

Black ginger (*Kaempferia parviflora* Wall. ex Baker): A systematized narrative review on phytochemistry and pharmacological importance

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ABSTRACT:

Background: *Kaempferia parviflora* Wall. ex Baker is a medicinal plant used by many people in Southeast Asia, especially Thailand. Its rhizome has been used in Asian traditional medicine for gastrointestinal tract disorders and allergic disorders, as an aphrodisiac, and as a body tonic, similar to the use of ginseng, hence its common name Thai ginseng. In recent years, research interest in this plant has strengthened due to its claimed antioxidant, anti-inflammatory, anti-obesity, anticancer, antimicrobial, and vascular-relaxing properties. **Methods:** This systematized narrative review summarizes the phytochemistry, pharmacological effects, molecular mechanisms, and clinical applications of *K. parviflora* from published studies between 2016 and 2026. An electronic search of PubMed, Scopus, and Web of Science was conducted. Articles were screened according to predefined inclusion and exclusion criteria, and the study-selection process was documented using a PRISMA-style flow diagram to enhance transparency. A total of 62 articles were included. **Results:** The rhizomes contain the polymethoxyflavones 5,7-dimethoxyflavone, 5,7,4'-trimethoxyflavone, and 3,5,7,3',4'-pentamethoxyflavone, anthocyanins, carotenoids, phytosterols, and essential oils. Preclinical studies have shown ingredients of the rhizomes with antioxidant (Nrf2/ARE activation), anti-inflammatory (inhibition of NF-κB, COX-2, and iNOS), anticancer (induction of apoptosis, anti-austerity, and PI3K/AKT-MAPK inhibition), antimicrobial, neuroprotective (cholinesterase inhibition and anti-amyloid effects), and metabolic effects. Vasoactive effects are mediated by the NO-cGMP pathway, K⁺ efflux and inhibition of Ca²⁺ influx. In humans, vasoactive effects have been accompanied by improved erectile function and cardiorespiratory response, with adverse effects rarely seen and not severe, even at doses of up to a maximum of 1.35 g/day. Nevertheless, the evidence base is relatively weak due to small sample sizes. **Conclusions:** Black ginger shows promise as a potential source of bioactive polymethoxyflavones as nutraceuticals and pharmacological agents, although difficulties remain in overcoming low oral bioavailability of methoxyflavones and the lack of large clinical trials over an extended period.

KEYWORDS: Antioxidant activity, black ginger, clinical applications, *Kaempferia parviflora* Wall. ex Baker, pharmacological activities, polymethoxyflavones.

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1. INTRODUCTION

Kaempferia parviflora Wall. ex Baker is a medicinal plant used by many people in Southeast Asia, especially in Thailand. It is known as Krachaidum or Krachaidam in Thailand. [1,2] Its rhizome has been used in Asian traditional medicine for gastrointestinal tract disorders and allergic disorders, as an aphrodisiac, and as a body tonic, similar to the use of ginseng, hence its common name Thai ginseng. [1,3] In recent years, research interest in this plant has strengthened due to its claimed antioxidant, anti-inflammatory, anti-obesity, anticancer, antimicrobial, and vascular-relaxing properties. [1, 2]

Polymethoxyflavones are the most abundant compounds in the rhizome and are considered the major bioactive components, with up to 15 polymethoxyflavones that have one to five methoxy groups. [4, 5] Other secondary metabolites include anthocyanins, carotenoids, vitamins, fatty acids, phytosterols and volatile essential oils. [3] Several narrative reviews that describe individual activities exist, but the phytochemistry has not been properly integrated with the available pharmacology, molecular mechanisms and clinical evidence in the literature to date. [3,5]

Herein, we provide a thorough and updated review that integrates recent discoveries (2016-2026) regarding the pharmacological mechanisms, clinical evidence, formulation strategies of *K. parviflora*. It also highlights the relationship between polymethoxyflavone chemistry, molecular pharmacology targets, bioavailability enhancement strategies, and therapeutic applications such as metabolic function enhancement, anticancer effects, muscle performance enhancement, and lifespan assessment. Finally, gaps in translational knowledge are highlighted concerning safety, standardization and clinical validation, which may guide future research aimed at the development of *K. parviflora* as an evidence-based nutraceutical/pharmaceutical agent.

2. METHODOLOGY

Search strategy: Relevant articles related to *Kaempferia parviflora* Wall. ex Baker (black ginger) were identified through systematic searches of the PubMed, Scopus, and Web of Science Core Collection databases using predefined Boolean search strategies ([Table 1](#)). The literature search was restricted to English-language publications published between 1 January 2016 and 15 June 2026. The final literature search was completed on 15 June 2026. The PubMed database was searched using the following strategy: ("Kaempferia parviflora" OR "K. parviflora" OR "black ginger" OR "Krachaidum" OR "Krachai-dam") AND ("polymethoxyflavones" OR "phytochemistry" OR "phytochemical constituents" OR "pharmacological activity" OR "antioxidant activity" OR "anti-inflammatory activity" OR "anticancer activity" OR "antimicrobial activity" OR "neuroprotective activity" OR "metabolic effects" OR "cardiovascular effects" OR "physical performance" OR "therapeutic effects" OR "clinical applications" OR "molecular mechanisms"). Filters applied included English language, publication date from 1 January 2016 to 15 June 2026, and research articles and reviews.

The Scopus database was searched using the following TITLE-ABS-KEY strategy: TITLE-ABS-KEY(("Kaempferia parviflora" OR "K. parviflora" OR "black ginger" OR "Krachaidum" OR "Krachai-dam") AND ("polymethoxyflavones" OR "phytochemistry" OR "phytochemical constituents" OR "pharmacological activity" OR "antioxidant activity" OR "anti-inflammatory activity" OR "anticancer activity" OR "antimicrobial activity" OR "neuroprotective activity" OR "metabolic effects" OR "cardiovascular effects" OR "physical performance" OR "therapeutic effects" OR "clinical applications" OR "molecular mechanisms")). Filters applied included English language, publication period from 1 January 2016 to 15 June 2026, and relevant document types including research articles and reviews.

