pharmacological activity. They consist of gingerols and its 6, 8, and 10 derivatives and the corresponding series of homologous shogaol and zingerone, obtained from heat or alkali treated gingerols [26]. Shogaol, paradol, and gingerols have been depicted to be responsible for the pungent taste and smell of ginger [1, 27]. The terpene components of ginger, sesquiterpenes and

monoterpenes, are believed to be the volatile fractions [27]. The sesquiterpenes are thought to be a major contributor to the savor of ginger, while the monoterpenes are referred to as the most abundant terpenes in fresh ginger oil [24]. The main sesquiterpenes, zingiberene and β-bisabolene, are responsible for its aromatic scent, while others include α-farnesene, β-sesquiphellandrene, and α-curcumene [21].

Phenolic compounds of ginger are majorly derived from fresh ginger rhizomes, while the terpenes are derived from distillation of ginger oils [26] although their quantity has been found to vary depending on the region of germination. This may be dependent on climate or edaphic conditions as well as genetic variations [28]. The pungent compounds (gingerols, methyl gingerols, shogaols, paradol, and gingerdiones), volatile oil, and other compounds extracted by means of ethanol or acetone constitute the oleoresin [29, 30]. Volatile oils are about 1–4%, lipids about 6–8%, proteins about 9%, and carbohydrates about 50–80% [28] while geraniol is the major essential oil derived in ginger [8].

Zingerone, geraniol, gingerols, shogaols, gingerdiols, gingerdiones, and dehydrogingerdiones have been reported to have antioxidant activity; 6-, 8-, and 10-gingerol and 6-gingerdiol possessed antifungal activity. While 6-gingerol had established antidiabetic and reno-protective activities, zingerone, 6-shogaol, 6-gingerol (anticancer, anti-obesity, and gastroprotective activities), and gingerol and its pungent derivatives (anti-inflammatory activity), 6-shogaol (analgesic, neuroprotective, and strong gastroprotective activities), 6-gingerol, and 6-shogaol, acted against platelet aggregation; 10-gingerol had larvicidal activity; and 6-, 8-, 10-gingerol possessed inotropic activity [24].

5. Pharmacological potentials

The review from most countries of the world such as Egypt [20], Korea [17], Pakistan [15], India [16, 31, 32], Oman [5], Brazil [33], Canada [34] etc. had established the pharmacological potentials of this popular plant, *Zingiber officinale* (Roscoe), used most times as spice. Additionally, while some reports centers on the action of ginger, others point to the effect of its active components as they target specific diseases including but not limited to diabetes [35], inflammation [25], cancer [22], emetics [36], nausea and vomiting [37] and so on. Thus, the pharmacological potentials (antioxidant, anticancer, antitumor, anti-inflammatory, antihyperglycemic, antihypertensive, anticholesterolemic, antimicrobial, neuroprotective, antiulcer, antiemetic, hepatoprotective) and toxicity profiles of ginger as submitted in these reports are presented one after the other below.

5.1 Antioxidant

The overproduction of free radicals (ROS) in situation where the antioxidant defense mechanism is compromised results into a state of oxidative stress. In order to overcome the excessive free radical (FR) generation and oxidative stress, antioxidants play an important role. Numerous medicinal plants (MPs) and/or their constituents have established their prominence in preventing the onset of diseases particularly those triggered by FR. Ginger, a good example of MPs with excellent antioxidative effect, has been found to exert this action by lowering peroxidation of lipid such as the inhibition of ascorbate/ferrous complex in rat liver microsomes as cited by Rahmani et al. [20] and Mele [17] in the report of Reddy and Lokesh [38] using a concentration of 150 mM (**Table 1**). Ginger or its derivatives (extracts, compounds, or active components) and gingerol are found to have good scavenging effect against superoxide anion and hydroxyl radicals [63–65]. In fact, further

