Aspects of Molecular Medicine 5 (2025) 100075

Contents lists available at ScienceDirect

Aspects of Molecular Medicine

journal homepage: www.journals.elsevier.com/aspects-of-molecular-medicine

Current insights on the effects of medicinal plants in the management of obesity and infectious diseases: An update from 2020

Ezichi Favour Ofoezie [a,*], Chinwendu Angela Ogbonna [b], Ezinne Tiffany George [c], Chioma Juliet Anunobi [d], Sandra C. Olisakwe [e], Simeon Babarinde [f], Chidera Godson Chukwuemeka [g], Uzochukwu Eric Ogbonna [h], Chibuzo Collette Amafili [i], Justina Onyinyechi Omaba [j], Henry Nnaemeka Ogbonna [a,**]

[a] *Department of Biochemistry, College of Natural Sciences, Michael Okpara University of Agriculture, Umudike, Abia State, Nigeria*
[b] *Department of Microbiology, Federal Polytechnic, Nekede, Owerri, Nigeria*
[c] *Division of Cardiovascular Disease, University of Alabama at Birmingham, US*
[d] *Department of Anatomy, University of Nigeria Nsukka, Nigeria*
[e] *Department of Hematology and Oncology, University of Alabama at Birmingham, US*
[f] *Department of Biology and Biochemistry, University of Bath, UK*
[g] *Department of Medical Laboratory Science, Nnamdi Azikiwe University, Nnewi, Nigeria*
[h] *Department of Mathematics, Imo State University, Owerri, Nigeria*
[i] *Department of Nursing, Ebonyi State University, Nigeria*
[j] *Department of Microbiology, Ebonyi State University, Nigeria*

ARTICLE INFO

Handling Editor: Prof A Angelo Azzi

Keywords:
Infectious disease
Obesity
Medicinal plants
Phytochemicals
Mechanism

ABSTRACT

Medicinal plants have long played a pivotal role in traditional medicine, and their integration into modern healthcare is gaining recognition for their potential in treating a range of conditions, including obesity and infectious diseases. Their bioactive compounds offer a natural, sustainable alternative to synthetic drugs, with significant therapeutic benefits. This review focuses on the recent advances of medicinal plants in addressing two major global health challenges: obesity and infectious diseases. In modern medicine, these plants are valued for their ability to manage weight by influencing metabolic processes such as fat oxidation, insulin sensitivity, and inflammation. Additionally, their antimicrobial properties offer effective solutions against drug-resistant pathogens, presenting a complementary approach to conventional treatments. Through a comprehensive analysis of bioactive compounds, the review investigates their mechanisms, including enzyme inhibition, modulation of immune response, and disruption of microbial growth and biofilm formation. Key findings indicate that these phytochemicals demonstrate both anti-obesity and antimicrobial activities, with potential to reduce inflammation, improve metabolic health, and combat drug-resistant infections. In essence, medicinal plants hold significant promise as natural therapeutic agents for managing obesity and infectious diseases. Their ability to target multiple biological pathways simultaneously makes them effective in addressing the complex interplay between metabolic disorders and immune dysfunction.

1. Methods

Authors conducted a literature review on ethnopharmacology, molecular pathways and antimicrobial resistance sourced from various database and original research articles. Information was obtained from PubMed, ResearchGate, Google Scholar, WHO website, Taylor and Francis and Wiley Online compiled and critically analysed to observe trends and current Insights.

2. Medicinal plants in obesity and infectious disease management

The systematic exploitation of ethnopharmacological studies has the potential to greatly enhance the discovery of bioactive substances that

* Corresponding author.
** Corresponding author.
E-mail addresses: Ezichiofoezie@gmail.com (E.F. Ofoezie), henryogbonna@bath.edu (H.N. Ogbonna).