The Web of Science Core Collection database was searched using the following Topic (TS) field strategy:

TS=("*Kaempferia parviflora*" OR "*K. parviflora*" OR "black ginger" OR "Krachaidum" OR "Krachai-dam") AND TS=("polymethoxyflavones" OR "phytochemistry" OR "phytochemical constituents" OR "pharmacological activity" OR "antioxidant activity" OR "anti-inflammatory activity" OR "anticancer activity" OR "antimicrobial activity" OR "neuroprotective activity" OR "metabolic effects" OR

"cardiovascular effects" OR "physical performance" OR "therapeutic effects" OR "clinical applications" OR "molecular mechanisms"). The applied filters included Web of Science Core Collection, English language, document types of Articles and Review Articles, and publication period from 1 January 2016 to 15 June 2026.

Table 1: Search strategy used to identify relevant literature

Database	Exact search strategy	Filters applied	Records retrieved (n)
PubMed	("Kaempferia parviflora" OR " <i>K. parviflora</i> " OR "black ginger" OR "Krachaidum" OR "Krachai-dam") AND ("polymethoxyflavones" OR "phytochemistry" OR "phytochemical constituents" OR "pharmacological activity" OR "antioxidant activity" OR "anti-inflammatory activity" OR "anticancer activity" OR "antimicrobial activity" OR "neuroprotective activity" OR "metabolic effects" OR "cardiovascular effects" OR "physical performance" OR "therapeutic effects" OR "clinical applications" OR "molecular mechanisms")	English language; publication date: 1 January 2016–15 June 2026; article types: Research articles and Reviews	246
Scopus	TITLE-ABS-KEY(("Kaempferia parviflora" OR " <i>K. parviflora</i> " OR "black ginger" OR "Krachaidum" OR "Krachai-dam") AND ("polymethoxyflavones" OR "phytochemistry" OR "phytochemical constituents" OR "pharmacological activity" OR "antioxidant activity" OR "anti-inflammatory activity" OR "anticancer activity" OR "antimicrobial activity" OR "neuroprotective activity" OR "metabolic effects" OR "cardiovascular effects" OR "physical performance" OR "therapeutic effects" OR "clinical applications" OR "molecular mechanisms"))	English language; publication date: 1 January 2016–15 June 2026; document types: Articles and Reviews	178
Web of Science Core Collection	TS=(" <i>Kaempferia parviflora</i> " OR " <i>K. parviflora</i> " OR "black ginger" OR "Krachaidum" OR "Krachai-dam") AND TS=("polymethoxyflavones" OR "phytochemistry" OR "phytochemical constituents" OR "pharmacological activity" OR "antioxidant activity" OR "anti-inflammatory activity" OR "anticancer activity" OR "antimicrobial activity" OR "neuroprotective activity" OR "metabolic effects" OR "cardiovascular effects" OR "physical performance" OR "therapeutic effects" OR "clinical applications" OR "molecular mechanisms")	Web of Science Core Collection; English language; publication date: 1 January 2016–15 June 2026; document types: Articles and Review Articles	129

Study selection or screening process: In this review, a total of 553 records related to *Kaempferia parviflora* (black ginger) were identified through searches of three databases: PubMed (246), Scopus (178), and Web of Science (129). After removing 194 duplicate records, 359 records remained for title and abstract screening. At this stage, 104 records were excluded because they did not focus on the phytochemistry, pharmacological activities, molecular mechanisms, or clinical aspects of *K. parviflora*. The remaining 255 reports were assessed for eligibility

through full-text evaluation. Of these, 193 reports were excluded for the following reasons: duplicate publication (n = 154), an unrelated or irrelevant topic (n = 12), insufficient results (n = 10), lack of original contribution (n = 5), and unavailable full text (n = 12). The remaining 62 studies met the inclusion criteria and were included in the qualitative narrative synthesis. Study identification, screening, eligibility assessment, and inclusion were conducted in accordance with the Preferred Reporting Items for

Systematic Reviews and Meta-Analyses (PRISMA) guidelines to promote transparency and reproducibility (Figure 1).

This narrative review was prepared in accordance with the Scale for the Assessment of Narrative Review Articles (SANRA). The review addresses the importance of the topic, clearly defines its objectives, describes the literature search approach, provides appropriate references, presents scientific reasoning, and summarises relevant evidence to support its conclusions.

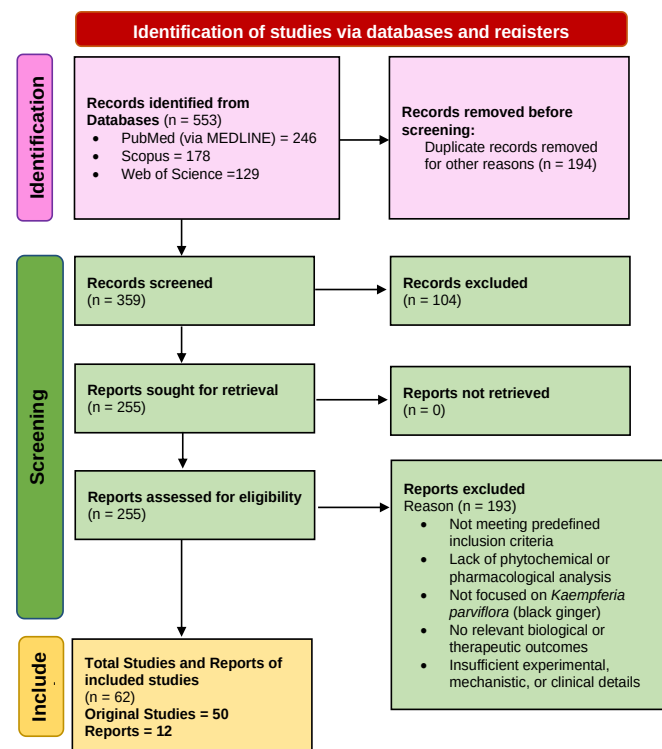


Figure 1: PRISMA diagram

Inclusion criteria: The following inclusion criteria were applied: original articles, systematic reviews, meta-analysis, toxicological studies, clinical trials, and phytochemical investigation on *K. parviflora*; phytochemical investigation on the constituents of *K. parviflora* including polymethoxyflavones and other phytochemicals; biological activities including antioxidant, anti-inflammatory, anticancer, antimicrobial, neuroprotective, metabolic, cardiovascular, sexual, and physical performance; studies related to molecular pathways, biological mechanisms, safety evaluation, and clinical applications; published in English between 2016 and 2026 in peer-reviewed journals.

Exclusion criteria: Articles were excluded if they were (1) duplicates of previously published papers, (2) conference proceedings, editorials or commentaries, or non-peer-reviewed publications, (3) not related to *K. parviflora* or black ginger, (4) did not contain important experimental, mechanistic or clinical data, (5) not published in English, or (6) only descriptions of the plant and taxonomical information and lacking phytochemical, pharmacological, toxicological or therapeutic information.

