Journal of Holistic Integrative Pharmacy 6 (2025) 74–82

Contents lists available at ScienceDirect

Journal of Holistic Integrative Pharmacy

journal homepage: www.keaipublishing.com/en/journals/journal-of-holistic-integrative-pharmacy

A review on the pharmacological effects of *Alpinia offiinarum* Hance and its active ingredients

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ARTICLE INFO

Keywords:
Alpinia officinarum Hance
Active components
Pharmacological effects
Research progress

ABSTRACT

Alpinia officinarum Hance (*A. officinarum*), as an important interior-warming herb in traditional Chinese medicine, is used to warm interior and disperse cold, regulate *Qi* and relieve pain. Modern research has found that *A. officinarum* has various active components and pharmacological effects. With the deepening of related studies, more attention has been focused to *A. officinarum*. This article reviews and summarizes the active components and pharmacological effects of *A. officinarum* by searching recent domestic and international literature, in order to provide a reference for the research on the mechanisms of action of *A. officinarum* and its active components, as well as for further clinical applications and new drug development.

1. Introduction

Alpinia officinarum Hance (*gāo liáng jiāng*) is an interior-warming medicinal with significant application value, which has the effects of warming interior and dispersing cold, regulating *Qi*, and relieving pain. According to the ancient record in List of Famous Doctors (*Mingyi Bielu*) and contemporary pharmacopoeia record, *A. officinarum* is widely used to treat abdominal cold and pain, gastric cold and vomiting, belching, and acid reflux.[1–3] Except high medicinal value, it also plays an important role in daily diet, which is often used in medicinal diet or as a natural flavoring in food seasoning, with a large market both domestically and internationally. Currently, it is primarily produced in these provinces, including Hainan, Guangdong, and Guangxi.[4]

In recent years, researchers have isolated various chemical components from *A. officinarum*, including volatile oils, flavonoids, diphenylheptane, phenols, glycosides, and so on.[5] There was an increasing number of research reports on the chemical components and pharmacological activities of *A. officinarum*. Pharmacological studies have shown that *A. officinarum* exhibits pharmacological effects, such as antioxidant, antibacterial, antiviral, anticancer, anti-diarrheal, and anticoagulant activities (Fig. 1). This article provides a brief review on the pharmacological effects of *A. officinarum* and its active components in recent years, to offer a literature basis and theoretical support for better development and utilization of *A. officinarum*.

2. Methodology

First, a search was conducted using three synonyms—*Alpinia officinarum* Hance, *A. officinarum*, and Galangal—based on the national pharmacopoeia and relevant literature. Search engines, including TCMSP, PubMed, Sci-Hub, China National Knowledge Infrastructure (CNKI), and Google Scholar, were utilized to gather relevant literature from the past 20 years. Additionally, literature searches were performed using relevant databases, including open-access journals and theses.

3. Active components and their pharmacological effects

According to relevant reports, there are 130 kinds of components isolated from *A. officinarum* at present, and the chemical components mainly include flavonoids, volatile oils, diarylheptane, terpenoids, phenols, phenylpropanes, and so on. The specific pharmacological effects of the active components contained in *A. officinarum* reported in the literature are shown in Table 1.

4. Pharmacological effects of *A. officinarum*

4.1. Antioxidant

A. officinarum exhibits significant antioxidant activity. The alcohol extract of *A. officinarum* demonstrates the ability to scavenge free

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Peer review under the responsibility of Editorial Board of Journal of Holistic Integrative Pharmacy.

https://doi.org/10.1016/j.jhip.2025.03.006
Received 24 September 2024; Received in revised form 11 March 2025; Accepted 13 March 2025

