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Chemical composition, antimicrobial properties, and antioxidant activity of galangal rhizome

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Abstract

This study investigated the chemical composition (proximate composition, fatty acids, minerals, and phenolic compounds), antioxidant activity, and antimicrobial activity of galangal rhizomes. The rhizomes contain appreciable amounts of ash (5.38%), protein (5.86%), carbohydrate (81.13%), potassium (159.79 mg/kg), calcium (25.7 mg/kg), phosphorous (17.36 mg/kg), magnesium (15.57 mg/kg), iron (7.2 mg/kg) and manganese (3.82 mg/kg). Galangal rhizome oil is rich in unsaturated fatty acids (91.8%), elaidic (67.82%), linoleic (22.56%), palmitic (5.18%), and stearic (2.26%) acids found as the main fatty acids in the oil. Galangal rhizome extract contains substantial amounts of total phenolic content (53.18 mg GAE/g), total flavonoid content (14.12 mg CE/g), gallic acid (160.04 mg/100 g), (+)-catechin (124.33 mg/100 g), quercetin (105.34 mg/100 g), catechol (100.18 mg/100 g), isorhamnetin (82.2 mg/100 g), trans-cinnamic acid (81.97 mg/100 g) and protocatechuic acid (71.46 mg/100 g). The extract of galangal rhizomes also possessed high antioxidant activity, as assessed by DPPH (77.76%), ABTS (8.66 mmol TE/g), and FRAP (3.99 mmol TE/g), as well as antimicrobial activity against ten Gram-positive and Gram-negative pathogenic bacteria. In conclusion, Galangal is a rich source of nutrients and phytochemicals and exhibits antioxidant and antimicrobial activities.

Keywords: galangal rhizome; antioxidant; antimicrobial; bioactive compounds.

Practical Application: Galangal is a rich source of nutrients and phytochemicals and exhibits antioxidant and antimicrobial activities that help support health.

1 Introduction

Galangal is an important herb of the family Zingiberaceae, and the main galangal species are known as greater Galangal [*Alpinia galanga* (L.) Willd] and lesser Galangal (*Alpinia officinarum* Hance) are indigenous plant species found in Indonesia and China, respectively (Zhou et al., 2018), and they are currently cultivated worldwide. The rhizomes of both species are used as flavoring agents and spices in food and beverage products (Das et al., 2020). For centuries, Galangal has been used in traditional medicine in many countries around the world for treating diabetes mellitus, bronchitis, heart disease, stomachaches, colic, diarrhea, emesis, indigestion, abdominal pain, vomiting, breathing diseases, rheumatism, and inflammatory disorders (Basri et al., 2017; Das et al. 2020; Khairullah et al., 2020). It is also used as an improver of the eating apatite and voice, a preservative agent for fruits and vegetables, and a carminative, anti-itching, antiflatulent, and antifungal agent (Zhou et al., 2018).

Phytochemical analyses indicated that Galangal contains various compounds that make it a super ingredient for food, culinary, medicine, and cosmetic applications. The main phytochemicals in galangal rhizome are phenolic compounds, polyphenols, flavonoids, saponins, phenylpropanoids, glycosides, diarylheptanoids, sesquiterpenes, and diterpenes (Ajay & Vijaykumar, 2015; Das et al., 2020; Zhou et al., 2018). In addition, galangal rhizomes contain essential oils and have a rich profile of bioactive and volatile compounds with high pharmaceutical potential (Ravindran et al., 2012). Due to its rich phytochemical profile, Galangal possesses antioxidant, antibacterial, antifungal, antiviral, anti-inflammatory, anticancer, antiallergic, antihyperlipidemic, antiasthmatic, antiobesity, antiplatelet, antiemetic, neuroprotective, and gastroprotective activities (Zhou et al., 2018).