Ginger/derivatives	Potentials	Assay(s) employed	Type of study	Concentration(s) tested	Extracts (if any)	Country (where the report is published)	References
Ginger	Antioxidant	Lipid peroxidation	In vivo (rats)	150 mM	NI	India	Reddy and Lokesh, [38]
Ginger extracts	Hepatoprotective	Thioacetamide-induced (200 mg/kg i.p)	In vivo (rats)	250, 500 mg/kg	Ethanol	Malaysia	Bardi et al., [39]
Ginger extracts	Antiproliferative	Hep G2 cells	Cell lines	NI	Ethanol	Malaysia	Bardi et al., [39]
6-gingerol	Antioxidant, anti-inflammatory	UVB-induced intracellular reactive oxygen species levels	In vitro and in vivo (mice)	NI (200 μL)	Acetone	South Korea	Kim et al., [40]
Ginger	Antioxidant, antidiabetic	MDA, FRAP streptozotocin-induced	In vitro and in vivo (rats)	5% ginger in daily foods	NI	Iran	Afshari et al., [41]
Oleoresin, 6-gingerol, 8-gingerol, 10-gingerol, 6-shogaol, 6-hydroshogaol	Antioxidant, antimicrobial, anti-inflammatory	Nitric oxide, ABTS, DPPH, Disc diffusion	In vitro	NI	NI	India, Algeria	Dugasani et al., [42]; Li et al., [43]; Bellik, [44]
Ginger	Anticancer (prostrate and liver)	0.1% ethionine-induced	In vitro and in vivo	100 mg/kg	NI	USA, Malaysia	Karna et al., [45]; Habib et al., [46]
Ginger extracts	Anticancer (pancreas)	Panc-1 cells	Cell lines, in vivo	NI	Ethanol	Japan	Akimoto et al., [47]
	Anti-inflammatory, analgesic, hypoglycemic, safety profile	Hind paw	In vitro and in vivo	50–800 mg/kg	Ethanol	South Africa	Ojewole, [48]

Ginger/derivatives	Potentials	Assay(s) employed	Type of study	Concentration(s) tested	Extracts (if any)	Country (where the report is published)	References
Ginger oil	Antiarthritis, anti-inflammatory	Hind paw	In vivo	33 mk/kg	NI	Malaysia	Sharma et al., [49]
Ginger	Antidiabetic	Streptozotocin -induced	In vivo	100, 300, 500 mg/kg bw	Aqueous	Malaysia	Abdul Razaq et al., [50]
Ginger	Antidiabetic	Standard spectrophotometric methods (glycation inhibition, glucose diffusion)	In vitro	5, 10, 20, 40 g/L	Aqueous	Pakistan	Sattar et al., [51]
6-gingerol	Antidiabetic	Streptozotocin-induced	In vivo	25, 50 mg/kg bw	Aqueous	Malaysia	Sukalingam et al., [52]
Ginger, 6-, 8-, and 10-gingerol, while 6-shogaol	Antihypertensive	Pentothal -induced	In vivo	3–10 mg/kg	Aqueous	Pakistan	Ghayur et al., [53]
Ginger	Anticholesterolemic	NI	In vivo	50, 500 mg/kg	Aqueous	Kuwait	Thompson et al., [54]
Ginger	Antibacterial	Disc diffusion	In vitro	0.125, 0.25, 0.5, 1.0% 35.25, 75, 250, 500 mg/ml 20, 40, 60, 80, 100 g/ml	Ethanol, ethyl acetate, n-hexane aqueous, ethanol aqueous, ethanol	Nigeria Nigeria	Malu et al., [55] Ekwenye and Elegalam, [56] Sebiomo et al., [57]
Oleoresin, essential oil	Antifungi and antibacterial (antimicrobial)	Disc diffusion	In vitro	NI (3 uL)	NI	Algeria	Bellik, [44]

Ginger/derivatives	Potentials	Assay(s) employed	Type of study	Concentration(s) tested	Extracts (if any)	Country (where the report is published)	References
Ginger	Neuroprotective	Monosodium glutamate-induced	In vivo	100 mg/kg	Aqueous	Saudi Arabia	Waggas, [58]
Ginger 6-gingerol	Gastroprotective	HCl-ethanol induced	In vivo	1000 mg/kg 100 mg/kg	Acetone	Japan	Johji et al., [59]
6-gingerol, 6-shogaol	Gastric suppression	Hexobarbital induced	In situ	1.75–3.5 mg/kg (i.v), 70–140 mg/kg (oral)	NI	Japan	Suwekawa et al., [60, 61]
Ginger	Hepatoprotective	Carbon tetrachloride-induced Acetaminophen-induced	In vivo In vivo	100 mg/kg (singly), 50 mg/kg (combination with 100 mg/kg curcumin) 200, 400 mg/kg	NI Aqueous ethanol	Egypt India	Abdullah et al., 2016 Ajith et al., [62]

NI: Not indicated

Table 1.
Pharmacological potentials of ginger and its derivatives.