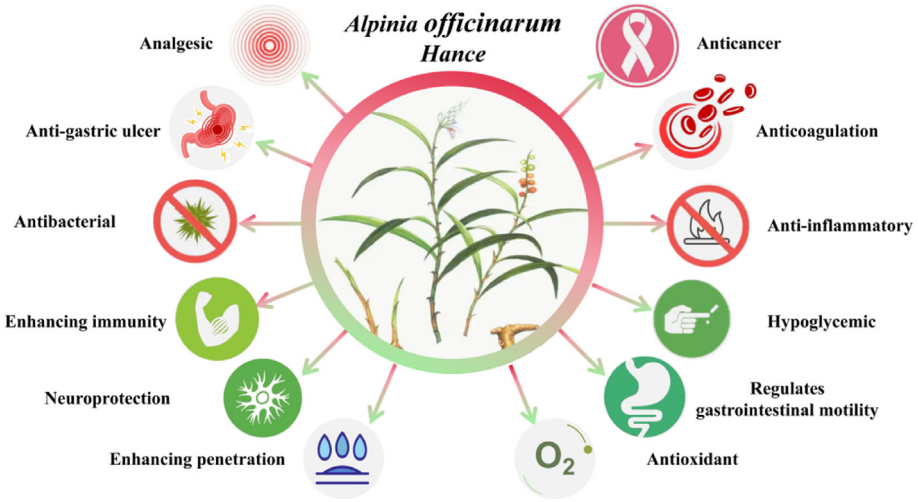

Fig. 1. Pharmacological effects of *Alpinia officinarum*.

radicals, reduce iron ions, and inhibit the activity of key metabolic enzymes, which notably decreases the leakage rate of lactate dehydrogenase in damaged PC12 cells, reduces the intracellular content of malondialdehyde (MDA), and enhances the activity of intracellular superoxide dismutase (SOD) and glutathione peroxidase (GSH-Px), thereby maintaining normal cell morphology.[139,140] It was found that *A. officinarum* extract alleviated the inhibitory effects of oxidants on the proliferation of V79-4 cells, and the cells survival rate increased by 48%. It was speculated that flavonoid compounds were the primary antioxidant active components of *A. officinarum*.[141]

Among the flavonoids, the C-2-C-3 double bond and the C-3 hydroxyl group possess antioxidant potential, enabling galangin to exhibit antioxidant properties. It can inhibit lipid peroxidation in rat liver microsomes induced by carbon tetrachloride and also effectively suppress copper ion-mediated low-density lipoprotein (LDL) peroxidation. Galangin protects DNA from oxidative damage and effectively scavenges other oxidative groups, with mechanisms involving two direct mechanisms: hydrogen ion transfer and single electron transfer, as well as an indirect mechanism through the complexation of Fe^{2+} [142]. Recent studies have also revealed that galangin exerts its antioxidant effects by promoting SIRT1/PGC-1α/Nrf2 signaling pathway (Fig. 2).[143]

4.2. Antibacterial

The alcohol extract of *A. officinarum* exhibits strong inhibitory effects against *Phytophthora infestans*, *Streptococcus*, *Candida albicans*, *Prototheca wickerhamii*, and beer yeast.[144] Its antibacterial effect may be associated with the inhibition of β-ketoacyl carrier protein reductase, which subsequently inhibits the synthesis of fatty acids in bacterial biofilm, further destroyes the bacterial outer membrane, and ultimately prevents bacterial proliferation. Antibacterial assays revealed that the water, alcohol, and methanol extracts of *A. officinarum* demonstrated moderate to strong antibacterial activity against *Bacillus cereus*, *Staphylococcus aureus*, *Pseudomonas aeruginosa*, and *Escherichia coli*.[145] The methanol extract of *A. officinarum* exhibits antibacterial activity against clotrimazole-resistant *Candida albicans*, *Klebsiella pneumoniae*, *Bordetella bronchiseptica,* and *Staphylococcus aureus*.[146] Further studies indicate that the methanol extract of *A. officinarum* shows superior inhibitory effects on the swarming motility of *Pseudomonas aeruginosa* compared to catechin at double the concentration, which revealed that *A. officinarum* had certain potential in inhibiting bacterial virulence.[147]

Flavonoids are recognized as the primary antibacterial components of *A. officinarum*. The quantification of galangin content, as outlined in the 2015 edition of the Chinese Pharmacopoeia, is regarded as one of the criteria for assessing the quality of *A. officinarum*. Research has demonstrated that galangin inhibits bacterial growth by directly damaging the plasma membrane of the cells or indirectly causing damage through autolysis or weakening of the cell wall, leading to subsequent osmotic lysis, ultimately resulting in a bacteriostatic effect.[148]