These therapeutic beliefs of *Alpinia galanga* are attributed to its secondary metabolites, including phenolic acids, flavonoids, saponins, terpenes, and essential oils (Zhou et al., 2021). A. Galangal rhizome essential oil (AGREO) is an aromatic oily liquid derived from dried and fresh A. galangal rhizomes with a slightly spicy fragrance. AGREO has received high significance worldwide due to its incredible therapeutic potential as an antitumor, antioxidant, insecticidal, and anti-inflammatory agent (Zhang et al., 2020; Sahoo et al., 2020). A recent study reported that Galangal flowers had a 3-fold higher total phenol content than rhizomes (10.5 vs. 3.33 mg GAE/g powder). These findings suggest that antimicrobial and antioxidant agents extracted from galangal flowers could be used as natural food preservatives or therapeutic agents (Tang et al., 2018). Accordingly, current research reported that the utmost regularly suggested antibacterial activity mechanism of essential oils and their components comprises bacterial structure alterations and functionality, interference with the energy metabolism system, and disruption of DNA, whole-cell protein, and the metabolism group (Jugreet et al., 2020).

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Plant-based food is a significant part of the human diet and an important source of nutrients. Besides nutrients of lipids, carbohydrates, protein, minerals, and vitamins, plants also encompass numerous secondary metabolites compounds (e.g., polyphenols, flavonoids, alkaloids, tannins, saponins, etc.), which exhibit several physiological benefits for the human body (Li et al., 2022). *Alpinia officinarum Hance* showed strong inhibitory activity for pancreatic lipase, α-glucosidase, and α-amylase with percentages of 66.76 ± 0.83, 99.33 ± 0.29 and 12.89 ± 2.04, respectively, hence, this plant can act as good antiobesity agent (Li et al., 2022). It was reported that Galangal (*Alpinia galanga*) contains many bioactive compounds such as essential oils, tannins, glycosides, phenolic compounds, and diterpenes (Półtorak et al., 2019).

In foods, galangal rhizome is usually used as a flavoring agent in soups, meats, vegetable curries, sauces, and sambals, and it is applied to reduce the undesirable odor in red meat and seafood (Das et al., 2020). In addition to its traditional application in food, recent studies on the application of Galangal as a preservative and functional ingredient in meat (Juntachote et al., 2007), biscuits (Klunklin & Savage, 2018), and sausages (Półtorak et al., 2018) demonstrated that galangal delays lipid oxidation and extends the shelf life of foods (Das et al., 2020). This study investigated the chemical composition of galangal rhizome, fatty acids of galangal rhizome oil, and bioactive properties of galangal rhizome extract.

2 Materials and methods

2.1 Materials and chemicals

Galangal (*Alpinia galanga*) rhizomes were obtained from the local market in Riyadh, cleaned manually, milled, and stored at –20°C in a tight container until use. Phenolic compound standards with purity >97.5%, Folin–Ciocalteu reagent, aluminum chloride, sodium nitrite, ascorbic acid, 2,6-dichlorophenol indophenol dye, 2,2-diphenyl-1-picrylhydrazyl (DPPH), and fatty acid methyl ester (FAME) standards were purchased from Sigma–Aldrich Company Ltd. (Hamburg, Germany). All other chemicals used were of analytical grade.

2.2 Extraction procedure

The extraction method was designed to obtain the highly effective extract as described previously by Lee et al. (2003) and based on our screening tests. In brief, 5 g of galangal powder was extracted by dissolving it in 50 mL of methanol: water (80:20, v/v), stirring for 3 h, and filtering through Whatman No. 1. Filter paper and then dry using a rotary evaporator. The dried extract was kept in sealed tinted bottles and stored at 4 °C until further use.

2.3 Chemical composition

The moisture, crude protein, fat, and ash contents of galangal powder were determined according to the official standard methods (Association of Official Analytical Chemists, 2018).

2.4 Mineral determinations

Mineral determination of Galangal was performed by ICP AES (Varian-Vista). In brief, a 0.5 g dried sample was hydrolyzed with 5 mL of a mixture of 65% HNO_3 and 35% H_2O_2 in a microwave system (Cem-MARS Xpress). After hydrolysis, the volume was increased to 20 ml with Milli-Q, the samples were analysed by ICP AES, and the concentration of minerals was checked by using the certified values of related minerals (National Institute of Standards and Technology).