reports indicated that upon further heating (ginger), this activity remained unaffected [66]. Furthermore, it diminishes the ultraviolet B (UVB)-induced intracellular reactive oxygen species (ROS) and cyclooxygenase (COX)-2 in in vitro and in vivo studies [40]. Other derivatives of ginger such as oleoresin, 6-shogaol, 6-dehydroshogaol, 1-dehydro-6-gingerdione, 6-gingerol, 8-gingerol, 10-gingerol, and essential oil possess pharmacological activities such as antioxidant, antimicrobial, etc., against 2,2-azino-bis-3-ethylbenzothiazoline-6-sulfonic acid (ABTS), 1,1-diphenyl-2-picrylhydrazyl (DPPH), hydroxyl radical, and microbial strains such as *Bacillus subtilis*, *Bacillus cereus*, *Staphylococcus aureus*, *Escherichia coli*, *Candida albicans*, *Penicillium* spp., and *Aspergillus niger* [42–44].

5.2 Antitumor/anticancer

Cancer is one of the noncommunicable diseases with great negative impact on global population. It is caused by persistent increase in abnormal human body cells leading to the formation of tumors (of malignant cells) with the possibility to be metastatic [67]. The continuous multiplication of these cells is sometimes associated to influence oxidative stress. A number of treatment (chemotherapy, radiotherapy, synthetic drugs, etc.) are currently available; however, they come with one or several side effects (nausea, hair fall), hence, the need for alternative form of treatment or therapy particularly from MPs. In recent times, quite a number of plant species had found their relevance in the prevention and treatment of cancer, and efforts of researchers to continually develop new moieties are overwhelming. Ginger is a great example of such MPs with excellent prophylactic and curative anticancer properties. Although it must be noted that these effects are not available for all cancer types, several reports on ginger and its derivative (gingerol) have established numerous effects on different types of cancer (lung, colon, ovarian, prostrate, etc.) in a study conducted in the United States by Karna et al. [45] however, daily oral administration of ginger at a concentration of 100 mg/kg body weight (bw) inhibited PC-3 xenograft growth, indicating its effect against prostate cancer in vitro and in vivo. Additionally, the same concentration in another study [46] reduced the increased activity of tumor necrosis factor-alpha (TNF-α) due to the blockage of rat's liver cancer. Its effect on Panc-1 cells and other cell lines in an in vitro and animal model had been established against cancer of the pancreas, while combining the spice with other spices such as garlic and turmeric provided effectiveness against breast cancer [68]. In line with the aforementioned effects, derivatives of ginger, e.g., 6-shogaol, 8-shogaol, 10-shogaols, 6-gingerol, 6-paradol, and zingerone in several studies had also exhibited activities against different form of cancer including lung, colon, colorectal, ovarian, prostrate as cited by Rahmani et al. [20] and Gunathilake and Rupasinghe [34] from numerous studies. Interestingly, ginger was also reported to hinder tumor growth achieved through different molecular mechanism such as upregulation of suppressor gene, apoptosis, induction, and inactivation of vascular endothelial growth factor (VEGF) (molecular pathways), a tumor angiogenic factor that triggers tumor development and progression [20].

5.3 Anti-inflammatory

Inflammation is a response (defense) felt by the body to dangerous stimuli such as injury to tissues or allergens. However, when these responses are beyond normal, it manifest into arrays of derangements including but not limited to allergies, cancer, autoimmune disorder, metabolic syndrome, and cardiovascular diseases [69]. Interestingly, there are reports of relationship between oxidative stress-triggered FR

and inflammation. The use of nonsteroidal anti-inflammatory drugs (NSAIDs) is employed to ameliorate acute and chronic types of inflammation. NSAIDs exhibit this action by inhibiting the enzyme (cyclooxygenase, COX 1 and 2, and/or lipoxygenase, 5, 10, 15) involved in the breakdown of arachidonic acid to prostaglandins. Unfortunately, there are numerous side effects emanating from the use of NSAIDs, hence the search for alternative form of treatment with minimal or no side effects in natural products. Intriguingly, numerous MPs have shown to be effective against inflammatory diseases. Ginger, an example of such MPs including its derivatives, has been reported to possess anti-inflammatory potentials [17] in vitro and in vivo studies [34]. Ojewole [48] submitted the analgesic, anti-inflammatory, hypoglycemic, and safety effect of ginger extract at a dose range of 50–800 mg/kg bw (**Table 1**). Thirty-three mg/kg bw ginger oil given to rats also alleviated acute and chronic arthritis [49]. Interestingly, ginger exhibits its anti-inflammatory activity in other solvents aside water (used in folkloric medicine), as the reports of Rani et al. [70] corroborate this when ethyl acetate-extracted ginger revealed the best anti-inflammatory effect better than water, methanol (polar solvents), and hexane (nonpolar) against cyclooxygenase and lipoxygenase known as anti-inflammatory enzymes as cited by Gunathilake and Rupasinghe [34] and Mele [17] from various reports. Additionally, ginger plays a very good role in regulating the release of mediators (nitric oxide, prostaglandins), cytokines, TNF, and interleukin (IL)-1, IL-8, via several biochemical pathways attributed to inflammation, etc. [17, 20, 25, 33, 34].