Diarylheptanes are one of the characteristic chemical components in *A. officinarum*, and the reports on their antibacterial activity have been increasing in recent years. Three new and 10 known diarylheptane components were isolated from the ethanol extract of *A. officinarum*, all of which demonstrated pharmacological activity against *Helicobacter pylori*.[149] The diarylheptane compound 5-hydroxy-7-(4″-hydroxy-3″-methoxyphenyl)-1-phenyl-3-heptanone in *A. officinarum* exhibits antibacterial activity against multi-drug resistant pathogenic *Escherichia coli*, and it is also effective in countering inflammatory response induced by bacterial lipopolysaccharides. The mechanism of action primarily involves the interaction of this compound with a subgroup of bacterial DNA gyrase, achieving the dual therapeutic effect of antibacterial and anti-inflammatory.[150]

4.3. Anti-inflammatory and analgesic

A. officinarum extract exhibits significant anti-inflammatory and analgesic effects, which confirm the effect of *A. officinarum* in relieving pain. *A. officinarum* significantly inhibits acute inflammation such as toe, ear, and abdominal swelling in mice. It demonstrates notable analgesic effects in both chemically induced (acetic acid) and physically induced (thermal) pain models.[151] Experimental results indicate that the water extract of *A. officinarum* significantly reduces the number of writhing responses and increases the threshold of pain response in mice, and its pharmacological mechanism involves the antagonism of cholinergic receptors and plays an analgesic role.[152] The chloroform extract of *A. officinarum* exerts anti-inflammatory and analgesic effects by inhibiting the activity of prostaglandin (PG) synthetase and phospholipase A2, thereby obstructing the metabolism of arachidonic acid (AA) into PG. The alcohol extract achieves anti-inflammatory effects by blocking the activation of the TLR4 and JAK/STAT pathways induced by lipopolysaccharides (LPS) and inhibiting the phosphorylation of JNK, p38, IκBα, and STAT.[153]

Current research on the anti-inflammatory effect of *A. officinarum* primarily focuses on individual compounds, particularly the anti-inflammatory activity of galangin. Modern studies have shown that galangin has significant anti-inflammatory activity and has certain therapeutic effects on rheumatoid arthritis, nephritis, ulcerative colitis, and neuroinflammation. Its anti-inflammatory mechanism is mainly associated with the inhibition of inflammatory mediators and nuclear factor-κB (NF-κB), phosphatidylinositol-3 kinase (PI3K)/protein kinase B (AKT),

Table 1
Active components and their pharmacological effects of *Alpinia officinarum*.

Components	Pharmacological action	Reference
Flavonoids		
galangin	Antibacterial, anticancer, anti-inflammatory, anti-proliferative, antioxidant, inhibition of hypertrophic scar formation, liver protection	6–12
medicarpin	Anti-depression, osteogenesis, antioxidant, antiapoptosis	13–15
isorhamnetin	Anti-diabetes, lipid-lowering, anti-inflammatory, antioxidant, endothelial protection, antithrombotic, anti-platelet aggregation, myocardial protection, liver protection	16–19
kaempferide	Anticancer, anti-proliferation, anti-atherosclerosis, anti-inflammatory, liver protection, anti-obesity, anti-diabetes, protection of nerves and heart, inhibition of hypertrophic scar formation	20–23
quercetin	Antibacterial, antioxidant, anticancer, antiviral, anti-inflammatory	24–27
rhamnocitrin	Anti-inflammation, antioxidant	28
chrysin	Antiviral, anti-inflammation, anti-diabetes, anticancer, antioxidant, heart protection, neuroprotective, anti-anxiety, anti-depression	29–32
3-*O*-methylquercetin	Antioxidant, anti-inflammatory, anticancer	33–36
apigenin	Anticancer, antiviral, antibacterial, antioxidant, anti-inflammatory, heart protection	37–40
pinobaksin	Antioxidant, antibacterial, anti-inflammatory, anti-parasitic, anti-mutagenic, anti-proliferative, anti-angiogenic	41
pinocembrine	Neuroprotective	42
galangin-3-methyl ether	Antibacterial, antifungal	43
Volatile oil		
1,8-cineole or eucalyptol	Antibechic, antibacterial, anti-inflammatory, analgesic, antiviral	44–46
β-pinene	Antihypertensive	47,48
α-terpineol	Sterilization, antioxidant	49
camphor	Antioxidant, anti-inflammatory, sedation	50
Diarylheptane		
curcumin	Antioxidant, anti-inflammatory, anticancer, antibacterial, antihypertensive	51–54
5-hydroxy-1,7-diphenylheptan-3-one	Antiviral, antioxidant, anti-diabetes	55,56
5-methoxy-1,7-diphenylhept-3-one	Antiviral	57
5-methoxy-7-(4′-hydroxyphenyl)-1-phenylheptan-3-one	Antiviral	57
5-hydroxy-7-(4-hydroxy-3-methoxyphenyl)-1-phenylheptan-3-one	Antiviral, antioxidant	58,59
5-hydroxy-7-(4-hydroxyphenyl)-1-phenylheptan-3-one	Antiviral, antibacterial	60
(3*R*,5*R*)-1,7-bis(4-hydroxy-3-methoxyphenyl)-3,5-heptanediol	Neuroprotective, anti-inflammatory, anti-adipogenic	61,62
(4*E*)-1,7-diphenylhept-4-en-3-one	Anticancer	63
(4*E*)-7-(4-hydroxy-3-methoxyphenyl)-1-phenylhept-4-en-3-one	Anti-inflammatory, anti-insulin resistance	64
alpinoid C	Anticancer	65
alpinin C	Anticancer	66
alpinisin A		67

