PHARMA RESEARCH BULLETIN
Open Access Journal (ISSN: 2582-676X)

Review article
Volume 3, 2021, 18-29

Phytochemistry and Pharmacological Actions of Ginger: An In-Depth Review

Anmol Kaur [1], Shivani [1], Ajmer Singh Grewal [1*], Kumar Guarve [1]

[1] Guru Gobind Singh College of Pharmacy, Yamunanagar, Haryana, India

* Correspondence: ajmergrewal2007@gmail.com; ajmer.singh@gnkgei.ac.in

Received: 28 October 2021; Accepted: 18 November 2021; Published: 24 November 2021

Abstract: *Zingiber officinale* (generally known as ginger) is one of the utmost extensively employed herbs and food flavouring agents. *Z. officinale* belongs to the family Zingiberaceae which has over 1200 species in 53 genera. *Z. officinale* is widely used in traditional medicinal systems to treat a wide range of illnesses. In the last few decades, *Z. officinale* was extensively explored for its medicinal potential by innovative scientific methods and a diversity of bioactive molecules were derived from this plant and investigated pharmacologically. The present study is collective information concerning the phytochemistry and pharmacological activities of the herb *Z. officinale*.

Keywords: Ginger; Gingerols; Phytochemistry; Pharmacological actions; *Zingiber officinale*.

1. Introduction

Traditional medical systems have used herbs and plants as a source of therapeutic compounds for centuries. Traditional healthcare systems, as well as the herbal and pharmaceutical industries, rely heavily on medicinal plants. The therapeutic efficacy of these medicinal plants depends on the certain bioactive chemical compounds belonging to flavonoids, alkaloids, tannins, and phenolic class which produce a significant physiological action on the human body (Pieters and Vlietinck, 2005; Chopra and Dhingra, 2021; Katiyar et al., 2012). *Zingiber officinale* (family: Zingiberaceae) is one of the important medicinal plants with an array of nutritional and ethnomedicinal values therefore, widely used worldwide as a flavouring agent, spice and herbal medicine. Traditionally, it is used in Africans, Arabian, Ayurveda, Caribbean, Chinese, Siddha and many other medicinal therapies for the management of a variety of diseases such as asthma, constipation, cough, dyspepsia, indigestion, inflammation, loss of appetite, nausea, pain, palpitation and vomiting. *Z. officinale* has been intensively investigated for its therapeutic potential using cutting-edge scientific methods in recent decades. In addition, a wide range of bioactive chemicals have also been extracted from different plant parts and pharmacologically analysed (Anh et al., 2020; Li et al., 2019). This plant has been reported to possess analgesic, anticancer, antidiabetic, anti-inflammatory, antimicrobial, antioxidant, hepatoprotective, immunomodulatory, larvicidal and nephroprotective activities (Kiyama, 2020; Unuofin et al., 2021).

2. Taxonomy

Kingdom: Plantae
Division: Magnoliophyta
Order: Zingiberales
Family: Zingiberaceae
Genus: *Zingiber*
Species: *Zingiber officinale*

3. Vernacular Names

Zingiber officinale is commonly known as ginger in English. Other names of *Z. officinale* in different languages worldwide are listed in Table 1 (Kiyama, 2020).

Table 1. Vernacular names of *Z. officinale*.

Name	**Language**
Adrak	Urdu
Ada	Bengali
Adarakha	Hindi
Adi, Adrak	Punjabi
Adu	Gujarati
Aduwa, sutho	Nepali
Alla, Hasishunti	Kannada
Allamu, Allam	Telugu
Ardrak, Ale	Marathi
Gember	Dutch
Gemeiner ingber/ingwer	German
Gengibre/jengibre	Spanish
Gingembre	French
Ginger	English
Gingimbre	Caribbean
Imbir lekarski	Polish
Inchi	Malayalam
Injee, Allam, Lakottai, Inji	Tamil
Jahe	Indonesian
Katubhadra, Srngavera	Sanskrit
Khing	Thai
Saenggang	Korean
Sheng jiang	Chinese
Shokyo	Japanese

4. Geographical Coverage

Z. officinale is widely distributed in many countries in southern and eastern Asia, including India, China, Indonesia, Nigeria, Nepal, and Thailand. As far as the growing environment is concerned, it is typically found in tropical and subtropical climates. India produced 4.1 million tonnes of ginger globally, accounting for 44 percent of the total (Zanariah et al., 2015).

5. Morphology

The plant has fleshy, branching rhizomes and is between 0.5 and 1 metre tall (Figure 1). This plant possesses a strong scent and flavour. The leaves are sessile, attenuated to thin, and lanceolate or linear-lanceolate with an acuminate apex. The bracts are oblong, light green or yellowish at the margins, and mucronate at the apex of the ovoid inflorescence. The flower is yellowish-green with lanceolate lobes, and the calyx tube is approximately 1 cm long (Zanariah et al., 2015).