3. PLANT TRAITS AND TRADITIONAL APPLICATIONS:

K. parviflora Wall. ex-Baker, a rhizome-forming herbaceous perennial plant in the Zingiberaceae family, is native to Thailand and widespread in Southeast Asia, Malaysia, and parts of China. [1,6,7] It has tuberous roots and small white flowers with a purple border. Growing in moist, wet soil and 30 to 35 °C climates, it can reach 90 cm (35 in) in height. The dark purple stemless rhizome is used for medicinal and commercial purposes. [4] A number of methods for cultivation and conservation, including *in vitro* culture, vivipary, and shade treatment, have been investigated to maintain a supply as demand increases. [5]

The principal active phytochemicals in the black rhizome are polymethoxyflavones, especially 5,7,4'-trimethoxyflavone, 5,7-dimethoxyflavone, 3,5,7,3',4'-pentamethoxyflavone, and the essential oil components camphene, β-pinene, α-pinene, and endo-borneol. [5,8] Anthocyanins are another major class of phenolic constituents in the black rhizome. [3] The maceration extraction technique has been accepted to be the most widely applicable while the microwave-assisted extraction is the most efficient method of extraction for the methoxyflavones and the supercritical CO₂ extraction is the most suited for essential oils. [5]

Traditionally, the rhizome is used to treat colic, inflammation, ulcer, abscess, allergy, gout, osteoarthritis, digestive system disorders, allergic diseases, sexual performance, and the nourishment of the body. [1,6] In traditional Chinese medicine terminology, the plant is described as being of flat nature with acrid and sweet

tastes, as well as a channel tropism to the kidney, spleen, stomach, and liver. Traditionally, it was used to treat kidney essence deficiency, sexual apathy, obesity, diabetes, and depression. [7] These historical therapeutic uses form the bases of many of the pharmacological studies described below.

Pharmacological activities: For *K. parviflora*, the evidence for biological activities has been generated from different levels of experimentations and include *in-silico* (prediction by computer), *in-vitro* (test tube), *in-vivo* (animal testing), observational (involving humans), and controlled clinical studies. These findings provide a good overview of how the biological activities of black ginger have been translationally studied.

In-silico evidence: Computational studies have begun to explore how compounds from *K. parviflora* exert their pharmacological effects by predicting possible protein targets of black ginger's polymethoxyflavones using molecular docking and correlation approaches, suggesting potential interactions with proteins associated with cellular signaling pathways and apoptosis. These computational predictions provide potential molecular targets as the basis for the anticancer activities of black ginger, which still require validation in cellular and animal studies. [9]

In-vitro evidence: The majority of experimental evidence for the antioxidant, anticancer, antimicrobial and neuroprotective effects of *K. parviflora* has been produced *in vitro*. A range of biochemical assays and cell-based models have been used to study the multitude of biological effects of black ginger extracts and isolated bioactive compounds.

Antioxidant activity: Black ginger rhizome extract has a high antioxidant capacity in several assays. It scavenged DPPH and ABTS radicals with IC₅₀ values of 3.0 ± 0.1 mg/mL and 19.4 ± 1.2 µg/mL, respectively. Inhibition of lipid peroxidation was 80.0 ± 4.5% at 20 µg/mL. At a concentration of 10 mg/mL, the essential oil extracted from the rhizome showed 80.90% DPPH free radical scavenging and 94.04% ABTS free radical scavenging with IC₅₀ values to

be 0.451 ± 0.051 mg/mL and 0.527 ± 0.022 mg/mL, respectively. Higher levels of phenolic and flavonoids in the black ginger oil contributed considerably to its stronger antioxidant activity compared to other Zingiberaceae species. [8,10,11]

Anticancer activity: Most anticancer studies on *K. parviflora* are conducted using cancer cell lines. The ethanolic extract of black ginger was shown to induce a dose-dependent cytotoxic effect and apoptosis in the MCF-7 and MDA-MB-231 human breast cancer cell lines (IC₅₀: 60-85 µg/mL). The treatment resulted in an increased caspase-3 activity (approximately 4.1-fold increase), indicative of apoptosis. Among the isolated polymethoxyflavones, 5-hydroxy-7,4'-dimethoxyflavone (5-OH-7,4'-DMF), exhibited preferentially cytotoxic to MCF-7 with an IC₅₀ of 24.12 ± 0.45 µM while retaining cell viability of more than 80% in fibroblast cells (non-cancerous). [12]

Black ginger extract exhibited anti-austerity activity in pancreatic carcinoma in nutrient starvation. 5-hydroxy-7-methoxyflavone (0.8 µM PC₅₀) showed the most effective anti-austerity activity. Black ginger extract inhibited proliferation, migration and invasion of ovarian cancer cells, induced intrinsic apoptosis, inhibited MMP-2/9 activity, and downregulated the PI3K/AKT and MAPK signaling pathways. [9] Molecular docking studies also suggest that some polymethoxyflavones may interact with proteins involved in apoptosis, but these findings require further experimental verification. [12]

Antimicrobial activity: Extracts of black ginger have demonstrated *in-vitro* antimicrobial activity against Gram-positive and Gram-negative bacteria, yeasts, dermatophyte fungi. An essential oil of the fresh rhizome inhibited growth of *Escherichia coli*, *Listeria monocytogenes*, and *Staphylococcus aureus* at concentrations ranging from 30 to 200 mg/mL. [11] Further extracts were found to have antibacterial activity on *Micrococcus luteus* and antifungal activity on *Rhizoctonia solani* and *Fusarium oxysporum*; treatment with these antifungal extracts produced morphological changes and collapse in the fungi. [8,10]

Endophyte extracts have been found to show antibacterial activity against *S. aureus* at a minimum inhibitory concentration (MIC) of 64 µg/mL. They also have anti-biofilm activity against dental caries associated bacteria. [9]

Neuroprotective activity

In vitro tests (cell-based assays) of black ginger and its polymethoxyflavone components showed neuroprotective activity, with the capacity to inhibit cholinesterase, decrease aggregation of Aβ₁₋₄₂, destabilize amyloid fibrils, and protect SH-SY5Y neuronal cells from Aβ-induced cytotoxicity. Of the isolated methoxyflavones, 5,7,4'-trimethoxyflavone was the most effective in antiaggregation and fibril-destabilizing assays. 3,5,7,3',4'-pentamethoxyflavone has been found to inhibit acetylcholinesterase dose-dependently. [13,14]

In addition, black ginger extract protected against glutamate-induced HT-22 hippocampal neuronal cell death at least in part by inhibiting apoptosis, decreasing intracellular ROS levels and phosphorylation of ERK, and restoring BDNF levels. [15] These preliminary data provide evidence that black ginger extract may have neuroprotective effects, but animal studies and clinical trials are warranted.