2.5 Total flavonoid content

The total flavonoid content was assessed as described previously (Hogan et al., 2009). Briefly, 1 mL of the galangal rhizome extract was mixed with 0.3 mL of NaNO2, 0.3 mL of AlCl3, and 2 ml of NaOH. After 15 min of incubation in the dark at ambient temperature, the absorbance was measured at 510 nm by using a spectrophotometer. The total flavonoid content of the galangal rhizome extract was determined as equivalents in mg quercetin (QE)/100 g.

2.6 Total phenolic content

The total phenolic content of galangal samples was assessed using a Folin–Ciocalteu (FC) assay method (Yoo et al., 2004). In brief, galangal rhizome extract was vortexed with 1 mL of diluted FC and 10 mL of Na2CO3 (7.5%). Deionized water was added to the mixture to a final volume of 25 mL, and the mixture was kept in the dark for 1 h. The absorbance was determined at 750 nm in a spectrophotometer. The total phenolic contents of galangal rhizome extracts were described in milligrams of gallic acid equivalents (mg GAE/100 g extract).

2.7 Antioxidant activity

Free radical scavenging activity analysis (DPPH)

The DPPH (1.1-diphenyl-2-picrylhydrazyl) method was used for free radical scavenging activity analysis of galangal rhizome extracts (Lee et al., 1998) with slight modifications. After 2 ml of a methanolic solution of DPPH was added to the extract, the mixture was vortexed vigorously and kept in the dark at ambient temperature for 30 min. Finally, the absorbance was recorded using a spectrophotometer at 517 nm, and the results are given as mmol Trolox (TE)/kg of fresh weight.

Radical cation scavenging activity test (ABTS)

The ABTS assay was performed according to (Sharma et al., 2008) with slight modifications. Briefly, $ABTS^{\bullet+}$ solution with ethanol was prepared to obtain an absorbance of 0.70 ± 0.02 at a wavelength of 734 nm. Then, 20 µL aliquots of the MPE were mixed with 200 µL $ABTS^{\bullet+}$ working solution. The mixture was incubated for 4 min at 25 °C in black, and the absorbance was measured. The ABTS activity is expressed as mmol of Trolox/g dry galangal rhizomes.

Ferric ion reducing antioxidant power (FRAP)

The FRAP analysis was conducted as described previously (Al-Duais et al., 2009) with some alterations. Briefly, 20 µL aliquots of the galangal rhizome extract were mixed with 200 µL of freshly prepared FRAP working reagent. The FRAP reagent consisted of 25 mL 300 mM acetate buffer (pH 3.6) and 2.5 mL 20 mM FeCl3.6H2O. In addition, 2.5 mL of 10 mM 2,4,6-tris(2-pyridyl)-S-triazine dissolved in 40 mM HCl was added, and the final mixture was incubated at 25°C in darkness for 8 min. Then, the absorbance was measured at 593 nm. The activities are expressed as mmol of Trolox/g dry galangal rhizomes.

Fatty acid composition

The fatty acids of galangal rhizome oil were esterified with methyl ester, and the fatty acid methyl esters (FAMEs) were analysed using gas chromatography (Shimadzu GC-2010) with a Teknokroma TR-CN100 (60 m × 0.25 mm, 0.20 µm thickness) capillary column and flame-ionization detector (FID) according to (Ghafoor et al., 2019). For analysis, 1 µL of FAMEs of the samples and commercial standard FAME mixture was injected into the column at 260 °C, and running was carried out at a flow rate of 1.51 mL/min to a total flow rate of 80 mL/min, and the split rate was also 1/40. The column temperature was set at 120 °C for 5 min, increased to 240 °C at a rate of 4 °C/min, and then maintained at 240 °C for 25 min, and the peaks were identified and quantified by comparing their retention time and peak area with those of the FAME standard.