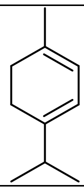
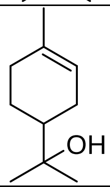
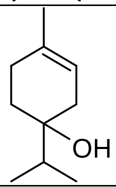
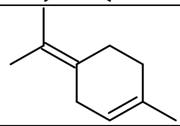
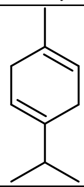
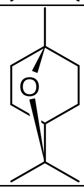
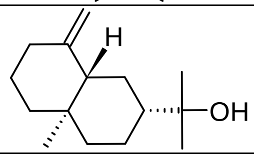
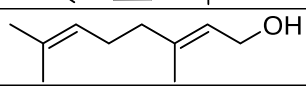
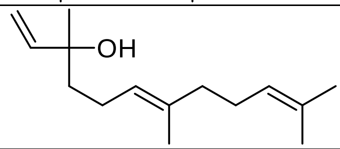
Ginger plant | **Ginger roots/rhizomes** | **Ginger dry extract**

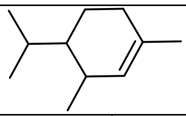
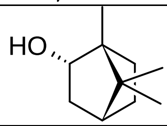
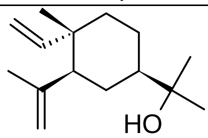
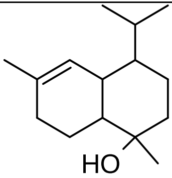
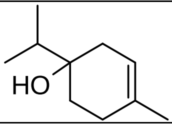
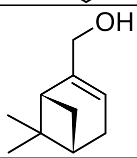
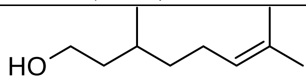
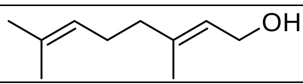
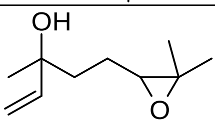
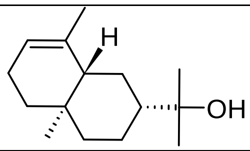
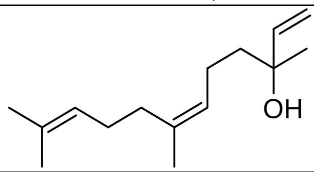
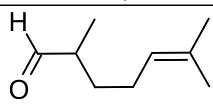
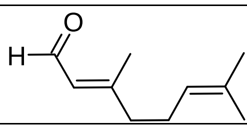
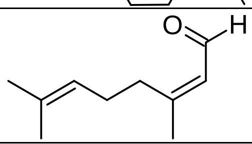
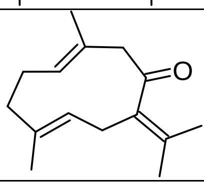
Figure 1. Morphology of *Z. Officinale* Rosce.

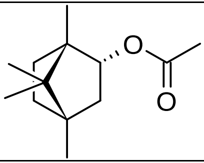
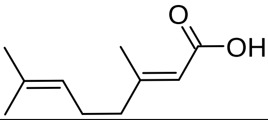
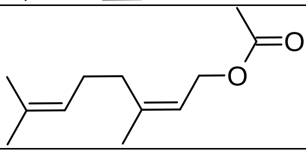
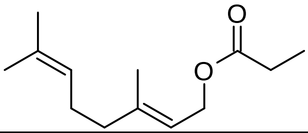
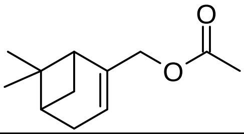
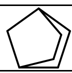
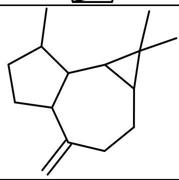
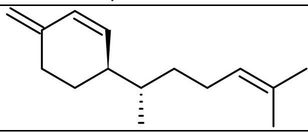
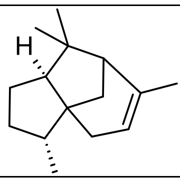
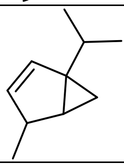
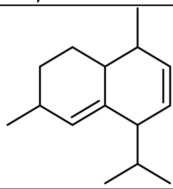
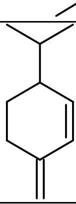
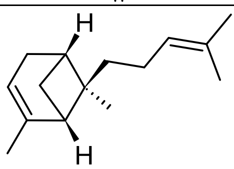
6. Phytochemistry