https://doi.org/10.1016/j.amolm.2025.100075
Received 28 November 2024; Received in revised form 12 March 2025; Accepted 18 March 2025
Available online 19 March 2025

demonstrate substantial effectiveness in addressing a variety of specific health problems. For instance, numerous medicinal plants harbour the potential to serve as both therapeutic interventions and preventive strategies specifically aimed at effectively combating obesity and its myriad related comorbidities (Nyakudya et al., 2020). These functions also include their roles in providing pertinent antimicrobial properties, managing elevated fever effectively, and delivering pain relief effects in diverse contexts. While the biological activities of specific plants are extensively utilized in traditional medicine practices around the world, there exists a significant deficiency in the scientific community concerning the comprehensive evaluation of various plant extracts for their numerous pharmacological attributes, particularly in relation to these pressing health concerns. Obesity itself is acknowledged as the most prevalent nutritional disease impacting populations globally, and despite the considerable advancements made in different areas of human health and medical research, the prevalence of obesity continues to escalate at alarming rates (Rahman et al., 2022). The complications that arise from obesity and associated nutritional issues significantly contribute to an increased susceptibility to various infectious diseases, which further complicates the health profiles of obese individuals and substantially enhances their mortality rates. A wealth of plant-derived compounds emerges as essential sources for numerous bioactive substances known to delay the onset of obesity while concurrently impeding the expansion and proliferation of infectious diseases (Nyakudya et al., 2020; Negi et al., 2021; Rahman et al., 2022). In this context, we present a comprehensive overview of the engagement of the most extensively studied plants that are recognized for their significant roles in the management of obesity and its related disorders, including those specifically linked to antimicrobial activity and febrile infections. Moreover, our discussion will further extend to encompass the putative molecular targets associated with the bioactive compounds presented, thereby facilitating a deeper understanding of their intricate therapeutic mechanisms and potential applications in modern medicinal practices (Nyakudya et al., 2020; Negi et al., 2021; Rahman et al., 2022).

3. Obesity and current treatment approaches

Obesity a common disorder that results from the interaction of genetic, nutritional, lifestyle, and environmental factors (Piché et al., 2020). These metabolic conditions have emerged as a critical global health issue, often linked to arteriosclerosis, hypertension, cancer, diabetes, and osteoarthritis. Since 1990, adult obesity has more than