5.4 Antihyperglycemic

Diabetes mellitus (DM) is one of the noncommunicable diseases with major prevalence globally. It is an endocrine disorder or metabolic derangement characterized by hyperglycemia (elevated level of glucose in the blood) due to insufficient or ineffective insulin arising from abnormalities in carbohydrate, lipid, and protein. The treatment or management of DM could be non-pharmacological (exercise, dietary regimen) or pharmacological which entails the use of oral hypoglycemic agents (OHAs) such as sulphonyl ureas, biguanides, and so on. However, the use of these chemicals or synthetic agents is prone to side effects (obesity), unavailability, and unaffordability, hence the dire need for alternative form of treatment with little or no side effects. Surprisingly, these qualities are now found in medicinal plants. In fact, the World Health Organization in a number of their technical reports advocated and encouraged the use of MPs for diabetic control and management. It is interesting to note that quite avalanches of MPs have found their relevance as antidote to curing diabetes [71] and some of its related complications. Ginger is one of such MPs traditionally used to salvage diabetes. In fact, numerous reports are available in the literature [17, 34, 35] establishing the potential of this spice in in vitro and in vivo studies. A similar example is the report of Ojewole [48] as submitted previously in a section (above) of this report. Similarly, 500 mg/kg bw of its aqueous extract lowers plasma sugar level following streptozotocin induction [50] in animal model and in vitro [51]. Since there is a report of correlation between oxidative stress and DM [20] as well as other complications of DM such as hyperlipidemia, hypercholesterolemia, retinopathy, and neuropathy, various publications had revealed the potentials of ginger and its derivatives against these complications as cited by Gunathilake and Rupasinghe [34].

5.5 Antihypertensive

Hypertension, a silent killer (because it shows no symptoms), is characterized by continuous increase in blood pressure in the arteries of a person. It occurs

when the systolic and diastolic blood pressures rise above 140/90 mmHg, respectively. Findings revealed excessive salt intake, smoking, alcohol consumption, narrowing of the kidney, and use of birth control pills as some of the causes of hypertension, a risk factor to many cardiovascular diseases (CVD). Like diabetes, the treatment option may be non-pharmacological (lifestyle modification, etc.) or pharmacological involving the use of synthetic moieties such as diuretics, beta blockers (atenolol), angiotensin-converting enzyme inhibitor (Lisinopril), calcium channel blockers, etc. [72]. However, sadly too, all these antihypertensive agents bring about grievous adverse effects such as angioedema, dry cough, weakness, headaches, etc.; thus, there is need for a substitute form of therapy for sufferers of high blood pressure (HBP). Herbal products from MPs have come very handy in the fight geared toward treating HBP, and a notable example of such plant is ginger. In a study involving rats and guinea pigs, extracts of ginger at concentration range of 0.3–3 mg/kg lower the arterial blood pressure of these animals [34]. Additionally, similar study using ginger aqueous extract and its derivatives revealed similar action [53] (**Table 1**). The activity of ginger as antihypertensive agent was also corroborated in a study [73] involving human subject when twice daily intake of 10 g of the spice reduced the arterial blood pressure to 94.80 mmHg after 2 months. It is worthy of mention that the mechanism of the established action of this spice was through the stimulation of muscarinic receptors and calcium channel blockage.