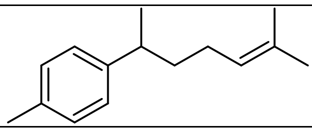
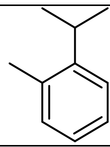
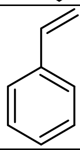
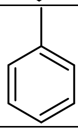
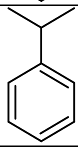
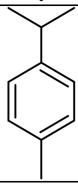
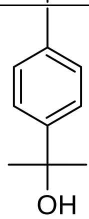
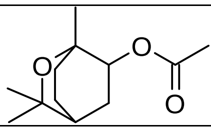
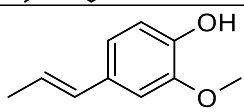
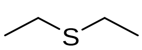
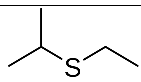
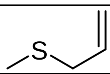
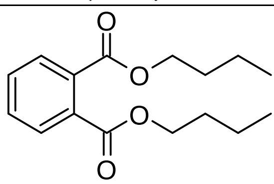
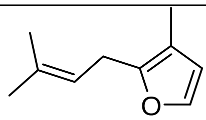
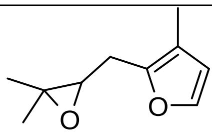
More than 100 chemical components that have been isolated from *Z. officinale* were found through a literature search. Gingerols, essential oils, diarylheptanoids, and others represented in Table 2 make up the majority of the ingredients. The blend of several compounds that make up *Z. officinale* a pungent component, collectively known as gingerol, which includes gingerdiols, gingerdiones, shogaols, paradols and zingerone. In addition to contributing significantly to the typical spicy flavour, gingerols are also essential for a number of biological processes. The functional group 3-methoxy-4-hydroxyphenyl is present in the structure of gingerols (Vedashree et al., 2020). Another important component of *Z. officinale* is an essential oil, which is mostly made of the compounds camphene, phellandrene and pinene (Liu et al., 2019). The plant contains 0.25 percent to 3.0 percent essential oil overall (Ma et al., 2004). In addition to the aforementioned, *Z. officinale* has also yielded phenylpropanoids, flavonoids, nucleosides, polysaccharides, proteins, cellulose, as well as a vast variety of carbohydrates and trace elements (Lin et al., 2010; Mao et al., 2019).

Table 2: Major phytoconstituents present in *Z. officinale*.

Chemical class	Compound	Structure	References
Terpenes	*α*-Terpinene		Tan, 2011
Terpenes	*α*-Terpineol		Tan, 2011
Terpenes	4-Terpineol		Tan, 2011
Terpenes	Terpinolene		Tan, 2011
Terpenes	*c*-Terpinolene		Tan, 2011
Terpenes	Cineole		Tan, 2011
Terpenes	*β*-Eudesmol		Tan, 2011
Terpenes	Nerol		Tan, 2011
Terpenes	*trans*-Nerolidol		Tan, 2011

Terpenes	*cis*-Piperitol		Tan, 2011
Terpenes	Borneol		Tan, 2011
Terpenes	Elemol		Tan, 2011
Terpenes	*tau*-Muurolol		Tan, 2011
Terpenes	1-Isopropyl-4-methylcyclohex-3-enol		Tan, 2011
Terpenes	Myrtenol		Tan, 2011
Terpenes	Citronellol		Tan, 2011
Terpenes	Geraniol		Tan, 2011
Terpenes	*cis*-Linalool oxide		Tan, 2011
Terpenes	*α*-Eudesmol		Tan, 2011
Terpenes	Nerolidol		Tan, 2011
Terpenes	2,6-Dimethylhept-5-enal		Tan, 2011
Terpenes	(*E*)-Citral		Tan, 2011
Terpenes	(*Z*)-Citral		Tan, 2011
Terpenes	Germacrone		Tan, 2011

Terpenes	L-Bornyl acetate		Tan, 2011
Fatty acids	Geranic acid		Tan, 2011
Terpenes	Neryl acetate		Tan, 2011
Terpenes	Geranyl propionate		Tan, 2011
Terpenes	Myrtenyl acetate		Tan, 2011
Terpenes	Bicyclo[2.2.1]heptanes		Tan, 2011
Terpenes	allo-Aromadendrene		Tan, 2011
Terpenes	*β*-Sesquiphellandrene		Tan, 2011
Terpenes	*α*-Cedrene		Tan, 2011
Terpenes	*β*-Thujene		Tan, 2011
Terpenes	Cadina-5,8-diene		Tan, 2011
Terpenes	*β*-Phellandrene		Tan, 2011
Terpenes	*α*-Bergamotene		Tan, 2011