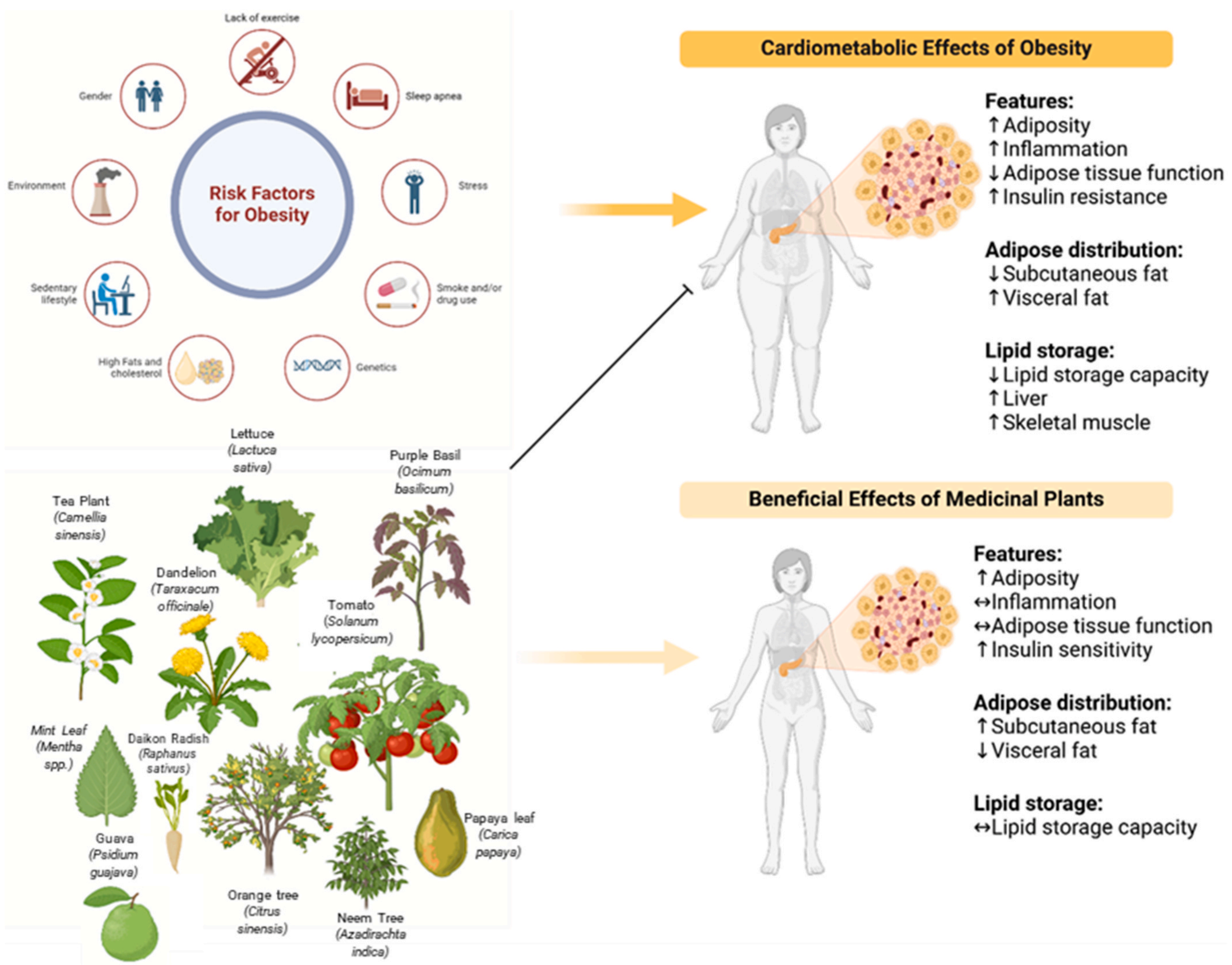

Fig. 1. Classification of Obese Phenotypes and the Role of Medicinal Plants in Modulating Obesity-Associated Risks. This figure shows obesity risk factors, its cardiometabolic effects, and the potential benefits of medicinal plants. The left panel outlines obesity risk factors, such as lack of exercise, high-fat diets, and genetics. The top right shows obesity's adverse effects, including increased adiposity, inflammation, insulin resistance, and a shift towards visceral fat and ectopic lipid storage. The bottom right illustrates how medicinal plants may counteract these effects by improving insulin sensitivity, balancing adipose tissue distribution, and stabilizing lipid storage, highlighting their potential as anti-obesity therapies.

doubled, and adolescent obesity has quadrupled, with approximately 2.5 billion adults overweight and 890 million adults classified as obese globally in 2022 (World Health Organization [WHO], 2023; Mohajan and Mohajan, 2023; Islam et al., 2024). World Health Organization (WHO) reports that pharmacological approaches to weight control remain challenging due to obesity's complex etiology. Current management strategies include blocking nutrient absorption, modulating fat metabolism, and regulating adipose signals (Ghosh et al., 2021). Although global efforts focus on dietary and lifestyle changes like caloric restriction and increased exercise, these strategies have not fully addressed obesity, especially in aging populations. Anti-obesity medications are therefore recommended as additional solutions. Several drugs, including orlistat, lorcaserin, phentermine/topiramate, bupropion/naltrexone, and liraglutide, target obesity by increasing noradrenaline, dopamine, and serotonin. However, they often cause side effects like cardiovascular complications, blood pressure changes, and hormonal disruptions (Kumar et al., 2022; Kosmalski et al., 2023). Sibutramine, once widely used, was recently withdrawn due to its link with non-fatal cardiovascular events (Alobaida et al., 2021). These non-viable apharmacological outcomes highlight the need for alternative treatments. Given their therapeutic potential and historical use in traditional medicine, medicinal plants such as illustrated in Fig. 1 are increasingly considered for obesity management (Saglam and Sekerler, 2024). Various plant parts (leaves, stems, roots, seeds, flowers, fruits) are rich in bioactive compounds and they account for 25–50 % of drugs currently used in healthcare, with ongoing research focused on discovering new bioactive compounds (Babalola et al., 2024).