Phenolic compound determination

The extract of the galangal rhizome sample was filtered using a microporous filter (0.45 m) before HPLC injection. A high-performance liquid chromatography (HPLC) system (Shimadzu Corporation, Kyoto, Japan) was connected to a PDA detector with an Inertsil ODS-3 column (5 mm 4.6 mm 3250 mm) used for measuring and quantifying individual phenolic compounds. The mobile phase consisted of 0.05% acetic acid in water (A) and acetonitrile (B), and the flow rate was set at 1 mL/min. The gradient profile was 0-0.10 min 8% B; 0.10-2 min 10% B; 2-27 min 30% B; 27-37 min 56% B; 37-37.10 min 8% B; 37.10-45 min 8% B and 20 mL acetic acid, and the temperature was set at 30 °C. The wavelengths of the PDA detector were set at 280 and 330 nm, which were used for peak detection and measurement after a 1-h sample run. Phenolic compounds were determined according to the retention time and absorption spectra of standard compound peaks (Ghafoor et al., 2019).

Antimicrobial activity

Gram-positive bacteria (*Bacillus cereus*, *Clostridium perfringens*, *Listeria monocytogenes Micrococcus luteus*, *Bacillus coagulans*, and *Staphylococcus aureus*) and gram-negative bacteria (*Escherichia coli*, *Serratia marcescens*, *Pseudomonas aeruginosa*, *Salmonella typhimurium*, *Yersinia enterocolitica*, and *Klebsiella pneumoniae*) were used to determine the antibacterial activity of the galangal rhizome extracts using a disc diffusion method as previously described (Choi et al., 2006). Screening for antibacterial activity was performed using sheep blood agar (Oxoid) at 37 °C for 24 h. Galangal rhizome extract was mixed in sterile ethanol at a concentration of 0.70 mg/ml, and a final extract concentration of 0.1 mg/ml was obtained. The agar plates were inoculated using 0.1 mL inoculum of each bacterial strain. Discs impregnated with galangal rhizome extracts were then placed on the agar plate, followed by a 20 h incubation at 35 °C. This was followed by measuring the zones showing microbial growth inhibition around the discs.

Statistical analysis

All tests were performed in triplicate, and the means of the three replicates were obtained. Differences between data were analysed using analysis of variance (ANOVA) with JMP version 9.0 (SAS Inst. Inc., Cary, NC, USA). The results are presented as the means ± standard deviation (MSTAT C), and the results were considered statistically significant at $P < 0.05$.

3 Results and discussion

3.1 Proximate composition and mineral content of galangal powder

The proximate composition and mineral content of galangal rhizome powder are shown in Table 1. Galangal rhizomes contain a substantial quantity of ash, protein, oil, and carbohydrate. Previous reports indicated that fresh galangal rhizomes contain high amounts of moisture, considerable amounts of protein and carbohydrate, and minor quantities of lipid (Zanariah et al., 1997; Tanzima et al., 2011). The slight difference between the studies could be attributed to the differences in the galangal type used, condition (fresh and dried powder), growing geographic location, and postharvest processing conditions. The macromineral profile

Table 1. The chemical properties of galangal (*Alpinia galangal*).

Parameter	Mean ± SD
Moisture (%)	4.23 ± 0.09
Protein (%)	5.86 ± 0.03
Ash (%)	5.38 ± 0.11
Oil (%)	3.40 ± 0.05
Carbohydrate (%)	81.13 ± 1.23
Minerals (mg/kg)	
Ca	25.7 ± 2.35
K	159.79 ± 6.67
Mg	15.57 ± 0.95
Na	7.67 ± 0.60
P	17.36 ± 1.61
B	0.10 ± 0.01
Co	0.02 ± 0.00
Cr	0.05 ± 0.00
Cu	0.13 ± 0.01
Fe	7.20 ± 0.80
Mn	3.82 ± 0.19
Mo	0.01 ± 0.00
Ni	0.04 ± 0.00
Pb	0.12 ± 0.01
Zn	0.23 ± 0.05

Values are the means ± SD of triplicate samples.

of galangal rhizome powder showed high levels of potassium (159.79 mg/kg), followed by calcium (25.7 mg/kg), phosphorous (17.36 mg/kg), and magnesium (15.57 mg/kg). Among the trace minerals, high levels of iron (7.2 mg/kg) and manganese (3.82 mg/kg) were observed in galangal rhizome powder, whereas other trace minerals showed low amounts. Previous reports (Tanzima et al., 2011; Karim et al., 2017) also showed that the mineral profile of Galangal was partially comparable to that observed in this study, and the variations are likely due to the differences in the genetic background, growing location and conditions, postharvest conditions, and sample preparation and analysis conditions. The findings of this study indicate that galangal rhizomes are nutritionally valuable food spices.