Terpenes	*α*-Curcumene		Tan, 2011
Terpenes	*o*-Cymene		Tan, 2011
Terpenes	Styrene		Pang et al., 2017
Terpenes	Methylbenzene		Pang et al., 2017
Terpenes	Cumene		Govindarajan, 1982
Terpenes	*p*-Cymene		Lin and Hua, 1987
Terpenes	*p*-Cymen-8-ol		Tan, 2011
Terpenes	2-Acetoxy-1,8-cineole		Pang et al., 2017
Terpenes	Isoeugenol		Nishimura, 1995
Organo-sulphur compounds	Diethyl sulphide		Govindarajan, 1982
Organo-sulphur compounds	Ethyl isopropyl sulphide		Govindarajan, 1982
Organo-sulphur compounds	Methyl allyl sulphide		Govindarajan, 1982
Phthalates	Dibutyl phthalate		El-Ghorab et al., 2010
Furan derivatives	2-(3′-Methyl-2′-butenyl)-3-methylfuran		Nishimura, 1995
Furan derivatives	2-(2′,3′-Epoxy-3′-methylbutyl)-3-methylfuran		Nishimura, 1995

7. Ethnobotanical Uses

Ginger is crucial in the traditional Indian medicine system. Traditional Indian beverages contain it as an ingredient. Fresh ginger is one of the primary spices used in both vegetarian and non-vegetarian cuisines. Traditional medical treatment for cough and asthma consists of a mixture of fresh ginger juice, honey, and a small amount of fresh garlic juice (Kumar et al., 2011). In addition, It lessens all motion sickness symptoms, including cold sweats, nausea and vomiting (Yamahara and Huang, 1990). It exhibits larvicidal activity and supports immune system stimulation. Furthermore, it also demonstrated antimicrobial and antioxidant potential (Koshimizu et al., 1990).

8. Pharmacological Studies

In ayurvedic machines, ginger is used to remedy each communicable illness in addition to non-communicable illnesses. Ginger displays an exclusive pharmacological pastime (Table 3) which is very beneficial for the medicinal porous (Ali et al., 2008).

Table 3: Pharmacological action of *Z. officinale.*

Sr. No.	Pharmacological activity	Phytochemical	References
1	Anti-diabetic activity	6-Gingerol, gingerol, zingerone	Iranloye et al., 2011
2	Antioxidant activity	Gingerol	Iranloye et al., 2011
3	Anti-bacterial activity	6-Gingerol	Wang et al., 2020
4	Anti-diarrhoea activity	Zingerones, gingerols	Hosen et al., 2021
5	Cytotoxic activity	6-Gingerol, paradol	Jeena et al., 2011
6	Anthelmintic activity	Levamisole	Bazh and El-Bahy, 2013
7	Analgesic activity	Gingerdion	Funk et al., 2016
8	Anti-inflammatory activity	6-Shagaol, 6-gingerol	Funk et al., 2016
9	Hepatoprotective effect	Chlorogenic acid, hesperidin	Atta et al., 2010
10	Nephroprotective activity	Zingerone, 6-shagoal, 6-paradol	Afzal et al., 2001
11	Larvicidal activity	Gingerol	Afzal et al., 2001
12	Anti-tumour	6-Shogaol	Jeena et al., 2011
13	Anti-platelet activity	Gingerol, shogaol	Afzal et al., 2001
14	Anti-obesity	6-Shogaol, 6-gingerol	Afzal et al., 2001
15	Gastroprotective	Zingerone	Afzal et al., 2001
16	Asthma	Zingerone	Afzal et al., 2001
17	Anti-emetic	6-Gingerol	Afzal et al., 2001
18	Anti-melanogenesis	8-Gingerol	Afzal et al., 2001

8.1. Gastroprotective effects

In addition to being a common home treatment, ginger is extremely effective in treating a wide range of gastrointestinal conditions, such as belching, bloating, constipation, dyspepsia, epigastric discomfort, gastric ulcerations, gastritis, indigestion, nausea and vomiting. In animal experiments, ginger has also been found to be successful in preventing stomach ulcers. Additionally, numerous preclinical and clinical investigations have demonstrated that ginger has antiemetic properties against various emetogenic stimuli. However, conflicting results particularly in the management of chemotherapy-induced motion sickness, nausea and vomiting prevent us to make any clear conclusions on its effectiveness as a broad-spectrum antiemetic. Free radical scavenging, antioxidant, and lipid peroxidation inhibitory activities of ginger have been demonstrated, and these properties may have contributed to the observed gastroprotective benefits (Jeena et al., 2013; Zhou et al., 2006).

8.2. Anti-inflammatory activity

Ginger extracts had been previously confirmed through laboratory *via* the experimental version of rheumatoid arthritis, streptococcal mobileular wall (SCW) inflammatory results of ginger`s different secondary metabolites. Ginger essential oils avoided acute segments of joint swelling nor granuloma development at sites of SCW deposition in the liver. Pharmacological doses of 17-β estradiol elicited inflammation suggesting that essential oils might be performing as a phytoestrogen (Shen et al., 2005; Frondoza et al., 2004; Penna et al., 2003; Park et al., 1998; Casiraghi et al., 2007).