4. Bioactive Compounds in Medicinal Plants for obesity treatment

***Cosmos caudatus*:** *Cosmos caudatus*, an herbal plant native to Latin America and Southeast Asia, is known as Ulam raja in Malaysia and Kenikir in Indonesia (Ahda et al., 2023). Scientific research supports its traditional use in slowing aging, strengthening bones, and protecting against metabolic disorders (Panossian et al., 2021). Extracts from *Cosmos caudatus* have demonstrated preventive effects against hyperlipidemia, hypertension, and diabetes, due to their antihypertensive, antidiabetic, antioxidant, and antibacterial properties (Ahda et al., 2023; Latiff et al., 2021). Its anti-obesity potential has been linked to its anti-diabetes properties as a result of its useful bioactive constituents targeting glucose and fat metabolisms with C.caudatus causing the highest weight reduction by 42.5 % in an animal study compared to other significant herbs (Murugesu et al., 2020; Rahman et al., 2017; Sang et al., 2024) These bioactive compounds play a role in regulating obesity by inhibiting fat-metabolizing enzymes such as pancreatic lipase and lipoprotein lipase suggesting that *Cosmos caudatus* may help prevent obesity by limiting fat digestion, absorption, and accumulation. Key compounds like catechins and quercetin in *Cosmos caudatus* promote lipolysis, breaking down stored fat into free fatty acids and glycerol, leading to reduced body fat and improved metabolism (Pham et al., 2020). Studies have shown that quercetin, rutin, and chlorogenic acid in the extract significantly reduce cardiac output and induce diuresis in hyperlipidemic rats after 4 weeks of treatment (Rahman et al., 2017). Previously, studies according to Moshawih et al., (2017) recommended aqueous extracts of the plant containing quercetin as better effective against hypertension compared to the hexane and dichloroethane extracts with a moderate effect. However, recent studies have added that the latter has had quite significant effects (Ahda et al., 2023)._ Further studies by Firdaus et al. (2021) also identified compounds like catechin, kaempferol, quercetin, and procyanidin B1 as major contributors to its antihypertensive and fat metabolism-regulating effects. Additionally, *Cosmos caudatus* extract inhibits key enzymes involved in regulating glucose level after meal (Murugesu et al., 2020). In human studies, 8-week administration of *Cosmos caudatus* significantly improved insulin resistance and sensitivity in type 2 diabetic patients (Moshawih et al., 2017).

***Lawsonia inermis*:** *Lawsonia inermis*, or henna, is a plant from the *Lythraceae* family, known for its use as a cosmetic dye for thousands of years (Moutawalli et al., 2023). It contains a variety of bioactive compounds, including flavonoids, coumarins and alkaloids, which contribute to its therapeutic potential. These compounds have been shown to treat ulcers, bronchitis, leukoderma, hair loss, and jaundice, and exhibit antioxidant, anti-inflammatory, hepatoprotective, and hypoglycemic properties (Batiha et al., 2024). Rich in flavonoids and polyphenols, *Lawsonia inermis* helps neutralize oxidative stress, a key factor associated with obesity and metabolic disorders. Reducing oxidative stress can improve fat metabolism and overall metabolic health. The plant has shown potent free radical scavenging activity, high phenolic content, and strong pancreatic lipase inhibition (Khantamat et al., 2020). Its bioactive compounds, such as tannins and quinones, aid in reducing lipid accumulation by regulating fat metabolism and enhancing lipid breakdown (Batiha et al., 2024). Its phytochemical compounds like lawsonin, gallic acid, and ellagic acid inhibit fat accumulation by down-regulating genes involved in lipid synthesis and up-regulating genes promoting lipid degradation (Youl et al., 2024). This dual mechanism reduces fat storage and improves fat metabolism, contributing to weight loss. Additionally, its antioxidant and anti-inflammatory properties also contribute to metabolic regulation and combating obesity-related oxidative stress (Moutawalli et al., 2023).

Garcinia cambogia: *Garcinia cambogia*, a tropical tree native to Southeast Asia, India, and parts of Africa, belongs to the *Clusiaceae* family (Brown, 2023). Its primary weight-loss effects are attributed to hydroxycitric acid (HCA), known for suppressing appetite, increasing fat oxidation, and regulating lipid biosynthesis. HCA inhibits the ATP-citrate lyase, which converts carbohydrates into fat, thereby reducing fat production and promoting the use of stored fat for energy (Shanbhag, 2024). Studies have shown that *G. cambogia* effectively reduces body weight and fat mass in both animals and humans, though some human trials report only short-term weight loss (within 12 weeks) (Amini et al., 2024). Despite mixed results, *G. cambogia* offers additional benefits, including anti-inflammatory, antioxidant, antidiabetic, and hepatoprotective effects (Noreen et al., 2023). Animal studies have found no significant toxicity, and human trials show no major side effects when used at recommended doses. The anti-obesity effects of G. *cambogia* result from several mechanisms, such as suppressing fatty acid biosynthesis, reducing appetite, and increasing energy expenditure, which collectively reduce fat accumulation and weight gain (Davkova et al., 2024; Balkrishna et al., 2023). Research by El Gendy et al. (2024) showed that *G. cambogia* extract lowered serum leptin levels and improved glucose metabolism in obese mice, suggesting a leptin-like effect that enhances energy regulation and metabolic health. Additionally, Kim et al. (2008) found that a mixture of *G. cambogia* extract, soy peptide, and L-carnitine significantly reduced body weight and visceral fat in high-fat diet-induced obese rats. *Garcinia cambogia* shows promise as an anti-obesity agent by influencing lipid metabolism, hormonal regulation, and gene expression related to fat storage. Although promising, more research is needed to fully understand *G. cambogia* mechanisms and clinical efficacy in humans.