3.2 Fatty acid composition of galangal oil

The fatty acid composition of galangal oil is shown in Table 2. The major fatty acids in galangal oil were elaidic (67.82%), linoleic (22.56%), palmitic (5.18%), and stearic (2.26%) acids. Interestingly, galangal oil contains high amounts of unsaturated fatty acids (91.8%) and fewer saturated fatty acids (7.73%), giving a ratio of unsaturated fatty acids to saturated fatty acids of 11.94. Despite rare studies on the fatty acid profile of galangal rhizome oil, a recent study indicated that the major fatty acids in galangal rhizomes are palmitic (37.65%), oleic (28.12%), linoleic (13.59%), and stearic (13.06%) acids, indicating that the fatty acid profile is different from our findings (Saini et al., 2021). The variations between these studies are probably due to the differences in the growing and postharvest conditions of Galangal. The current study's findings suggest the high nutritional and health quality of galangal oil.

3.3 Bioactive properties of galangal rhizome extract

It is well known that antioxidants capture free radicals through different mechanisms based on the types of free radicals and phenolic compounds of the antioxidant ingredients. However, it generally occurs through the donation of hydrogen from the hydroxyl group of the phenolic compound, by which a stable free radical complex is formed and hence prevents lipid peroxidation (Juntachote & Berghofer, 2005). The total phenolic content, flavonoid content, and antioxidant activity of galangal rhizome extract are shown in Table 3. Galangal rhizome extract contains substantial amounts of total phenolic content (53.18 mg GAE/g) and total flavonoid content (14.12 mg CE/g). Similarly, the total phenolic content in galangal rhizomes in China was found to be 58.25 mg GAE/g)Lu, 2011). In addition, the total flavonoid content was found to be 13.78 mg CE/g in ethanolic extract of galangal rhizomes, which was higher than that of water extract of 1.48 mg CE/g (Mahae & Chaiseri, 2009). In contrast, different levels of total phenolic and flavonoid contents were reported in various extracts of galangal rhizomes (Juntachote et al., 2007; Mayachiew & Devahastin, 2008; Tang et al., 2018; Quoc, 2021). The antioxidant activity was assessed by three complementary methods: DPPH free radical scavenging activity, ABTS radical cation scavenging activity, and ferric ion reducing antioxidant power (FRAP). The Galangal rhizome extract showed that it possessed high antioxidant activity, as assessed by DPPH (77.76%), ABTS (8.66 mmol TE/g), and FRAP (3.99 mmol TE/g). In agreement with the results of the present study, dried rhizomes of *A. officinarum* were extracted by maceration in methanol and were subsequently screened for in vivo anti-inflammatory and in vitro antioxidant activity (Honmore et al., 2016). Additionally, it was reported that different parts of the *Alpinia galangal* plant are used to treat many diseases for their antifungal, antitumour, antimicrobial, anti-inflammatory, antidiabetic, antioxidant, antiulcer, and many other properties (Chouni & Paul, 2018).

Previous work on the antioxidant activity of galangal rhizome extract was reported to be 88.3% DPPH, 593.9 µmol TE/g ABTS, and 771.0 µmol TE/g FRAP (Lu et al., 2011), which are different from our findings. In another study, a range of 8.11-8.65 mmol TE/g was reported for the antioxidant activity of galangal rhizome extract as assessed by an oxygen radical absorbance capacity (ORAC) assay (Mahae & Chaiseri, 2009). In addition, the DPPH scavenging activity of galangal water and acetone extracts at different solvent concentrations and extraction times was found to be in the range of 80.06% to 90.54% (Quoc, 2021). Additionally, in line with the results of this study, the roots of *A. officinarum* were extracted at 80°C in 70% methanol for 3 h, exhibited high DPPH radical scavenging activity in a dose-dependent manner, and effectively inhibited lipid peroxidation in H2O2-treated V79-4 cells (Lee et al., 2003).