8.3. Antibacterial activity

The antibacterial potential of ginger essential oils was assessed by agar well diffusion and micro-broth dilution method on fish-borne pathogenic bacteria. In addition, the evaluation of *Z. officinale* and sweet orange (*Citrus sinensis*) revealed that *Bacillus subtilis* is the bacteria that is most susceptible to ginger extract. However, the essential oils failed in the impairment of *Aeromonas hydrophile* and *Vibrio parahaemolyticus*. Furthermore, Antibiotic-resistant *Yersinia enterocolitica* was found to be the most sensitive bacterial strain among tested gram-negative bacteria (Lei et al., 2017; De Jesus et al., 2020; Wood et al., 2010).

8.4. Anti-diabetic activity

Many species of the Zingiberene family, of which ginger is a part, are regularly reported for their anti-diabetic and hypoglycemic potential. According to research, ginger increases insulin sensitivity, action, and peripheral glucose utilisation *via* having regenerative effects on pancreatic cells. Other mechanisms include boosted hepatic expression of glycogen-regulating enzymes, decreased activity of carbohydrate-metabolizing enzymes, induced pancreatic insulin release, and reduced hepatic glucose generation (Sattar et al., 2012; Fajrin et al., 2020; Ademosun et al., 2021).

8.5. Anti-asthmatic

Ginger has been widely utilised in traditional medicine for the effective management of respiratory disorders. The ethanolic and aqueous extract of ginger rhizomes along with methylprednisolone were studied for the evaluation of anti-asthmatic activity in different animal models. Electrophoresis and ELISA were used for the evaluation of mRNA expression levels and protein levels of Th2-type markers, respectively. The ethanolic extract showed significant anti-asthmatic activity in mice (Khan et al., 2015).

8.6. Anti-fungal activity

Many common herbs have antimicrobial action because of their bioactive components, and several of them have emerged as novel potential anti-infective medicines. Only 0.3 % (*v/v*) concentration of ginger oil displayed complete inhibition against *Alternaria panax, Botrytis cinerea, Cylindrocarpon destructans, Fusarium oxysporum, Sclerotinia sclerotiorum*, and *Sclerotinia nivalis*. The findings of this study provide evidence that ginger essential oil is a potentially abundant source of natural antibiotics and may be used as an alternate anti-infective medication to combat the fungi that cause ginseng root rot (Cardile et al., 2009; Rahmani et al., 2014).

8.7. Antioxidant activity

Ginger showed significant anti-oxidant activity by inhibiting cyclooxygenase and lipoxygenase metabolites along with arachidonic acid. In addition, both shogaol and dehydroshogaol reduce NO production by inhibiting the LPS stimulated macrophages (Mashhadi et al., 2013; Dugasani et al., 2010; Semwal et al., 2015).

8.8. Anti-diarrheal activity

Ginger's antimicrobial profile and impact on the virulent epithelial cell colonisation and enterotoxemia of diarrheal pathogens were studied. *Z. officinale* didn't exhibit any antibacterial properties. Nevertheless, it prevented the synthesis of cholera toxin. However, there was a decline in the bacterial colonisation of HEp-2 cells. These findings suggested that *Z. officinale* affects bacterial and host cell metabolism to exert its anti-diarrheal effect (Hosen et al., 2021; Veena et al., 2021).

8.9. Cytotoxic activity

According to experimental research, 6-gingerol and 6-shogaol, two of the active components of ginger, have anticancer properties that are effective against gastrointestinal cancer. The anticancer potential of ginger is thought to be its capacity to modulate several signalling molecules, including NF-κB (Nuclear factor kappa B), STAT3 (signal transducer and activator of transcription 3), Nrf2 (nuclear factor erythroid 2-related factor 2), PI3K (phosphatidylinositol-3-kinase), MAPK (mitogen-activated protein kinase), Akt (Ak strain transforming), ERK (extracellular signal-regulated protein kinase) 1/2, TNF-α (tumour necrosis factor α), β-cell lymphoma protein 2 (Bcl-2)-associated X (Bax), COX-2 (cyclooxygenase-2), SAPK/JNK (stress-activated protein kinase /jun amino-terminal kinase), cyclin D1, CDK (cyclin-dependent kinase), MMP-9 (matrix metalloproteinase-9), BIRC5 (surviving), cIAP-1, XIAP (X-linked inhibitor of apoptosis), caspases-3, -9, p53, and other proteins regulating cell growth (Prasad and Tyagi, 2015; Park et al., 2014).

8.10. Anti-helminthic activity

Dried rhizomes of *Z. officinale* Roscoe and crude aqueous extract of the dried ground rhizomes showed anti-helminthic activity *in vitro* (Onyeyili et al., 2001).