Table 1 (*continued*)

Components	Pharmacological action	Reference
7-(4″-hydroxy-3″-methoxyphenyl)-1-phenyl heptan-3-one	Antitubercular	68
7-(4″-actetate-3″-methoxyphenyl)-1-phenyl heptan-3-one	Antitubercular	68
1-phenyl-4-(16,17-dimethyl-9,13-octadiene)-5-isopentenyl-7-(4″-methoxyl-3″-hydroxyl-phenyl)-3-heptanone	Feeding deterrent activity against	69
trans-(4*R*,5*S*)-epoxy-1,7-diphenyl-3-heptanone	Promote adipocyte differentiation	70
7-(4″-hydroxy-3″-methoxyphenyl)-1-phenyl-hepta-4*E*,6*E*-dien-3-one	Promote adipocyte differentiation	70
1,2-di-*O*-β-D-glucopyranosyl-4-allylbenzene	Antioxidant and α-glucosidase inhibitory activity	71
3,5-dihydroxy-1,7-diphenylheptane	Inhibited melanogenesis and LPS-induced NO production	72,73
Terpenoids		
muurolene	Antiviral, antibacterial, anti-inflammatory	74–76
cymene	Antibacterial, anticancer, antioxidant, anti-inflammatory, anti-nociceptive, anti-anxiety	77,78
valencene	Anti-inflammatory, anticancer	79,80
bisabolol	Anti-inflammatory, anti-nociceptive, anticancer, sedation, anti-anxiety	81,82
isoborneol	Antioxidant, antiviral, analgesic, anticoagulantion, antiapoptosis, neuroprotective	83–85
cadalene	Anti-inflammatory, antioxidant, anticancer	86,87
(*Z*)-caryophyllene	Insecticide	88
myrcene	Antioxidant, anti-tumor metastasis	89,90
linalool	Antioxidant, anti-inflammatory, analgesic	91,92
moslene	Antioxidant, anti-nociceptive	93
thymol	Anti-corrosion, antibacterial, anti-fungal, anti-inflammatory	94–96
limonene	Anti-fibrotic	97
farnesol	Anti-biofilm, antioxidant, anti-inflammatory, antiapoptosis	98,99
delta-guaiene	Platelet activating factor receptor antagonists, anti-platelet aggregators	100
nerol	Antioxidant, antibacterial, antispasmodic, expelling parasite, antiarrhythmic	101
Phenols		
β-guaiene	Antioxidant	102
4-ethylguaiacol	Anti-inflammatory, inhibiting intestinal peristalsis	103–105
zingerone	Anti-inflammatory, antioxidant, anticancer, anti-diabetes, anti lipid allergy, anti-diarrhea, antispasmodic	106–108
Phenylpropanoids		
methyleugenol	Anti-nociceptive, antioxidant	109
7-hydroxycoumarin	Antioxidant, anticancer, anti-hyperlipidemia, anti-diabetes, anti-fibrotic, anti-depression	110–114
3-phenylpropanoic acid	Antimicrobial	115
Other		
protocatechuic acid	Antioxidant, anti-inflammatory, anticancer	116,117
methyl cinnamate	Anti-obesity, reduces hypersensitivity reactions	118,119
capsaicin	Analgesia, anti-inflammatory	120–122
emodin	Anticancer, anti-fibrotic, anti-inflammatory, enhancing immunity, antiviral, antibacterial, anti-diabetes	123–125
vanillin		126–128