Animal (*in-vivo*) evidence: Animal research has supported the biological effects of *K. parviflora*. Its antioxidant effects, anti-inflammatory effects, neuroprotective effects, metabolic effects, cardiovascular effects, and physical performance role which have been shown in *in-vitro* studies have also been shown in animal models. These preclinical studies have also helped explain the molecular mechanisms that support black ginger's potential therapeutic effects.

Antioxidant and molecular pathway regulation: *In-vivo* experiments have shown that *K. parviflora* extract can reduce oxidative stress by activating the endogenous antioxidant defense system. Supplementation with black ginger extract can stimulate the Nrf2/ARE pathway, resulting in an increase in the expression of downstream antioxidant genes and an improved antioxidant status in the plasma of a mouse model. [16] Co-treatment of black

ginger extract with other antioxidant extracts *in vitro* demonstrated a potentiation effect on the expression of antioxidant responsive genes SOD1, SOD2, CAT, GPX1, Nrf2, GCLM and a decrement in the expression of Keap1 which may protect against oxidative stress in macrophages. [17]

Anti-inflammatory activity: The anti-inflammatory effects of black ginger have been confirmed in several animal models for inflammatory responses. For example, the extract of black ginger had anti-arthritic effects against a complete Freund's adjuvant-induced arthritis rat model, as seen in improved arthritis scores, decreased release of sulfated glycosaminoglycans, and a preserved proteoglycan content in cartilage explants. The effects are caused by inhibition of NF-κB and MAPK pathways, and modulation of necroptosis-related genes. [18]

In monosodium iodoacetate-induced osteoarthritis, black ginger extract decreased cartilage pathological indexes, alleviated degeneration of the joints, and inhibited inflammatory mediators, suggesting that black ginger extract may represent another approach to treating inflammatory disorders. [19]

Neuroprotective activity: Animal studies also suggest the neuroprotective properties of black ginger and polymethoxyflavones from black ginger against cognitive impairment due to memory deficits. Polymethoxyflavone compounds from black ginger have been shown to protect cognition in scopolamine-induced memory impairment in mice. [13] 5,7-dimethoxyflavone, 5,7,4'-trimethoxyflavone, and 3,5,7,3',4'-pentamethoxyflavone protected neural stem cells and microglia from amyloid-beta-induced neuroinflammation and prevented the inhibition of neurogenesis. [20]

These findings suggest that black ginger might have neuroprotective effects through the modulation of oxidative stress, neuroinflammation, and neuronal survival, but only animal and *in vitro* studies have been conducted to date, so human studies are required.

Metabolic effects: Preclinical metabolism studies have shown promising results using *K. parviflora*

supplementation in models of obesity and diabetes. In ob/ob mice, oral administration of black ginger extract (100 or 200 mg/kg/day, 8 weeks) decreased body volume and weight, adipose tissue accumulation, while increasing muscle fiber area, muscle weight, exercise tolerance, and grip strength. No important differences in food intake were seen. [21]

In mice fed a high-fat diet, black ginger reduced body fat mass, decreased adipocyte size, blood glucose, triglyceride, cholesterol, insulin, and leptin levels, promoted lipolysis, and inhibited adipogenesis. The mechanism of action involves activation of AMPK phosphorylation, and up-regulation of CPT1 and UCP1, with subsequent stimulation of energy expenditure. [22,23]

Moreover, black ginger extract as a ligand-binding agonist for PPAR γ improved the blood glucose tolerance and inhibited the deposition of lipids in adipose tissue, liver, and skeletal muscles of the diabetic Nagoya-Shibata-Yasuda mice. [24] Prevention of insulin resistance, hypertension, and development of fatty liver in obese type 2 diabetic animal models has also been reported. [23] The bioavailability and bioactivity of black ginger compounds in obese mice were increased by nanostructured lipid carriers, which reduced weight, body mass index (BMI), liver weight, and adipose tissue weight. [25]

Cardiovascular protective effects: Vascular and other preclinical studies on animals show that the compounds in black ginger may have cardioprotective effects. Black ginger also has been shown to induce endothelial-dependent relaxation of vascular smooth muscle, for example, in rat ventricular myocytes. [26]

Vasorelaxant effects of an isolated compound 5,7-dimethoxyflavone on isolated rat aortas were observed to be concentration-dependent (1 to 100 μ M). The effect seems to be related to the increased contents of NO, cGMP, and the decreased concentration of calcium ions. Involvement of the endothelial pathway, potassium efflux, and calcium channel regulation in the vasorelaxation of rat aortas is suggested by experiments that used endothelium

removal, NO/cGMP pathway inhibitors, cyclooxygenase inhibitors, and potassium channel blockers. [26,27]

Effects on physical performance and exercise: Animal studies have reported effects of black ginger extract on exercise performance and energy metabolism. In a mouse model, a single dose of black ginger extract (62.5 mg/kg) increased time to exhaustion, in part through increases in expression of skeletal muscle and liver genes involved in lipid, lactate, and glycogen metabolism. [28]

Chronic supplementation may have improved endurance performance and voluntary running distance possibly due to the increase in antioxidant capacity and metabolic adaptation. [16] An extract of black ginger improved muscle performance, endurance capacity and grip strength in obese mice. [21] There is sufficient preclinical evidence for antioxidant, anti-inflammatory, metabolic, neuroprotective, cardiovascular and ergogenic effects of *K. parviflora* supplementation in animal models, however further studies are needed to explore their clinical applicability in humans.

Observational and uncontrolled human studies: Human studies on *K. parviflora* have examined the effects on sexual functions and physical performance, as well as, cardiovascular risk factors, providing preliminary evidence for the physiological effects of black ginger supplementation in humans. However, these studies have been limited by open-label, small sample sizes, and the lack of placebo-controlled comparisons.