8.11. Hepatoprotective effect

Methanolic extract from ginger significantly restored the carbon tetrachloride-induced changes in the biochemical and cellular constituents of blood. The main active constituents of the methanolic extract of ginger include alkaloids, carbohydrates, glycosides, tannins, flavonoids, saponins, unsaturated sterols and triterpenes. The histological analysis of liver tissue also supported the hepatoprotective activity of ginger extract (Mitra et al., 1998).

9. Conclusions

Ginger and its chemical constituent play a vital role in herbal and medicinal action in both communicable and non-communicable diseases. Ginger is now days widely used as herbal medicine and also, and it’s taken in the form of dietary supplements. Ginger was used as a herb product from ancient times. Different pharmacological actions of ginger were reported including anti-asthma, anti-emetic, antihypertension, antifungal, antibacterial, and other various effects. Ginger is also reported for its anti-oxidant, anti-tumour, anti-apoptosis, and anti-inflammatory actions.

Conflicts of Interest

The authors declare no conflict of interest.

References

Ademosun MT, Omoba OS, Olagunju AI. (2021). Antioxidant properties, glycemic indices, and carbohydrate hydrolyzing enzymes activities of formulated ginger-based fruit drinks. J Food Biochem, 45(3), e13324.

Afzal M, Al-Hadidi D, Menon M, Pesek J, Dhami MS. (2001). Ginger: an ethnomedical, chemical and pharmacological review. Drug Metabol Drug Interact, 18(3-4), 159-190.

Ali BH, Blunden G, Tanira MO, Nemmar A. (2008). Some phytochemical, pharmacological and toxicological properties of ginger (Zingiber officinale Roscoe): a review of recent research. Food Chem Toxicol, 46(2), 409-420.

Anh NH, Kim SJ, Long NP, Min JE, Yoon YC, Lee EG, Kim M, Kim TJ, Yang YY, Son EY, Yoon SJ, Diem NC, Kim HM, Kwon SW. (2020). Ginger on Human Health: A Comprehensive Systematic Review of 109 Randomized Controlled Trials. Nutrients, 12(1), 157.

Atta AH, Elkoly TA, Mouneir SM, Kamel G, Alwabel NA, Zaher S. (2010). Hepatoprotective Effect of Methanol Extracts of Zingiber officinale and Cichorium intybus. Indian J Pharm Sci, 72(5), 564-570.

Bazh EK, El-Bahy NM. (2013). In vitro and in vivo screening of anthelmintic activity of ginger and curcumin on Ascaridia galli. Parasitol Res, 112(11), 3679-3686.

Cardile V, Russo A, Formisano C, Rigano D, Senatore F. (2009). Essential oils of Salvia bracteata and Salvia rubifolia from Lebanon: Chemical composition, antimicrobial activity and inhibitory effect on human melanoma cells. Journal of Ethnopharmacology 126, 265-272.

Casiraghi A, Ardovino P, Minghetti P, Botta C, Gattini A, Montanari L. (2007). Semisolid formulations containing dimethyl sulfoxide and α-tocopherol for the treatment of extravasation of antiblastic agents. Arch Dermatol Res, 299, 201-207

Chopra B, Dhingra AK. (2021). Natural products: a lead for drug discovery and development. Phytother Res, 35(9), 4660-4702.

De Jesus GS, Micheletti AC, Padilha RG, de Souza de Paula J, Alves FM, Leal CRB, Garcez FR, Garcez WS, Yoshida NC. (2020). Antimicrobial potential of essential oils from cerrado plants against multidrug-resistant foodborne microorganisms. Molecules, 25, 3296.

Dugasani S, Pichika MR, Nadarajah VD, Balijepalli MK, Tandra S, Korlakunta JN. (2010). Comparative antioxidant and anti-inflammatory effects of [6]-gingerol, [8]-gingerol, [10]-gingerol and [6]-shogaol. J Ethnopharmacol, 127(2), 515-520.

El-Ghorab AH, Nauman M, Anjum FM, Hussain S, Nadeem M. (2010). A comparative study on chemical composition and antioxidant activity of ginger (Zingiber officinale) and cumin (Cuminum cyminum). J Agric Food Chem, 58(14), 8231-8237.

Fajrin FA, Nugroho AE, Nurrochmad A, Susilowati R. (2020). Ginger extract and its compound, 6-shogaol, attenuates painful diabetic neuropathy in mice via reducing TRPV1 and NMDAR2B expressions in the spinal cord. J Ethnopharmacol, 249, 112396.

Frondoza C G, Sohrabi A, Polotsky A, Phan P V, Hungerford D S, Lindmark L. (2004). An in vitro screening assay for inhibitors of proinflammatory mediators in herbal extracts using human synoviocyte cultures. In Vitro Cell Dev Biol Anim, 40, 95-101.