Curcuma longa: *Curcuma longa*, widely known as turmeric or Indian saffron, has been used for centuries in traditional medicine to treat obesity and diabetes (Fuloria et al., 2022). Its active compound, curcumin, has shown remarkable anti-obesity effects by managing disorders like dyslipidemia, non-alcoholic fatty liver disease (NAFLD), cardiovascular disease (CVD), and type 2 diabetes (T2D) (Varì et al., 2021). Curcumin works by inhibiting fat cell formation, regulating lipid metabolism, and boosting energy expenditure. It also improves gut microbiota, enhancing metabolic health (Scazzocchio et al., 2020). By reducing inflammation, oxidative stress, and insulin resistance, curcumin addresses key factors in obesity-related conditions. Research shows that *C. longa* decreases leptin and pro-inflammatory mediators, while reducing reactive oxygen species (ROS) and raising insulin and adiponectin levels. Higher serum adiponectin and insulin, along with lower ROS, are linked to reduced obesity (Jabczyk et al., 2021). Additionally, *C. longa* inhibits the Egr-1 gene, which is associated with obesity development (Patel et al., 2020). This regulation of leptin, adiponectin, inflammatory markers, and oxidative stress further supports curcumin's anti-obesity effects (López-Ortega et al., 2022). Varì et al. (2021) found that curcumin significantly reduced body weight and omental fat in individuals with metabolic syndrome. Both in vitro and in vivo studies have confirmed these benefits, with research on mice fed a high-fat diet showing reductions in body weight and fat accumulation when curcumin was included (Li et al., 2021).

Coffea Arabica: *Coffea arabica*, a small tree native to Africa, produces coffee cherries rich in antioxidants and known for their anti-obesity and insulin-sensitizing effects (Garg et al., 2021). Its primary bioactive compounds include chlorogenic acids, caffeine, trigonelline, and diterpenes like cafestol (Alasmari et al., 2020). Chlorogenic acids, particularly caffeoylquinic acids (CQAs), play a crucial role in weight management by enhancing fat oxidation and improving glucose metabolism, which boosts insulin sensitivity (Wang et al., 2021). Caffeine, a central nervous system stimulant in coffee, promotes weight loss by acting as a thermogenic agent that increases energy expenditure (Van Schaik et al., 2021). It accelerates fat breakdown by inhibiting the degradation of cyclic AMP (cAMP), which in turn boosts thermogenesis. Additionally, caffeine blocks adenosine receptors (A1, A2A, A2B, A3), enhancing lipolysis and metabolic regulation (Shaik Mohamed Sayed et al., 2023). The combination of chlorogenic acids and caffeine positions *Coffea arabica* as a promising anti-obesity compound, offering both fat-burning and metabolic benefits.