(*continued on next page*)

Table 1 (*continued*)

Components	Pharmacological action	Reference
	Antioxidant, anticancer, anti-proliferative, anti-metastatic, anti-depression, myocardial protection	
methyl palmitate	Anti-inflammatory, anti-fibrotic, antioxidant	129,130
β-elemene	Anticancer	131
α-farnesene	Antioxidant, neuroprotection	132,133
L-bornyl acetate	Anti-inflammatory	134,135
myristic acid	Anticancer	136
β-sitosterol	Anti-inflammatory, anticancer, liver protection, antioxidant, heart protection, anti-diabetes, lipid-lowering	137,138

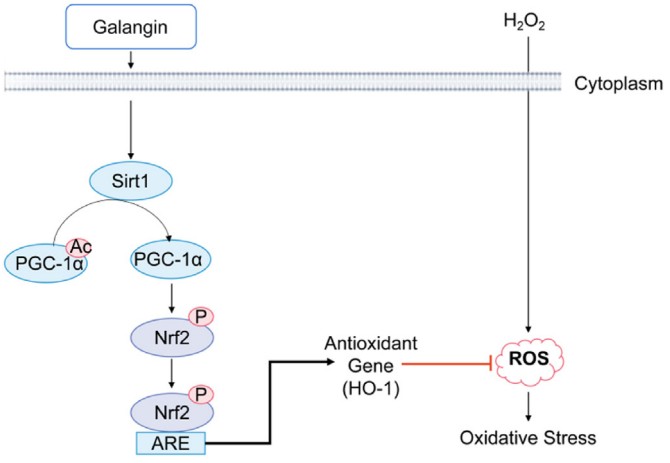

Fig. 2. Antioxidant effect of galangin by promoting SIRT1/PGC-1α/Nrf2 signaling pathway.

mitogen-activated protein kinase (MAPK), and other signaling pathways.[154–158] Galangin can induce the production of tolerogenic dendritic cells (tolDCs), inhibit the activation and proliferation of T cells, and promote the production of immunosuppressive regulatory T cells (Tregs), thereby exerting an anti-inflammatory role by regulating cellular immunity.[159] Further studies have indicated that 1,8-cineol, isolated from *A. officinarum*, has analgesic effects similar to non-opioid drugs by activating visceral surface receptors, increasing the release of histamine, bradykinin, prostaglandins, and 5-hydroxytryptamine, and inhibiting smooth muscle motility.[160]

4.4. Anticancer

Various components of *A. officinarum* were extracted and screened for tumor cell inhibition. The results indicated that 95% ethanol extract and petroleum ether extract of *A. officinarum* exhibited inhibitory effects on tumor cell lines, while *n*-butanol and water layer parts showed no inhibitory activity against the tumor cell lines.[161] Additionally, it has been reported that diphenylheptane compounds isolated from 80% acetone extract of *A. officinarum* inhibited the production of melanogenesis in rat melanoma cells induced by theophylline.[162] In the process of speculating the structure-activity relationship of the compounds, it is believed that the α,β-unsaturated ketone portion of the heptane chain in the compound structure may play a key role in antitumor activity, serving as the main pharmacophore for antitumor efficacy. An increase in unsaturation or conjugated systems, as well as the presence of more substituents on the phenyl rings at both ends, may contribute to the enhancement of activity.[163]