5.6 Anticholesterolemic

Cholesterol is a constituent of the plasma membranes (eukaryotic) representing sterols [74], needed for growth and development of higher organism. Hypercholesterolemia occurs when there is an elevated level of cholesterol though it suffices to say that there are good (high-density lipoprotein cholesterol (HDL-c)) and bad (low-density lipoprotein cholesterol (LDL-c)) cholesterol. Hypercholesterolemia is a risk factor to many diseases including CVD, atherosclerosis, myocardial infarction (MI), etc. [75] and there are reports of high level of cholesterol in the blood on the influence of excessive production of FRs [76–78]. The use of herbal medicines or MPs for therapeutic/curative or preventive measures against diseases is an age-long tradition [79]. Ginger is one of such herbal medicine with cholesterol-lowering properties. In a study by Thomson et al. [80] as cited by Gunathilake and Rupasinghe [34], oral administration of 500 mg/kg bw of aqueous extract brought down elevated level of cholesterol in Wistar rats. Another study using mice revealed a 29% reduction in the cholesterol level and other lipid profiles on the administration of 250 μmkg ethanolic extract studied on rabbits [81] and rats (100, 400 mg/kg bw) in a high-fat diet-fed rodents [82]. In the same vein, a study on human subject revealed a positive coadministration of atorvastatin (low dose) and ginger reducing cholesterol level in the blood particularly those subjects suffering from hepatic lesion or inflammation [83].

5.7 Antibiotic/antimicrobial

Infectious diseases are becoming the fastest cause of death globally. A number of bacterial etiological agents cause infections, and the use of antibiotics has become a panacea treatment to the ravishing effects of these microbiological agents. However, it is worthy of mention that the use of antibiotics despite their side effects is in recent times becoming ineffective due to the resistance of these microorganisms which is rapidly increasing [20]. In fact, as a result of these unpalatable trend in the antibiotics use, ongoing efforts have embraced the use of MPs in treating infectious

ailments, and a number of plants such as ginger are endowed with established antimicrobial effects as reflected in arrays of in vitro, in vivo, and preclinical studies using different solvents of extraction (ethanol, ethyl acetate, hexane) to inhibit microbial growth as presented by Rahmani et al. [20] and Gunathilake and Rupasinghe [34] from many submissions. Ginger derivatives such as 6-dehydrogingerdione, 6-gingerol, 10-gingerol, and 6-shogaol have established antibacterial effects against strains of bacteria and mycobacterial including *Acinetobacter baumannii*, *Helicobacter pylori*, *Mycobacterium avium*, and *M. tuberculosis* [17, 20, 34]. Interestingly, to corroborate the effectiveness of ginger and/or its derivatives, a report of potency surpassing common synthetic antibiotics in the fight against infectious diseases is noted [17, 34, 57].

5.8 Neuroprotective

Neuroprotection refers to the way and manner the central nervous system (CNS) is shielded from neuronal damages resulting from acute and/or chronic neurodegenerative disorders (such as stroke, Alzheimer's, Huntington's, Parkinson's diseases) as a consequence of CNS neurons breakdown and/or worsening of the cognitive or intellectual reasoning of the patients [84]. Intriguingly, the emergence of neurodegenerative diseases (NDD) is age-related, i.e., as individual age, so the possibility of suffering from NDD [85]. Medicinal plants such as ginger have continued to find its place in the management and/or treatment of diseases particularly NDD, and these effects are attributed to its inherent phenolic and flavonoid compounds [17, 20]. A root extract of ginger at 100 mg/kg bw extenuates the effect of monosodium glutamate-induced toxicity in rats (**Table 1**). The emergence or onset of many diseases is triggered by the production of FRs; similarly, since one of the complications of DM is neuropathy, hence, a relationship between FR, NDD, and diabetes is noted. Actually, ginger in separate studies was reported to promote or strengthen the antioxidant defense mechanism of the rat's brain following streptozotocin induction [86–88]. Furthermore, 6-shogaol was studied to inhibit microglia in transient global ischemia [89].

5.9 Antiulcer/gastroprotective

Ulcer (gastric or duodenal) is also a disease affecting majority of the populations of the world for more than ten (10) decades now [90], caused by discrepancies between the protective factors (bicarbonates, prostaglandins, mucin, nitric oxide) and aggressive factors (acid and pepsin) leading to a great deal of mortality and morbidity. Several factors [etiologic (*Helicobacter pylori*) or otherwise, e.g., sedentary lifestyle, diet, drug (NSAIDs), smoking, bacterial infection, free radicals, etc.] influence the emergence and/or progression of ulcer. The treatment involves the use of antimicrobial drugs (metronidazole, tetracycline, amoxicillin, etc.) geared toward eliminating *H. pylori*, antisecretory agents (omeprazole and so on), antagonist of H2 receptors (cimetidine, ranitidine, etc.), and other agents targeting the disruption of the cell wall or membrane of the bacteria (bismuth salt). However, these series of therapies bring about toxicities, thus the clamor for the alternative form of treatment with little or no toxicities, qualities found in medicinal plants such as ginger. The antiulcerative action of ginger is achieved via the elevation of mucin production [20] and enzyme (thromboxane synthetase) inhibition [17]. A number of studies proving the gastroprotective properties of ginger and some of its constituents such as 6-gingerol and 6-shogaol had been established as compiled or presented in the work of Rahmani et al. [20].