Some open-label human research has suggested that black ginger might have an effect on sexual health. One such research trial in healthy men 50-70 years old reported improved scores in the total, erectile function, intercourse satisfaction, and orgasmic function domains of the International Index of Erectile Function (IIEF) score after 30 days of supplementation with black ginger extract. Around 61.5% of participants experienced improved functioning of erection after supplementation. [29]

Another open-label study reported that supplementation with 100 mg/day of black ginger extract standardized to provide 5% 5,7-dimethoxyflavone for 4 weeks led to

improvements in the IIEF total, erectile function domain and intercourse satisfaction domain scores in men presenting with mild ED. [30]

Through a systematic review of seven human studies, *K. parviflora* supplementation appears to be helpful for hand grip strength and sexual function, but it is important to note that the number of human clinical studies is small and varied in their study design, study population, and type of supplement used. [31]

In human supplementation studies, cardiovascular endpoints have also been investigated. In trained air force cadets, 12 weeks of black ginger supplementation had no major effect on cardiovascular parameters, but heart rate recovery tended to increase. These findings should be taken with caution, as cardiovascular evidence is largely derived from preclinical vascular studies. [28]

Controlled clinical studies: While clinical evidence suggests that *K. parviflora* may have the potential for translational use, the focus of these studies has been mainly confined to exercise capacity, fatigue and physical performance, rather than any therapeutic effects on specific diseases.

A randomized controlled study with a functional drink containing a black ginger extract showed a meaningful effect on improving physical performance-related parameters (same increase in VO₂max, shuttle-run

performance, 5-minute distance-running capacity, and reduction in oxidative stress and lactate concentrations) in healthy adults after 12 weeks of supplementation. [32]

In a second double-blind randomized crossover trial, a black ginger extract containing polymethoxyflavones was administered and the effects of treatment on fitness and fatigue-related outcomes were assessed. Controlled clinical evidence was provided showing that bioactive compounds derived from black ginger may positively affect physical performance and exercise-related parameters. [33,34]

Despite getting positive results in controlled clinical trials, the database for *K. parviflora* in a clinical setting remains relatively small compared to the database available from *in vitro* and *in vivo* studies. *K. parviflora*'s biological activities, such as anticancer, neuroprotective, anti-inflammatory, metabolic, and cardiovascular activity, are mostly obtained from preclinical studies. Future studies that utilize larger randomized controlled trials, standardized extracts, longer periods of time, and validated clinical endpoints are needed to determine the therapeutic efficacy and safety of black ginger.

In [Table 2](#), some recent advancement in the field of pharmacology and therapeutic effects of *K. parviflora* are summarized. [Figure 2](#) represents the pharmacological activities of black ginger.

Table 2: Recent advances in the pharmacological and therapeutic potential of *K. parviflora*

S.No.	Research area	Key advance	Reference	Ref
1	Phytochemistry (new source)	Metabolic profiling and bioactivity assessment of rhizome oil of <i>K. parviflora</i> from Eastern India documented methoxyflavonoid composition and therapeutic potential as a new regional source.	Panigrahi et al., 2025	[9]
2	Exercise capacity	8-week KPE administration plus voluntary wheel running significantly enhanced submaximal endurance capacity and daily running distance in mice by raising plasma antioxidant levels and activating the Nrf2/ARE pathway in skeletal muscle.	Huang et al., 2024	[16]
3	Anticancer (breast cancer)	70% ethanol extract induced dose-dependent apoptosis in MCF-7 and MDA-MB-231 cells (IC ₅₀ 60–85 µg/mL) with up to 4.1-fold increased caspase-3 activity, attributed to 5,7-dimethoxyflavone and 3,5,7-trimethoxyflavone.	Watcharin et al., 2025	[35]
4	Anti-obesity (formulation)	Methoxyflavone-loaded nanostructured lipid carriers (BG-NLC, ~99 nm) improved GI stability and enhanced intestinal absorption/permeability by ~10–30%, reduced lipid accumulation and triglyceride production in adipocytes, and lowered body weight, BMI, and liver/adipose tissue weights in high-fat-diet mice.	Rimsueb et al., 2025	[25]
5	Anti-obesity	A 12-week randomized, double-blind, placebo-controlled trial involving 83 Korean adults	Sung et al., 2025	[36]

S.No.	Research area	Key advance	Reference	Ref
	(human trial)	showed that <i>K. parviflora</i> extract (SIRTMAX®) significantly reduced body fat mass, body fat percentage, body weight, BMI, and total/subcutaneous/visceral fat areas.		
6	Metabolic effects (human pilot)	Acute ingestion of a 200 mg <i>K. parviflora</i> -containing supplement significantly reduced respiratory exchange ratio at 120 and 180 min in healthy men, indicating increased fat oxidation.	Evans et al., 2025	[37]
7	Anti-diabetic / antioxidant phytochemistry	Chloroform extract of rhizomes showed the highest sterol content (432 ± 0.23 mg BSE/g) and phenolics ($1.19 \times 10^3 \pm 0.41$ mg GAE/g), with tectochrysin and 5,7-dimethoxyflavone as dominant flavonoids. The extract exhibited strong radical-scavenging and α -glucosidase inhibitory activity.	Prabakaran et al., 2024	[38]
8	Anticancer (melanoma)	Laos <i>K. parviflora</i> extracts, especially the dichloromethane fraction, inhibited melanoma cell migration, invasion, and proliferation through cell-cycle arrest and mitochondrial-mediated apoptosis (increased caspase-3, PARP, Bax; reduced Bcl-2 and MUDENG).	Park et al., 2024	[39]
9	Anticancer (<i>in silico</i>)	Molecular docking of 35 black ginger phytochemicals against 11 anticancer targets identified KP1, KP2, Viscumneoside VI, and 5-hydroxy-7-methoxyflavone as strong binders. KP2 showed good affinity against six targets (e.g., KDR -9.8 kcal/mol).	Pham & Hong, 2025	[40]
10	Sarcopenia/muscle health	Standardized KPE (100 and 200 mg/kg for 8 weeks) improved grip strength and endurance in aged mice, increased hindlimb muscle weight and myofiber cross-sectional area, suppressed TNF- α /IL-6 via NF- κ B inhibition, reduced MuRF-1 and MAFbx, and activated PI3K/Akt-mTOR signaling and mitochondrial biogenesis.	Kim et al., 2025	[41]
11	Phytochemistry – plant part comparison	First comprehensive analysis of leaves, stems, and rhizomes of <i>K. parviflora</i> from Vietnam's Central Highlands. Leaves showed the highest polyphenol/flavonoid content and strongest antioxidant, α -glucosidase, and acetylcholinesterase inhibition, whereas rhizomes rich in 5,7-dimethoxyflavone showed stronger tyrosinase inhibition. UHPLC-UV and GC-MS identified 36 compounds.	Doan et al., 2026	[42]
12	Anti-aging / formulation	Solid self-microemulsifying drug delivery system of <i>K. parviflora</i> extract showed safety in a 90-day toxicity study (125–500 mg/kg). In D-galactose-aged rats, it improved testicular weight, reduced malondialdehyde, normalized hormones, increased SIRT-1 and Bcl-2, and reduced SA- β -gal, p53, and caspase-3 expression.	Somintara et al., 2026	[43]
13	Cardiovascular – antithrombotic effects	<i>K. parviflora</i> essential oil (camphene 19.12%, β -pinene 18.88%, α -pinene 10.79%) inhibited ADP-induced platelet aggregation ($>95\%$ at 2 mg/mL), prolonged APTT (52.20 ± 14.57 s), and suppressed NO production in RAW 264.7 macrophages ($IC_{50} 53.47 \pm 0.71$ μ g/mL). Docking suggested interactions with Factor Xa, VKOR, COX-1, and PAR1.	Le et al., 2026	[44]
14	Nutraceuticals – antioxidant peptides	First peptidomic profiling of <i>K. parviflora</i> proteins using ultrafiltration, HPLC, and MALDI-ToF MS identified antioxidant peptides. The 3 kDa Tris-HCl extract showed the highest antioxidant activity and included unique peptide sequences such as ADPPHIIHASL.	Narayanasamy et al., 2026	[45]
15	Anti-obesity + sarcopenia	5,7-Dimethoxyflavone (20 or 50 mg/kg/day for 8 weeks), a major bioactive flavone from <i>K. parviflora</i> , reduced body weight, fat volume, and fat mass in ob/ob mice without appetite changes, while preventing obesity-associated muscle atrophy through AMPK and PI3K/Akt pathways and improving grip strength and treadmill endurance.	Kim et al., 2026	[46]