The primary anticancer pharmacological components of *A. officinarum* are galangin and its derivatives, which exhibit broad-spectrum anticancer activity. Its mechanism mainly includes: the regulation of PI3K-AKT, AMPK, NF-κB, and other signaling pathways, leading to cell cycle arrest, induction of apoptosis and autophagy, and inhibition of cell migration and invasion (Fig. 3).[158,164] According to the latest research report, galangin induces apoptosis in hepatocellular carcinoma cells by blocking the cell cycle at the G0/G1 phase through the inhibition of key mRNA and protein expression in the cell cycle.[165] Curcumin, a representative diarylheptane from *A. officinarum*, has potential anticancer activity by interacting with multiple signaling molecules within the cell.[166] It suppressed cancer cell proliferation and survival by suppressing the shh-Gli-FoxM1 pathway and Wnt pathway, both *in vitro* and *in vivo*.[167] Kaempferol, a flavanol compound found in *A. officinarum*, has extensive medicinal value.[168] Numerous studies have shown that kaempferol exhibits significant anti-tumor, antioxidation, anti-inflammatory, and other effects.[169] A number of basic studies have confirmed that kaempferol can inhibit the growth of breast, gastric, colon, liver, and pancreatic cancers, as well as other tumor tissues, by inducing apoptosis, cell cycle arrest, and autophagy.[170,171]

4.5. Anti-gastric ulcer

Different doses of total flavonoids from *A. officinarum* exhibit significant protective effects on three acute gastric ulcer models: water immersion restraint stress, pyloric ligation, and oral ethanol induced gastric mucosal injury, as well as in the chronic gastric ulcer model induced by acetic acid burning, markedly reducing the ulcer index in rats. The flavonoids in *A. officinarum* have the effect of anti-gastric ulcer and enhancing the protection of gastric mucosa. On the one hand, it can reduce the attack factors of gastric mucosal injury, including lowered gastric secretion and total acid excretion, and reduced pepsin activity. On the other hand, it enhances the activity of protective factors in the gastric mucosa, including increased gastric wall mucin levels in rats subjected to ethanol-induced gastric mucosal damage, elevated the activity of SOD in the gastric mucosa, and increased nitric oxide (NO) levels in the serum. The underlying mechanism may be related to the polyphenolic hydroxyl structures of the total flavonoids in *A. officinarum*, which possess antioxidant properties and the ability to scavenge free radicals.[172] Research indicates that acetone extracts of *A. officinarum* display a dose-dependent inhibition of hydrochloric acid-ethanol-induced ulcers, sodium

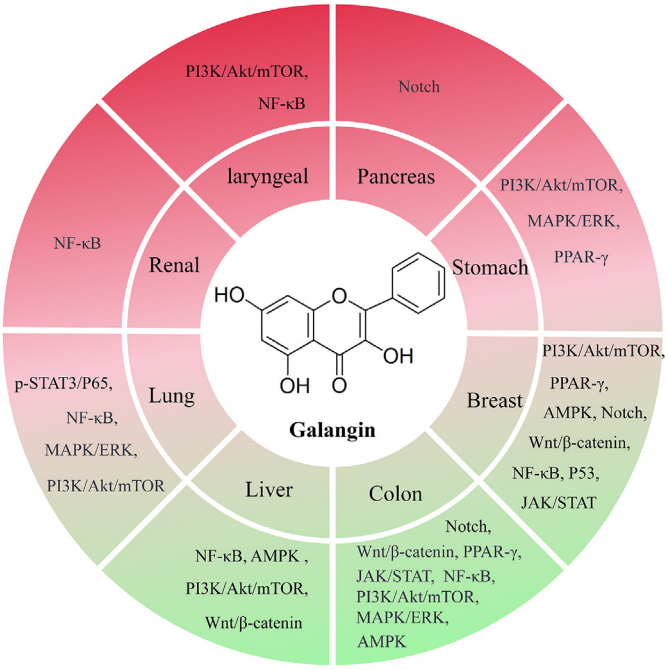

Fig. 3. Various pathway of galangin for different types of cancer.

hydroxide-induced ulcers, and ammonia-induced ulcers, confirming that *A. officinarum* possesses a notable anti-gastric ulcer effect.[173] Furthermore, the extracts can reduce the ulcer index in rats subjected to restraint-water immersion stress and significantly restore serum levels of interleukin-2 (IL-2) and epidermal growth factor (EGF). The mechanisms may be associated with the ability of *A. officinarum* to enhance the TH1 immune response in stressed rats, thereby improving cellular immune function.[174]