Factors such as genotypes, growing conditions, postharvest conditions, phenolic compound extraction solvents, and conditions

Table 2. The fatty acid compositions of galangal oil.

Fatty acids	% of oil
Palmitic (C14:0)	5.18 ± 0.89
Stearic acid (C18:0)	2.26 ± 0.01
Arachidic (C20:0)	0.14 ± 0.02
Behenic (C22:0)	0.15 ± 0.03
ΣSFA	**7.73 ± 0.12**
Oleic (C18:1 *cis*-Δ^9)	0.24 ± 0.00
Elaidic (C18:1 *trans*-Δ^9)	67.82 ± 0.61
Linolelaidic (18:2 *trans*, *trans*-Δ^9,Δ^{12})	0.50 ± 0.01
Linoleic (18:2 *cis*, *cis*-Δ^9,Δ^{12})	22.56 ± 0.25
Linolenic (18:3 *cis*, *cis*,*cis*-Δ^9,Δ^{12},Δ^{15})	0.90 ± 0.01
Arachidonic (20:4 *cis*, *cis*,*cis*, *cis*-$\Delta^5\Delta^8$,Δ^{11},Δ^{14})	0.25 ± 0.05
ΣUSFA	**92.27 ± 2.89**
USFA/SFA	**11.94**

Values are the means ± SD of triplicate samples. SFA: saturated fatty acid. USFA: unsaturated fatty acid.

Table 3. Total phenolic content, total flavonoid content, and antioxidant activity of galangal rhizome extracts.

Parameter	Mean ± SD
Total phenolic content (mg GAE/g)	53.18 ± 1.45
Total flavonoid content (mg CE/g)	14.12 ± 0.40
Antioxidant activity	
DPPH (%)	77.76 ± 0.08
ABTS (mmol Trolox/g)	8.66 ± 0.04
FRAP (mmol Trolox/g)	3.99 ± 0.01

Values are the means ± SD of triplicate samples. DPPH: 1,1-diphenyl-2-picrylhydrazyl. ABTS: 2,2-Azino-Bis (3-Ethylbenzthiazoline-6-Sulfonic Acid. FRAP: ferric reducing antioxidant power.

could significantly affect galangal extract's total phenolic and total flavonoid contents. Overall, galangal rhizome is a rich source of bioactive compounds (total phenolic and total flavonoid contents) and possesses great antioxidant activity and, therefore, could have high nutritional and health potential.

3.4 Phenolic compounds of galangal rhizome extract

The results of the phenolic compound profile of galangal rhizome extract are presented in Table 4. Galangal rhizome extract contains substantial amounts of phenolic compounds. The most abundant phenolic compound in the extract was gallic acid, followed by (+)-catechin, quercetin, catechol, isorhamnetin, trans-cinnamic acid, and protocatechuic acid. A similar phenolic profile of galangal rhizome extract was recently reported (El-Hadidy et al., 2020). Similarly, Tan et al. recognized 16 chemicals consisting of 12 flavonoids and 4 DAHs from A. officinarum methanol extract leaves using LC-mass spectrometry (MS)/MS, including quercetin, chrysin, and rutin. galangin, pinocembrin, acacetin, tectochrysin, apigenin, 3-O-methylgalangin, kaempfero, kaempferide, isorhamnetin, yakuchinone A, hannokinol oxyphyllacinol, and hexahydrocurcumin (Tan et al., 2015). In addition, reports also indicated that galangal rhizome extract contains galangin (Lu et al., 2011), catechin and coumaric acid (Mahae & Chaiseri, 2009), quercetin and rutin (Suzery et al., 2019), and epigallocatechin gallate (EGCG) and carnosic acid (Jongsawatsataporn & Tanaka, 2022) as the major phenolic compounds. Some of these compounds could be responsible for the antioxidant activity of galangal extract, as it was recently reported that quercetin is the main compound responsible for the antioxidant activity of Galangal (El-Hadidy et al., 2020).