Figure 2: Pharmacological activities of black ginger

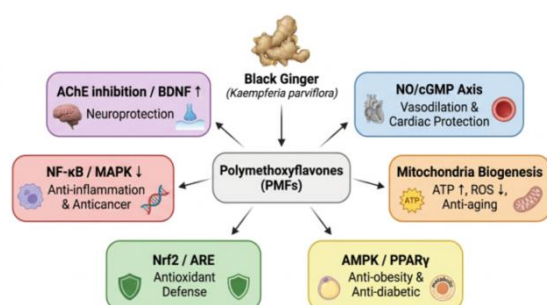


Figure 3: Molecular mechanisms of black ginger

Molecular mechanisms of black ginger: The pleiotropic pharmacology of black ginger seems to converge in a restricted number of molecular targets, the main being polymethoxyflavones, which account for most of its bioactivities. [1,4] Among the mechanisms, activation of the NO-cGMP pathway appears as a recurrent mechanism, as the extract improves eNOS expression in the penile vasculature and 5,7-dimethoxyflavone increases NO and cGMP levels and modulates cardiac contractility and Ca²⁺ transients. [26,29] Improved mitochondrial function may also contribute, since the extract upregulates PGC-1α, ERRα, NRF1, and Tfam and prevents the ATP depletion and ROS increase (which may play a role in both the anti-aging and metabolic effects). [2, 47]

In metabolic tissues, AMPK phosphorylation downregulates lipogenic signals and activates CPT1 and UCP1 to promote thermogenic functions. [21, 23] PPARγ ligand-binding improves glucose homeostasis and decreases lipid accumulation. [24] In skeletal muscle, PI3K/Akt signaling upregulates protein biosynthesis and hypertrophy, while Nrf2/ARE activation provides system and muscle-wide antioxidant defense. [16, 21] Anti-inflammatory and anticancer actions converge on inhibition of the NF-κB, MAPK, and PI3K/AKT signaling pathways, and induction of

intrinsic apoptotic cell death either via mitochondrial pathways or caspase activation. [9, 12, 18, 35] The anti-austerity effect on pancreatic cancer is a separate mode of action that is target-selective for nutrient deprivation. [48] The neuroprotective effect, through inhibition of cholinesterase, prevention of Aβ aggregation, BDNF restoration and inhibition of ERK signaling-mediated excitotoxicity as well as the other related pathways of oxidative defense, energy metabolites and inflammatory/apoptotic signaling pathways, explain the diverse effects reported for black ginger (Figure 3). [2]

Clinical evidence and therapeutic applications: Evidence in humans is emerging but remains sparse. A recent systematic review identified seven clinical studies for all indications. On hand grip strength and sexual erotic stimulus response, smaller studies report no apparent side effects even at doses as high as 1.35 g/day, but the authors found too little power for firm conclusions. [31] Greater safety is suggested by a randomized, double-blind, placebo-controlled trial of 52 healthy Japanese subjects given 750 mg/day of standardized extract for 4 weeks (none on extract experienced adverse events), and corroborative preclinical toxicology data (no genotoxicity observed in reverse mutation assays, and no toxicologically-relevant adverse events in a 90-day rat model after administration of standardized extract). [49,50] Acute toxicity studies also indicate the compound's approximate LD50 is >5,000 mg/kg. [51] For example, a 90-day study of a sports nutrition formulation containing black ginger reported a NOAEL of 1000 mg/kg. [52] The human studies included in this review are summarized in Table 3.

Therapeutic uses include aid to sexual function in males, performance enhancers for athletes, and anti-aging/metabolism products. Standardized extracts are found in dietary supplements, functional foods, and cosmeceuticals. A standardized polymethoxyflavone enriched extract promoted collagen and hyaluronic acid production in a photoaged skin model, and clinical studies found it non-irritating and non-sensitizing. [53]

Table 3: Summary of clinical studies evaluating the pharmacological effects and safety of *K. parviflora* extracts