4.6. Regulating gastrointestinal motility

Supercritical extract of *A. officinarum* significantly enhanced intestinal propulsion function of normal mice, and this effect was also reflected in rat ileal motility experiments.[175] In mouse models with stomach cold, the decoction of *A. officinarum* promoted gastrointestinal motility, possibly related to the up-regulation of gastrin (GAS), motilin (MTL), acetylcholine (ACh), and SOD levels and the down-regulation of MDA and IL-6 levels.[176] *A. officinarum* demonstrated a good anti-diarrheal effect for castor oil-induced diarrhea in mice, water extract and aqueous extract of *A. officinarum* markedly reduced the frequency of diarrhea. For diarrhea caused by senna leaves, the aqueous extract of *A. officinarum* significantly slowed down gastrointestinal propulsion and decreased the frequency of diarrhea in mice.[177,178]

Different chemical parts of *A. officinarum* (i.e., water extract, alcohol extract, volatile oil, ethyl acetate extracts from water extract, or alcohol extract) were screened through a mouse analgesia model and a pigeon anti-emetic model. The results demonstrated that all parts exhibited dual pharmacological effects of analgesia and anti-emetic, and the activity of alcohol extract was stronger than water extract.[179] Research indicated that the flavonoids from *A. officinarum* possessed significant gastrointestinal spasmolysis, inhibited the elevation of smooth muscle tension induced by ACh, thereby exerting anti-emetic and anti-diarrheal properties.[180] Pharmacological and pharmacodynamic tracking tests confirmed that galangin and kaempferol are the main effective components for anti-emetic, which are consistent with the therapeutic functions of *A. officinarum*.[179]

4.7. Hypoglycemic effect

A. officinarum exhibits an obvious hypoglycemic effect. In the hypoglycemic experiment of normal male New Zealand rabbits, oral administration of *A. officinarum* powder resulted in a marked reduction in blood glucose levels. In particular, the hypoglycemic effects were more pronounced with methanol and water extracts, suggesting that the mechanism behind its hypoglycemic action may be attributed to stimulation of pancreatic insulin secretion.[181]

It has been reported that galangin exerted a powerful anti-hyperglycemic effect by regulating glucose homeostasis, reversing the alterations in glycolysis and gluconeogenesis in rats.[182] Galangin has been shown to decrease levels of glucose, total cholesterol, free fatty acids, and LDL, while increasing levels of insulin and high-density lipoprotein (HDL) in plasma, suggesting that galangin has potential therapeutic efficacy on diabetes.[183] In streptozotocin induced diabetes rats, galangin by gavage effectively enhanced the production of glutathione peroxidase (GPX), SOD, and glutathione (GSH) in plasma and liver, while downregulating levels of thiobarbituric acid reactive substances, and alleviating liver mitochondrial damage and lipid peroxidation in the liver.[184,185] Furthermore, galangin has been found to significantly induce apoptosis and mitigate oxidative stress damage, reduce levels of reactive oxygen species (ROS) and MDA, and increase SOD content. This protective effect on diabetic nephropathy was mediated through the modulation of renin-angiotensin system (RAS) activation and the PI3K/AKT/mTOR signaling pathway.[186] Pharmacodynamic studies have proved that diarylheptane, which has several biological activities, is one kind of the main active ingredients in *A. officinarum*. (4*E*)-7-(4-Hydroxy-3-methoxyphenyl)-1-phenylhept-4-en-3-one (DPHB), (*R*)-5-hydroxy-1, 7-diphenyl-3-heptanone (DPHC) and 1,7-diphenyl-4*E*-en-3-heptanone (DPH5) derived from *A. officinarum* have been reported to exert anti-insulin resistance (IR) effects. The underlying mechanism may be related to the regulation of PI3K/AKT signaling, Nrf2/ARE signaling, GSK3β signaling, etc (Fig. 4).[56,64,187]

4.8. Enhancing penetration

Extracts of *A. officinarum* can effectively increase the permeability of Caco-2 cells (human colorectal cancer cells) and reduce the resistance of epithelial cells.[188] Studies investigating the effects of *A. officinarum* alcoholic extracts and compounds (*A. officinarum* oil and eucalyptol) on the transdermal absorption of 5-fluorouracil indicated that the alcoholic extract of *A. officinarum* exhibited a certain degree of penetration enhancement, while *A. officinarum* oil and eucalyptol had a stronger effect.[189]

4.9. Enhancing immunity

A. officinarum can stimulate the growth of endothelial reticular cells in mice, increase the number of peritoneal exudative cells (PEC), and promote the growth of splenocytes. Further studies have shown that polysaccharide components present in the extracts enhance the ability to clear carbon particles from the blood and enhance immunity by promoting the mitosis of lymphocytes.