Several bioactive compounds have been extracted from the *Alpinia galangal* plant, such as β-pinene, 1'S-1'-acetoxychavicol acetate, α-bergamotene, 1'S-1'-acetoxyeuginol acetate, 1,8-cineol, 1'-acetoxychavicol acetate (galangal acetate), α-fenchyl acetate, β-farnesene, β-bisabolene, β-sitosteroldiglucoside (AG-7), β-sitsteryl arabinoside (AG-8), and p-hydroxycinnamaldehyde (Honmore et al., 2016).

The rich phenolic profile of galangal rhizomes suggested their great nutritional health potential and consequently could be recommended for regular food utilization.

Table 4. Phenolic compounds of galangal extract (GE).

Phenolic compounds	mg/100 g
Gallic Acid	160.04 ± 2.65
Protocatechuic acid	71.46 ± 1.85
(+)-Catechin	124.33 ± 3.77
Catechol	100.18 ± 2.82
Syringic Acid	37.09 ± 0.44
Caffeic Acid	13.96 ± 0.81
Rutin trihydrate	11.47 ± 0.62
p-Coumaric Acid	2.93 ± 0.39
trans-Ferulic Acid	11.67 ± 0.53
Apigenin 7 glucoside	16.40 ± 0.21
Resveratrol	6.66 ± 0.43
Quercetin	105.34 ± 2.80
trans-Cinnamic Acid	81.97 ± 1.73
Naringenin	2.36 ± 0.02
Kaempferol	0.66 ± 0.01
Isorhamnetin	82.21 ± 1.82

Values are the means ± SD of triplicate samples.

3.5 Antimicrobial activity of galangal rhizome extract

The results of the antimicrobial activity of galangal rhizome extract against Gram-positive and Gram-negative food pathogenic bacteria are shown in Table 5. It is well known that an inhibition zone of more than 6 mm is considered significant for considering the extract to have antimicrobial activity (Elgayyar et al., 2001). It is worth noting that galangal extract possessed high antimicrobial activity against most assessed strains, except *Escherichia coli* and *Bacillus coagulans,* as the inhibition zones against these strains were less than 6.0. The low inhibition of Galangal against *E. coli* could be attributed to the inability of the hydrophobic galangal extract to penetrate through the lipopolysaccharide monolayer outer membrane of the strains (Oonmetta-aree et al., 2006). Our results showed that the highest inhibition zone of 12.0 ± 0.12 mm was found for *Klebsiella pneumoniae ATCC 10031, followed by Yersinia enterocolitica ATCC 27729*, *Micrococcus luteus* ATCC 10240, *Bacillus cereus* ATCC 14579, *Staphylococcus aureus ATCC* 29737, *Listeria monocytogenes* ATCC 19114 and *Pseudomonas aeruginosa* ATCC 9027, *Clostridium perfringens* ATCC 13124 and *Serratia marcescens* ATCC 13880 and *Salmonella typhimurium* ATCC 14028, with inhibition zones of 6.0 ± 0.05 mm. In agreement with these findings, it was reported that 1'-acetoxyeugenol acetate was identified as the highest

Table 5. Antimicrobial activity of galangal extracts.