Study	Study type and quality	Population/sample size	Extract/product standardization (marker compound and concentration)	Dose and duration	Key outcomes	Major limitation
Saokae w et al. [31]	Systematic review and meta-analysis of clinical trials (secondary evidence; included seven clinical trials)	Seven clinical trials involving heterogeneous populations	Different <i>K. parviflora</i> preparations were included across studies; standardization varied among trials. Specific marker compounds and concentrations were not consistently reported.	Various <i>K. parviflora</i> doses (up to 1.35 g/day)	Reported improvements in hand grip strength (two studies) and sexual erotic stimulus response (one study); no major adverse events reported	Limited number of clinical trials, heterogeneity in formulations, doses, outcome measures, and variable evidence quality
Toda [33]	Double-blind randomized crossover clinical trial	Healthy adults (sample size not specified in available report)	Polymethoxyflavone-rich <i>K. parviflora</i> extract; specific marker compound(s) and concentration not reported	Dose and duration not clearly reported	Evaluated effects on physical fitness and fatigue-related parameters	Small-scale trial, limited duration, and insufficient information regarding long-term efficacy
Hirsh et al. [29]	Open-label clinical study (low-to-moderate evidence quality due to absence of control group)	13 healthy males aged 50–70 years	<i>K. parviflora</i> extract; standardized marker compound and concentration not reported	Daily supplementation for 30 days	Improved International Index of Erectile Function (IIEF) total score, erectile function, intercourse satisfaction, and orgasmic function; 61.5% participants reported improved erection function	Small sample size, open-label design, and placebo effect cannot be excluded
Yoshino et al. [49]	Randomized double-blind placebo-controlled clinical trial (higher methodological quality)	52 healthy adults	<i>K. parviflora</i> tablets; marker compound(s) and extract standardization not reported	750 mg/day (5 × 150 mg tablets) for 4 weeks	No treatment-related adverse events; supported short-term safety of <i>K. parviflora</i> supplementation	Short intervention period and healthy population limit evaluation of long-term safety and therapeutic efficacy
Li et al., in Xu et al. [30]	Open-label clinical study	Men aged 50–68 years with mild erectile dysfunction (sample size not specified)	KaempMax™ extract standardized to 5% 5,7-dimethoxyflavone (DMF)	100 mg/day for 1 month	Improved IIEF total score, erectile function, and intercourse satisfaction domains	Lack of placebo control and small study population limit interpretation of efficacy
Onsiri	Randomized	57 air force	<i>K. parviflora</i> extract	360 mg/day for	No significant effect on	Population

Study	Study type and quality	Population/sample size	Extract/product standardization (marker compound and concentration)	Dose and duration	Key outcomes	Major limitation
et al. [28]	placebo-controlled parallel clinical trial	cadets	capsules; marker compound(s) and concentration not reported	12 weeks	lactate threshold; improved heart rate recovery over time	restricted to young healthy males; limited generalizability
Wattanathorn et al. [32]	Randomized clinical trial	Healthy adults aged 19–60 years (sample size not specified)	Functional drink containing <i>K. parviflora</i> extract; supplied as 90 or 180 mg/serving. Specific marker compound(s) and concentration not reported	90 or 180 mg/serving for 12 weeks	Increased VO_2 max and running performance; reduced oxidative stress markers and lactate levels	Limited sample information and unclear contribution of individual compounds within the functional drink
Sung et al. [36]	Randomized, double-blind, placebo-controlled clinical trial	83 Korean adults	<i>Kaempferia parviflora</i> extract (SIRTMAX®); marker compound and concentration should be verified from the original publication.	Extract supplementation for 12 weeks; the dose should be verified from the original publication.	Significant reductions in body fat mass, body fat percentage, body weight, BMI, and total, subcutaneous, and visceral fat areas compared with placebo.	Relatively small sample size and short intervention duration, limiting the generalizability of the findings and assessment of long-term efficacy and safety.

4. SAFETY, PHARMACOKINETICS AND STANDARDIZATION

OF *K. parviflora*

Pharmacokinetics: Pharmacokinetics studies show that methoxyflavones from *K. parviflora* have a rapid absorption and reach peak plasma concentration (C_{max}) from 1.17 to 1.83 h (dose-dependently): the C_{max} of 0.34-0.83 $\mu\text{g/mL}$, followed by a slow elimination phase (2.03-2.60 h). As for other polymethoxyflavones, they are extensively metabolized with the formation of demethylation products and glucuronides, with numerous phase I and II metabolites. Oral bioavailability remains low, likely due to poor water solubility and low intestinal absorption, but lipid-based nanoformulations of nanostructured lipid carriers and solid self-microemulsifying drug delivery systems improve gastrointestinal stability and intestinal permeability to cause an increase in systemic exposure. [25]

Toxicology: Although available toxicological evidence remains limited, reproductive safety and potential herb–drug interactions have been investigated in specific studies. Further research is required to establish the reproductive safety profile and characterize potential interactions. However, a 90-day study of 125, 250, and 500 mg/kg/day of solid SMEDDS formulation has reported no differences in clinical signs, hematology, biochemistry, or organ histopathology. [43] In reproductive studies, serum testosterone levels increased; extract reversed the reductions in sperm count, motility, viability, and testis architecture following fenitrothion exposure in mice. [54] In herb-drug interactions, *K. parviflora* competitively inhibited CYP3A-mediated midazolam metabolism (K_i 78.14 $\mu\text{g/mL}$), and its extract increased midazolam's AUC and C_{max} by 2.3- and 1.9-fold, respectively, in rats. Care is advised with other drug exposure. [55]

Several toxicological evaluations found no significant adverse or genotoxic effects associated with *K. parviflora* extract administration, which, while supportive of the herb's safety profile, do not provide evidence of therapeutic efficacy and should be interpreted as distinct from positive pharmacological findings. Specifically, a randomized, double-blind, placebo-controlled trial evaluating the safety of daily *K. parviflora* consumption reported no clinically significant adverse events over the study period, and a related sub-chronic toxicity and mutagenicity study using the same standardized extract found no evidence of genotoxicity or mutagenic activity. [49,50] Similarly, a single-dose toxicity study classified the extract as essentially non-toxic under the tested conditions, again reflecting an absence of effect rather than a demonstrated benefit, and a 90-day repeated-dose oral toxicity study in Wistar rats reported no significant toxicological changes attributable to the extract. [51,52] In addition, a murine reproductive study examining *K. parviflora* extract in combination with the pesticide fenitrothion was designed around the possibility of only partial or non-significant protection against fenitrothion-induced reproductive toxicity, illustrating that not all investigated outcomes in this literature are uniformly favorable. [54] These findings demonstrate that a meaningful subset of the available evidence consists of null or non-significant results, and their inclusion is essential to providing a balanced and unbiased synthesis of the current literature on *K. parviflora*.