4.10. Anticoagulation and anti-platelet aggregation

The 100% concentration of water extract of *A. officinarum* exhibits a significant anticoagulant effect, while the 150% concentration can completely anticoagulate, showing an effect similar to that of heparin at 250 μg/mL. The anticoagulant mechanism may be related to the inhibition of platelet aggregation and the formation of thromboplastin. This experiment also confirmed that water extract of *A. officinarum* protects SOD activity and reduces MDA content of ischemic and hypoxic myocardium, comparable to those of *Salvia miltiorrhiza*.[190]

4.11. Neuroprotection

The role of *A. officinarum* in neuroprotection has increasingly garnered attention, demonstrating therapeutic potential in neurological diseases such as Alzheimer's disease (AD) and Parkinson's disease (PD).

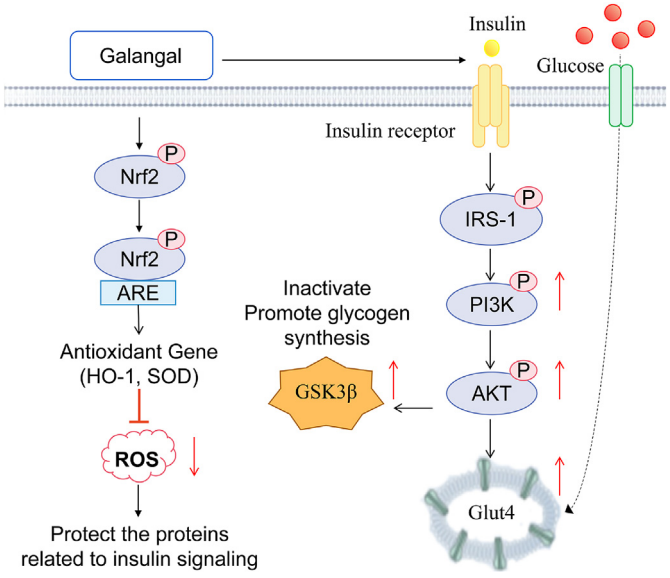

Fig. 4. Mechanism of anti-insulin resistance effect of *Alpinia officinarum*.

As a flavonoid with acetylcholinesterase inhibitory activity, galangin enhanced the transmission of acetylcholine neurotransmitters and improved cognitive function, spatial learning, and memory ability of AD model rats, indicating that galangin may serve as one of the potential candidate drugs for AD treatment.[191]

Galangin can alleviate motor impairments in PD mice by shortening rotation time, suppressing the expression of inflammatory factors TNF-α, IL-6, IL-1β, COX-2, and iNOS in BV-2 cells induced by LPS, reducing the inflammatory damage of substantia nigra dopaminergic (DA) neurons, and playing an anti-PD effect.[192]

5. Conclusion

A. officinarum has a long history of medicinal use and is an important interior-warming medicinal in traditional Chinese medicine. At present, the pharmacological activities of *A. officinarum* and its active components have been clearly elucidated, and its mechanisms of antioxidant free radicals, anticancer proliferation, anti-inflammatory, and analgesic gradually being understood. *A. officinarum* is primarily used in healthcare sector, generally for the treatment and adjunctive therapy of tumors and inflammation. However, there remains considerable potential for further development and utilization. On the basis of treating traditional gastrointestinal diseases, the scope of clinical application of *A. officinarum* has also expanded to a certain extent. Nonetheless, the specific chemical components and mechanisms through which these compounds exert therapeutic effects in the treatment of gastrointestinal diseases require further investigation. Therefore, there is a pressing need for extensive foundational and systematic research to provide more robust experimental evidence for the future utilization and development of *A. officinarum*. Furthermore, in recent years, research reports on the active components of *A. officinarum* have been limited, so further investigation into its constituents is warranted.

CRediT authorship contribution statement

Jiahui He: Writing – original draft, Software, Resources, Methodology, Investigation, Formal analysis, Data curation. **Yanfen Chen:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Chaoyan Yang:** Writing – review, Validation, Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study was supported by the Guangdong Provincial Natural Science Foundation General Project (No. 2023A1515011128).

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