Bacteria	Inhibition zone (mm)	
	GE (10 µg/uL)	Penicillin (10 µg)
Gram-negative		
Escherichia coli ATCC 10536	5.0 ± 0.05	26.0 ± 0.09
Serratia marcescens ATCC 13880	7.0 ± 0.02	30.0 ± 0.12
Pseudomonas aeruginosa ATCC 9027	9.0 ± 0.10	20.0 ± 0.19
Salmonella typhimurium ATCC 14028	6.0 ± 0.05	19.0 ± 0.13
Yersinia enterocolitica ATCC 27729	11.0 ± 0.02	13.0 ± 0.04
Klebsiella pneumoniae ATCC 10031	12.0 ± 0.12	16.0 ± 0.08
Gram-positive		
Bacillus cereus ATCC 14579	9.0 ± 0.07	18.0 ± 0.18
Clostridium perfringens ATCC 13124	7.0 ± 0.01	12.0 ± 0.10
Listeria monocytogenes ATCC 19114	9.0 ± 0.04	11.0 ± 0.01
Micrococcus luteus ATCC 10240	10.0 ± 0.09	17.0 ± 0.08
Bacillus coagulans (Laboratory Isolate)	2.0± 0.02	16.0 ± 0.10
Staphylococcus aureus ATCC 29737	9.0 ± 0.09	25.0 ± 0.12

Values are the means ± SD of triplicate samples. Galangal Extract (GE).

compound in flowers and exhibited the strongest antimicrobial activity among all fractions, with MIC50 values of 34 µg/ml against Staphylococcus aureus and 68 µg/ml against Listeria monocytogenes (Tang et al., 2018).

Penicillin showed higher inhibition zones for all tested strains than the galangal rhizome extract, which could be attributed to the fact that pure preparations of penicillin were used, whereas in the case of galangal extract, the crude extract was used. Purification of the compounds responsible for the antimicrobial activity of galangal extract is needed, and this will increase the potential application of Galangal as a source of antimicrobial compounds. Additionally, wide utilization of Galangal in foods could be recommended due to its high antioxidant and antimicrobial activities. Similarly, previous reports indicated that galangal extract and oils possessed antimicrobial activity against various food pathogenic bacteria [(Oonmetta-aree et al., 2006; Mayachiew & Devahastin, 2008; Özkinali et al., 2017; Tang et al., 2018; Muniandy et al., 2019)]. Galangal extract possessed antimicrobial activity against Gram-positive strains, namely, *Staphylococcus aureus*, *Staphylococcus epidermidis,* and *Listeria monocytogenes* (Muniandy et al., 2019). In another study, galangal extract showed inhibition of gram-positive strains, whereas it was less effective against gram-negative strains, namely, *Salmonella sp*., *Enterobacter aerogenes,* and *Pseudomonas aeruginosa* (Oonmetta-aree et al., 2006).

4 Conclusion

This study indicates that galangal rhizomes contain appreciable quantities of essential nutrients such as protein, minerals (K, Ca, Fe, Mg, and Mn), unsaturated fatty acids (elaidic and linoleic acids), and phenolic compounds, namely, (+)-catechin, quercetin, catechol, isorhamnetin, and gallic, trans-cinnamic and protocatechuic acids. The galangal rhizome extract exhibited high antioxidant (DPPH, ABTS, FRAP) and antimicrobial activities. The fact that *Alpinia galanga* contains important minerals and essential fatty acids, in addition to its high nutritional value, according to the results of this study, indicates the high effectiveness of this plant in the prevention and treatment of many malnutrition diseases, especially those related to micronutrients and other chronic diseases in which minerals and essential fatty acids play a role. Notably, these components can stimulate biochemical reactions and improve the vital functions of living organisms. The work also concluded that the plant contains high vital importance, effective compounds, and a significant ability to act as natural antioxidants. This gives the plant great importance in scavenging free radicals and enhancing oxidative stress defense, thus preventing treatment and managing various serious diseases, such as cancer, diabetes, cardiovascular disease, liver disease, and bones.

Moreover, the plant extract's high antimicrobial ability makes it a natural immune booster and a cheap, safe, and effective alternative to synthetic antibiotics with dual effects. This plant's capabilities allow it to be exploited to improve health and nutritional status and improve the economy through its use in multiple applications in the pharmaceutical, food, cosmetic, and other industries. Additionally, it will be very important to conduct further studies to isolate and define the different bioactive components of the plant and study its different effects at the level of the living cell.

Conflicts of Interest

No potential conflict of interest was reported on behalf of all authors.

Data Availability Statement

The data used to support the findings of this study are included within the article

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