Capsicum annuum: *Capsicum annuum*, commonly known as red pepper, is native to southern North America and northern South America (Yuca, 2022). This popular spice exhibits anti-obesity effects largely due to capsaicin, its active compound concentrated in the fruit's placenta (Duranova et al., 2022). Capsaicin promotes weight loss by enhancing thermogenesis, the body's heat-generating process (Werner, 2021). Research shows that capsaicin stimulates thermogenesis in brown adipose tissue (BAT), facilitating fat breakdown. A single dose can elevate whole-body energy expenditure and core temperature by activating the sympathetic nervous system (Saito et al., 2020). This thermogenic activity, combined with enhanced fat metabolism, contributes to its anti-obesity properties. For an effective anti-obesity compound, increasing energy expenditure or reducing energy intake without adverse effects is crucial. Capsaicin stimulate the release of norepinephrine and epinephrine from the adrenal medulla, activating adrenergic receptors and boosting energy expenditure (Werner, 2021). It also activates transient receptor potential vanilloid 1 (TRPV1) receptors, further promoting fat metabolism and reducing body fat through increased energy expenditure in adipose tissues (Zhu, 2022). Studies indicate that mice fed a capsaicin-enriched diet showed increased TRPV1 receptor mRNA expression in adipose tissue and a 24 % reduction in visceral fat (Shin et al., 2020). This supports the role of capsaicin-induced TRPV1 activation in metabolic regulation, potentially aiding weight-loss treatments. Additionally, capsaicin reduced body weight, body fat, and serum lipid levels—including triglycerides, also both low-density and high-density lipoprotein—in obese rats (Azlan et al., 2022). It up-regulates the expression of PPARα, PPARγ, uncoupling protein-2, and adiponectin while down-regulating leptin (Lu et al., 2020). These findings highlight capsaicin's potential as an anti-obesity compound.

Hibiscus sabdariffa: *Hibiscus sabdariffa,* commonly known as Roselle, has long been used as a beverage and traditional remedy in countries like Thailand, Nigeria, China, and India (Islam et al., 2021). Its diverse bioactive compounds, including flavonoids (quercetin and luteolin), chlorogenic acid, gossypetin, hibiscetin, phenols, phenolic acids, and anthocyanins like delphinidin-3-sambubioside and cyanidin-3-sambubioside, contribute to its therapeutic potential (Yasmin et al., 2023). These compounds as illustrated in Table 1 offer antioxidant, anti-inflammatory, and anti-carcinogenic benefits while supporting the management of diabetes, cardiovascular disease, and obesity (Scaria et al., 2020). Anthocyanins in *H. sabdariffa* specifically help reduce fat accumulation by enhancing insulin sensitivity, increasing lipoprotein lipase activity, and inhibiting genes involved in adipogenesis, leading to reduced fat mass (Yildiz et al., 2020). In vivo studies on obese rats show that *Hibiscus sabdariffa* extract lowers visceral fat, reduces inflammatory cytokines, and improves insulin sensitivity (Janson et al., 2021). Additionally, both in vitro and in vivo studies suggest that the extract inhibits α-amylase, reducing sugar and starch absorption to aid in weight loss (Izquierdo-Vega et al., 2020; Zulfiqar et al., 2022; Singh et al., 2022). ***Hibiscus sabdariffa's*** weight-reducing effects are primarily attributed to its polyphenols and flavonoids, which inhibit fat accumulation and support metabolic health. While these research have provided evidence of the anti-obesity effect of *H. sabdariffa*, additional work is recommended to confirm if it acts alone or in synergy with other bioactive components in relation to a recent systematic review and meta-analysis by Dilokthornsakul et al. (2024)

Table 1
Medicinal plants used in the treatment of Obesity.