Funk JL, Frye JB, Oyarzo JN, Chen J, Zhang H, Timmermann BN. (2016). Anti-inflammatory effects of the essential oils of ginger (Zingiber officinale Roscoe) in experimental rheumatoid arthritis. PharmaNutrition, 4(3), 123-131.

Govindarajan VS. (1982). Ginger--chemistry, technology, and quality evaluation: part 1. Crit Rev Food Sci Nutr, 17(1), 1-96.

Hosen MZ, Biswas A, Islam MR, Hossain SJ. (2021). Anti-bacterial, anti-diarrheal, and cytotoxic activities of edible fruits in the Sundarbans mangrove forest of Bangladesh. Prev Nutr Food Sci, 26(2), 192-199.

Iranloye BO, Arikawe AP, Rotimi G, Sogbade AO. (2011). Anti-diabetic and anti-oxidant effects of Zingiber officinale on alloxan-induced and insulin-resistant diabetic male rats. Niger J Physiol Sci, 26(1), 89-96.

Jeena K, Liju VB, Kuttan R. (2011). A preliminary 13-week oral toxicity study of ginger oil in male and female wistar rats. Int J Toxicol, 30, 662-670.

Jeena K, Liju VB, Kuttan R. (2011)Antioxidant, anti-inflammatory and antinociceptive activities of essential oil from ginger. Indian J Physiol Pharmacol, 57, 51-62.

Katiyar C, Gupta A, Kanjilal S, Katiyar S. (2012). Drug discovery from plant sources: an integrated approach. Ayu, 33(1), 10-19.

Khan AM, Shahzad M, Raza Asim MB, Imran M, Shabbir A. (2015). Zingiber officinale ameliorates allergic asthma via suppression of Th2-mediated immune response. Pharm Biol, 53(3), 359-367

Kiyama R. (2020). Nutritional implications of ginger: chemistry, biological activities and signaling pathways. J Nutr Biochem, 86, 108486.

Koshimizu K, Ohigashi H, Tokuda H, Kondo A, Yamaguchi K. (1988). Screening of edible plants against possible anti-tumor promoting activity. Cancer Lett, 39(3), 247-257.

Kumar G, Kathie L, Rao KVB. (2011). A review on pharmacological and phytochemical properties of Zingiber officinale Roscoe (Zingiberaceae). J Pharm Res, 4(9), (2011), 2963-2966.

Lei H, Wei QN, Wang Q, Su AX, Xue M, Liu Q, Hu QH. (2017). Characterization of ginger essential oil/palygorskite composite (GEO-PGS) and its anti-bacteria activity. Mater Sci Eng C, 73, 381-387.

Li H, Liu Y, Luo D, Ma Y, Zhang J, Li M, Yao L, Shi X, Liu X, Yang K. (2019). Ginger for health care: An overview of systematic reviews. Complement Ther Med, 45, 114-123.

Lin RJ, Chen CY, Chung LY, Yen CM. (2010). Larvicidal activities of ginger (Zingiber officinale) against Angiostrongylus cantonensis, Acta Trop, 115(1-2), 69-76.

Lin ZK, Hua YF. (1987). Study on chemical constituents of ginger essential oil in Sichuan. Org Chem, 6, 444-448.

Liu Y, Liu J, Zhang Y. (2019). Research progress on chemical constituents of Zingiber officinale Roscoe. Biomed Res Int, 2019, 5370823.

Ma J, Ji XL, Yang L, Liu ZL. (2004). Diarylheptanoids from the rhizomes of Zingiber officinale. Phytochemistry, 65, 1137-1143.

Mao QQ, Xu XY, Cao SY, Gan RY, Corke H, Beta T, Li HB. (2019). Bioactive Compounds and Bioactivities of Ginger (Zingiber officinale Roscoe). Foods, 8(6), 185.

Mashhadi NS, Ghiasvand R, Askari G, Hariri M, Darvishi L, Mofid MR. (2013). Anti-oxidative and anti-inflammatory effects of ginger in health and physical activity: review of current evidence. Int J Prev Med, 4(Suppl 1), S36-S42.

Mitra SK, Venkataranganna MV, Sundaram R, Gopumadhavan S. (1988). Protective effect of HD-03, a herbal formulation, against various hepatotoxic agents in rats. J Ethnopharmacol, 63(3), 181-186.

Nishimura O. (1995). Identification of the characteristic odorants in fresh Rhizomes of ginger (Zingiber officinale Roscoe) using aroma extract dilution analysis and modified multidimensional gas chromatography-mass spectroscopy. J Argic Food Chem, 43(11), 2941-2945.