Standardization Challenges: Standardization is difficult because of variability in the phenolic compound contents. The levels of the total phenolic content, total flavonoid content and trimethoxyflavone of the elite accession KH-THA 10 of the 21 accessions grown under controlled atmosphere were 47.534 mg GAE/g TPC, 7.887 mg RE/g TFC, and 42.95 µg/mg TMF. These varied due to genetic and agronomic factors. [56] Extraction methods influence variability: in optimized ultrasound-assisted extraction, ethanol concentration is the most important variable, and its optimum is different for yield (54.24% v/v) and total

methoxyflavone content (95.00% v/v). [57] Quantitative profiling of methoxyflavones enabled the differentiation between the two established varieties of *K. parviflora* and marker-based chemotaxonomic standardization. [58]

Critical appraisal and limitations of the current evidence:

Although *K. parviflora* exhibits considerable pharmacological potential, several challenges limit its clinical translation and therapeutic utilization. Previous reviews have mainly emphasized methoxyflavones, polymethoxyflavones, phytochemical characterization, traditional applications, or selected biological activities. Tan et al. (2024) [1], Chen et al. (2018) [2], Chew and Nyam (2025) [3], Aidiel et al. (2023) [4], Hardini et al. (2025) [5], and Hairunisa et al. (2024) [59] provided important insights into the chemistry and biological significance of *K. parviflora*; however, comprehensive integration of molecular mechanisms, clinical evidence, pharmacokinetics, formulation strategies, safety evaluation, and standardization aspects remains insufficient. Major limitations include variations in extraction methods, plant sources, preparation procedures, and polymethoxyflavone composition, which contribute to inconsistent biological outcomes [60]. Differences in experimental doses, treatment duration, administration routes, and biological models further complicate comparison among studies. Moreover, available evidence is predominantly based on *in vitro* and animal studies, while clinical investigations remain limited by small sample sizes and short intervention periods. Insufficient pharmacokinetic data, including absorption, metabolism, bioavailability, and tissue distribution, restrict understanding of therapeutic relevance. Therefore, the present review provides an updated and integrated assessment of *K. parviflora*, linking phytochemical diversity with pharmacological mechanisms, clinical evidence, delivery approaches, safety profiles, and standardization requirements to support future translational applications.

Future perspectives: Despite encouraging preclinical findings and early clinical investigations, several challenges remain before *K. parviflora* can be translated into clinically

validated applications. A major limitation is the poor oral bioavailability of PMFs, which may restrict systemic exposure and reduce biological effectiveness.[2,4] Pharmacokinetic studies have demonstrated rapid absorption (C_{max} 0.34–0.83 $\mu\text{g/mL}$ within 1.17–1.83 h) and relatively short half-lives (2.03–2.60 h), highlighting the need for improved delivery strategies to enhance absorption, stability, and sustained availability of bioactive constituents.[61] Emerging approaches, including nanostructured lipid carriers, cyclodextrin complexes, self-micro-emulsifying drug delivery systems, and nanosuspensions, have shown potential for improving the bioavailability and biological activity of *K. parviflora*-derived compounds.[4,25,62]

Future research priorities should include: (i) well-designed, adequately powered, and long-term randomized controlled trials to establish the efficacy, safety, and clinical relevance of *K. parviflora* preparations in areas such as erectile function, physical performance, and metabolic health, where current human evidence remains limited by small sample sizes and short intervention periods; (ii) comparative investigation of individual PMFs and standardized extracts to clarify compound-specific pharmacological effects and distinguish the contribution of isolated compounds from complex plant preparations; (iii) establishment of standardized extraction procedures, validated analytical methods, and pharmacopeial quality criteria to improve reproducibility and batch-to-batch consistency; (iv) integration of pharmacokinetic and pharmacodynamic studies to better define the relationship between bioactive compound exposure and biological responses; (v) development of appropriate regulatory frameworks and evidence-based guidelines to support safe clinical translation and commercialization; and (vi) sustainable cultivation practices and conservation strategies to ensure long-term availability of high-quality *K. parviflora* raw materials.[2,5,6,31,49,53]

5. CONCLUSION:

The medicinal plant *K. parviflora* contains diverse phytochemicals, particularly polymethoxyflavones, which

have demonstrated antioxidant, anti-inflammatory, antimicrobial, anticancer, neuroprotective, metabolic, cardiovascular, and physical performance-related activities. Current research has provided insights into several underlying molecular mechanisms, including NO–cGMP signaling, AMPK/PPAR γ activation, Nrf2-mediated antioxidant responses, and regulation of NF- κ B/MAPK and PI3K/AKT pathways. Available human studies, although limited in number and duration, have reported potential beneficial effects mainly related to erectile function, exercise performance, and metabolic parameters.

However, translation into clinical practice remains constrained by several factors, including poor oral bioavailability of polymethoxyflavones, variability among preparations, differences in extraction methods and phytochemical composition, limited long-term human studies, inconsistent clinical endpoints, and the absence of comprehensive standardization. Furthermore, the predominance of preclinical evidence highlights the need for cautious interpretation of biological effects observed in experimental models. Future investigations focusing on improved delivery systems, pharmacokinetic optimization, standardized formulations, comprehensive safety evaluation, and well-controlled clinical trials are required to establish the clinical relevance of *K. parviflora*. At present, black ginger represents a promising source of bioactive compounds with potential applications in functional foods and health-supporting interventions. Nevertheless, further clinical validation is necessary to determine its precise role in supporting human health and its possible contribution to the management of chronic disease-related conditions.

Abbreviations:

ABTS – 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid)

AMPK – AMP-activated protein kinase

ARE – Antioxidant response element

BMI – Body mass index

DPPH – 2,2-Diphenyl-1-picrylhydrazyl

GC-MS – Gas chromatography–mass spectrometry

HPLC – High-performance liquid chromatography

IC₅₀ – Half-maximal inhibitory concentration

IIEF – International Index of Erectile Function

KPE – *Kaempferia parviflora* Wall. ex Baker extract

MAPK – Mitogen-activated protein kinase

MCF-7 – Michigan Cancer Foundation-7

NF-κB – Nuclear factor kappa B

Nrf2 – Nuclear factor erythroid 2-related factor 2

NO – Nitric oxide

PI3K – Phosphoinositide 3-kinase

PPARγ – Peroxisome proliferator-activated receptor gamma

PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses

ROS – Reactive oxygen species

SANRA – Scale for the Assessment of Narrative Review Articles

SIRT-1 – Sirtuin 1

SMEDDS – Self-microemulsifying drug delivery system

TFC – Total flavonoid content

TPC – Total phenolic content

UCP1 – Uncoupling protein 1

VO₂max – Maximal oxygen uptake

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