PLANT	COMPOUNDS	MECHANISM OF ACTION	REFERENCES
Cosmos caudatus	Quercetin, Chlorogenic acid, Catechin,Kaempferol and Saponin	Down-regulate the expression of transcription factors like PPARγ (Peroxisome Proliferator-Activated Receptor gamma), Boost lipolysis through activation of hormone-sensitive lipase (HSL) and hinder pancreatic lipase (PL).	He et al. (2024); Rahman et al. (2017); Sang et al., 2024
Lawsonia inermis	Quercetin, Apigenin, Tannins, Alkaloids Saponins, Gallic acid	Decrease the expression of PPARγ and C/EBPα genes and transcription factors related to the formation of fat cells. Stimulate lipolysis by activating enzymes like hormone-sensitive lipase (HSL), which breaks down stored triglycerides into free fatty acids	He et al. (2024); Kumar et al. (2022)
Garcinia cambogia	Hydroxycitric acid (HCA)	Inhibit ATP-citrate lyase, thereby reducing the availability of acetyl-CoA, thereby limiting the synthesis of fatty acids and cholesterol	Tomar et al. (2019); Gwaltney-Brant (2021).
Camellia sinensis	Catechins and Caffeine	Enhance thermogenesis, inhibit the activity of digestive enzymes, such as pancreatic lipase and activation of AMPK which enhances fat oxidation and inhibits fat synthesis in the liver	Basu et al. (2023); Xu et al. (2023)
Curcuma longa	Curcumin	Decrease the expression of PPARγ, C/EBPα and fatty acid-binding protein 4 (FABP4) related to the formation of fat	Chen et al. (2021)
Coffea Arabica	Caffeine and Chlorogenic acids	Increase the release of free fatty acids from fat cells and boosts thermogenesis.	Kumar et al. (2022)
Capsicum annuum	Capsaicin	Enhance thermogenesis and reduce appetite by regulating hormones such as ghrelin and leptin.	Duranova et al. (2022); Shaik Mohamed Sayed et al. (2023)
Hibiscus sabdariffa	Hydroxycitric acid (HCA), anthocyanin and flavonoids.	Inhibit the activity of lipogenic enzymes, promoting fat metabolism and improving insulin sensitivity	Gwaltney-Brant (2021);
Ilex paraguariensis	Caffeine, quercetin, rutin, theobromine, chlorogenic acid	enhance thermogenesis and increase pancreatic Lipase activities	Aziz et al. (2023)
Caralluma fimbriata	Pregnane Glycosides, Flavonoids and Saponin	enhance lipolysis and modulate the activity of hunger-related hormones like ghrelin	Shaik Mohamed Sayed et al., 2023

suggesting H.sabdariff had acted synergistically with *Lippia Citriodora.*

Ilex paraguariensis: *Ilex paraguariensis*, or Yerba Mate, is a popular beverage in North America and Europe, recognized for its potential weight loss and fat reduction benefits (Gerber et al., 2023). Made from the dried leaves of the plant, it is abundant in bioactive compounds, particularly polyphenols like flavonoids (quercetin and rutin) and phenolic acids (chlorogenic and caffeic acids), along with caffeine and saponins and is depicted in Table 1. Chlorogenic acid plays a significant role in weight management by inhibiting adipogenesis, the formation of new fat cells (Paluch et al., 2021). Research shows that it can suppress genes involved in fat cell differentiation, as evidenced in laboratory cell cultures (3T3-L1 cells) and animal models of high-fat diet-induced obesity (Sudhakar et al., 2020). Studies indicate that Ilex paraguariensis can help reduce insulin resistance, body weight gain, decrease visceral fat, and lower serum cholesterol, triglycerides, and LDL cholesterol levels (Kudo et al., 2024; Maiztegui et al., 2023; Valença et al., 2022). Notably, a clinical trial in Korea demonstrated that a daily intake of 3g of Yerba Mate over 12 weeks resulted in significant reductions in waist-to-hip ratio, body fat mass, and body fat percentage, along with improvements in visceral fat (Gutiérrez-Cuevas et al., 2024). Another trial using green mate powder extract (1200 mg/day) for six weeks reported a marked decrease in body fat mass with no adverse effects. Additionally, Ilex paraguariensis offers various health benefits, including the modulation of signaling pathways, enhancement of intestinal motility, inhibition of oxidative stress, and reduction of inflammation. Animal studies have shown it can lower cholesterol, leptin, and blood glucose levels, contributing to overall weight reduction (Aziz et al., 2023). Its ability to decrease preadipocyte differentiation and lipid accumulation in fat cells underscores its potential as a natural solution for obesity management (Gawron-Gzella et al., 2021).

5. Tomato *(Solanum lycopersicum)*

Tomatoes are widely recognized for their beneficial effects in managing obesity and diabetes, primarily due to their high content of the antioxidant lycopene, dietary fiber, and vitamins. Lycopene helps combat oxidative stress, a significant contributor to insulin resistance and metabolic dysfunction. The fiber in tomatoes slows the absorption of sugars, promoting stable blood glucose levels and improving insulin sensitivity. Moreover, the low-calorie content of tomatoes makes them an excellent food choice for weight management, aiding in reducing visceral fat and improving overall metabolic health (Ali et al., 2020).