5.10 Antiemetic

Ginger in a study using rodents was found to possess anti-serotonin and 5-HT3 receptor antagonism effect in inducing nausea and vomiting during post-surgery [91]. Derivatives of ginger such as gingerol, shogaols, galanolactone, and diterpenoid were also established to reduce nausea and vomiting [92]. Others revealed that the reports of management of nausea and vomiting in cancer patients are also available in the literature [93].

5.11 Hepatoprotective

The liver is the second largest organ (after the skin) in the body where metabolism of drugs or chemical substance occurs. Hence, important attention is required for this organ for good health status and well-being. Liver ailments also constitute a major health problem in the world today caused sometimes by exposure or ingestion of toxic chemicals (carbon tetrachloride, thioacetamide, certain antibiotics, excessive alcohol intake, etc.), and the use of conventional drugs for the treatment of liver diseases is ineffective and comes with side effects. However, solace has been found with MPs such as ginger as alternative means to treating these ailments. Report of relief from liver cirrhosis following carbon tetrachloride-induced liver toxicity in rats as ginger singly or either in combination with curcumin at 100 mg/kg bw ameliorated the liver injury to the animal [94]. Additionally, ginger in another report at 200, 400 mg/kg bw fortified the activity of antioxidants enzymes (superoxide dismutase, catalase, glutathione peroxidase) while lowering the activity of liver function enzymes (alanine transaminase, aspartate aminotransferase) in the acetaminophen-induced hepatic injury [62] as also corroborated by Rahmani et al. [20] in several studies.

5.12 Toxicity profiles

Toxicity may be acute, subacute, chronic, and subchronic [95]. These studies are carried out to provide information about the safety profile of a substance. Medicinal plants are used as a form of therapeutic measure over a long period against numerous diseases. In fact, despite the fact that the active precursors of a number of chemical moieties or drugs are obtained from plant, the acceptance of herbal medicine and/or formulations are exceedingly growing globally. Intriguingly, 80% of the entire global population are using herbal products for the maintenance of their health due to their perceived thought of originating from nature, lesser side effects, efficacy, safety, affordability, etc., although in some quarters, a very few of these medicinal plants have been reported to cause one form of illness (to the liver and kidney). However, report from several studies has not linked ginger in a way to any of these injuries. This fact is corroborated in reports ascertaining the safety of ginger in different concentrations, 0.5–1.0 g, 2.5 g/kg, 100, 333, 500, 1000, 2000 mg/kg bw, in animal studies for different experimental study period ranging from 10 days, 35 days, 3 months to 2 and half years as nontoxic [20] even during pregnancy (rats) and gynecological operation as revealed by a clinical study [34].

5.13 Other pharmacological activities

The effectiveness of ginger against diseases affecting the eye and other ailments such as osteoarthritis, migraine attack, platelet aggregation, gastrointestinal disturbances, nematode invasion, etc. has been established [15, 17, 18, 20, 34].

6. Conclusion

The world is filled with enormous diseases causing major setbacks to the health status of humanity. Unfortunately, the synthetic moieties adopted for therapeutic and preventive measures are not helping (at all) as they are characterized with side effects. Medicinal plants such as ginger are now being embraced as the alternative options for combating various simple or life-threatening ailments. Since various efforts had established the effectiveness of ginger and its corresponding derivatives on a number of ill-health (though lacking clinical reports), there is much hope in the future that ginger might be able to rescue humankind from these evolving derangements causing setbacks to their living and/or survival.

Acknowledgements

The authors acknowledge Directorate Research and Development, University of Free State, South Africa, for the Postdoctoral Research Fellowship granted by Dr. FO Balogun tenable in the research group of Phytomedicine and Phytopharmacology at the Department of Plant Sciences, Faculty of Natural and Agricultural Sciences, University of the Free State, Qwaqwa, Free State.

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