Onyeyili PA, Nwosu CO, Amin JD, Jibike JI. Anthelmintic activity of crude aqueous extract of Nauclea latifolia stem bark against ovine nematodes. Fitoterapia. 2001 Jan;72(1):12-21.

Pang X., Cao J., Wang D., Qiu J., and Kong F., “Identification of ginger (Zingiber officinale Roscoe) volatiles and localization of aroma-active constituents by GC-olfactometry,” J Argic. Food chem. J AGR FOOD CHEM, vol. 65, no. 20, pp. 4140–4145, 2017.

Park GH, Park JH, Song HM, Eo HJ, Kim MK, Lee JW, Lee MH, Cho KH, Lee JR, Cho HJ, Jeong JB. Anti-cancer activity of Ginger (Zingiber officinale) leaf through the expression of activating transcription factor 3 in human colorectal cancer cells. BMC Complement Altern Med. 2014 Oct 23;14:408.

Park K -K, Chun K -S, Lee J -M, Lee S S, Surh Y -J. Inhibitory effects of [6]-gingerol, a major pungent principle of ginger, on phorbol ester-induced inflammation, epidermal ornithine decarboxylase and skin tumor promotion in ICR mice. Cancer Lett. 1998; 129 139-44.

Penna SC, Medeiros MV, Aimbire FSC, Faria-Neto HCC, Sertié JAA, Lopes-Martins RAB. (2003). Anti-inflammatory effect of the hydroalcoholic extract of Zingiber officinale rhizomes on rat paw and skin oedema. Phytomedicine, 10, 381-385.

Pieters L, Vlietinck AJ. (2005). Bioguided isolation of pharmacologically active plant components, still a valuable strategy for the finding of new lead compounds. J Ethnopharmacol, 100(1-2), 57-60.

Prasad S, Tyagi AK. (2015). Ginger and its constituents: role in prevention and treatment of gastrointestinal cancer. Gastroenterol Res Pract, 2015, 142979.

Rahmani AH, Shabrmi FM, Aly SM. (2014). Active ingredients of ginger as potential candidates in the prevention and treatment of diseases via modulation of biological activities. Int J Physiol Pathophysiol Pharmacol, 6(2), 125-136.

Sattar NA, Hussain F, Iqbal T, Sheikh MA. (2012). Determination of in vitro antidiabetic effects of Zingiber officinale Roscoe. Braz J Pharm Sci, 48, 601-607.

Semwal RB, Semwal DK, Combrinck S, Viljoen AM. (2015). Gingerols and shogaols: Important nutraceutical principles from ginger. Phytochemistry, 117, 554-568.

Shen CL, Hong KJ, Kim SW. (2005). Comparative effects of ginger root (Zingiber officinale Rosc.) on the production of inflammatory mediators in normal and osteoarthrotic sow chondrocytes. J Med Food, 8, 149-153.

Tan JN. (2011). GC-MS Study on chemical constituents of volatile oils from ginger in different producing areas. Asian J Tradit Med, 7(4), 23-25.

Unuofin JO, Masuku NP, Paimo OK, Lebelo SL. (2021). Ginger from farmyard to town: nutritional and pharmacological applications. Front Pharmacol, 12, 779352.

Vedashree M, Asha MR, Roopavati C, Naidu MM. (2020). Characterization of volatile components from ginger plant at maturity and its value addition to ice cream. J Food Sci Technol, 57(9), 3371-3380.

Veena H, Gowda SK, Achur RN, Thippeswamy NB. (2021). Molecular mechanism of Escherichia coli H10407 induced diarrhoea and its control through immunomodulatory action of bioactives from Simarouba amara (Aubl.). J Microbiol, 59(4), 435-447.

Wang X, Shen Y, Thakur K, Han J, Zhang JG, Hu F, Wei ZJ. (2020). Antibacterial Activity and Mechanism of Ginger Essential Oil against Escherichia coli and Staphylococcus aureus. Molecules, 25(17), 3955.

Wood TK. (2010). Insights on Escherichia coli biofilm formation and inhibition from whole-transcriptome profiling. Environ Microbiol, 11, 1-15.

Yamahara J, Huang Q. (1990). Gastrointestinal motility enhancing effect of ginger and its active constituents. Chem Pharm Bull, 38(2), 430-431.

Zanariah U, Nordin NI, Subramaniam T. (2015). Ginger species and their traditional uses in modern applications. J Ind Technol, 23(1), 59-70.

Zhou HI, Deng M, Xie QM. (2006). The modulatory effects of the volatile oils of ginger on the cellular immune response in vitro and in vivo in mice. J Ethnopharmacol, 105, 301-305.

How to cite this article: Kaur A, Shivani, Grewal AS, Guarve K. Phytochemistry and pharmacological actions of ginger: an in-depth review. Pharma Research Bulletin, 2021, 3(1), 18-29.