6. Mint leaf *(Mentha* spp*)*

Mint, particularly *Mentha piperita*, is a popular herb known for its role in managing obesity and diabetes. The menthol and flavonoids present in mint leaves help in regulating blood glucose levels by improving insulin sensitivity and stimulating fat oxidation. Mint also has appetite-suppressing effects, which can help with weight control by reducing overeating. The anti-inflammatory properties of mint reduce adipose tissue inflammation, a common issue in obese and diabetic individuals, thereby supporting better metabolic health and more effective blood sugar regulation as illustrated in (Fig. 1) (Saqib et al., 2022).

Caralluma fimbriata: *Caralluma fimbriata*, a prominent medicinal plant native to Asia, belongs to the Apocynaceae family within the Asclepiadoideae subfamily (Ansari et al., 2022). Known for its appetite-suppressing properties, this edible succulent cactus is commonly found throughout India. Folklore in North India attributes appetite-suppressing qualities to this cactus. Standardized extracts of C. fimbriata are recognized as safe and effective for addressing obesity and overweight issues in Australia, India, and the USA (Anwar et al., 2022). Numerous studies involving both animals and humans have investigated the weight-loss effects of this plant, thanks to its key phytochemical constituents, including pregnane glycosides, flavone glycosides, megastigmane glycosides, and saponins (Anwar et al., 2022; Jayawardena et al., 2021). The appetite-suppressing effects of *C. fimbriata* are mainly attributed to its active component, pregnane glycosides. These compounds are suspected to lower ghrelin levels in the stomach and reduce neuropeptide Y in the hypothalamus, resulting in reduced appetite and subsequent weight loss (Kumar et al., 2022). Recent research suggests that consuming Caralluma extract for 60 days can significantly reduce waist size, appetite, and calorie intake (Rao et al., 2021). A comparative study showed that after 60 days of C. fimbriata extract intake, participants experienced reductions in weight, BMI, body fat, waist circumference, and food consumption (Rao et al., 2021). These findings could contribute to the development of natural remedies for obesity management.

7. Lettuce *(Lactuca sativa)*

Lettuce, a low-calorie vegetable, plays an important role in obesity and diabetes management due to its high water content and dietary fiber, which help control hunger and regulate blood sugar levels as shown in (Fig. 1). The fibers in lettuce slow down carbohydrate absorption, preventing rapid increases in blood glucose levels and aiding in better glycemic control (Slavin and Lloyd, 2012). Lettuce also contains antioxidants such as beta-carotene and flavonoids that reduce oxidative stress, a significant contributor to the development of insulin resistance. Regular consumption of lettuce can complement weight management efforts by enhancing satiety and promoting healthier eating patterns, especially in individuals with type 2 diabetes (del Río-Celestino and Font, 2020).

8. Purple basil *(Ocimum basilicum)*

Purple basil, a variant of the widely known Ocimum basilicum, is rich in bioactive compounds such as flavonoids, essential oils, and antioxidants, all of which contribute to its beneficial effects in obesity and diabetes management. Purple basil has been shown and illustrated in (Fig. 1) to modulate blood sugar levels by improving insulin sensitivity and reducing adiposity (Kamelnia et al., 2023). The plant's essential oils possess anti-inflammatory properties that help mitigate inflammation, a key factor in insulin resistance and the development of type 2 diabetes. Moreover, purple basil's high antioxidant content, particularly anthocyanins, helps combat oxidative stress, which contributes to metabolic dysfunction in obese individuals. Fig. 2 illustrates that the plant mimics the actions of Clenbuterol, an anti-obesity medication by facilitating fat burning though a stimulation of beta-2-adrenegic receptors (Chakhtoura et al., 2023).

9. Daikon radish (Raphanus sativus)

Daikon radish, a root vegetable commonly used in Asian cuisine, is beneficial for managing obesity and diabetes due to its low-calorie content and high fiber, which promotes satiety and regulates blood sugar levels. The fiber in daikon slows down the digestion and absorption of carbohydrates, preventing rapid blood sugar spikes. Additionally, daikon contains anthocyanins and other phytonutrients that have antioxidant properties, which help reduce oxidative stress and inflammation associated with insulin resistance. Daikon is a powerful dietary addition for controlling glucose levels as research has revealed that the **α-cyclodextrin-stabilized 4-methylthio-3-butenyl isothiocyanate from daikon can contribute to the prevention of diet-induced obesity hence,** aiding weight management (Okamoto et al., 2019).

10. Guava *(Psidium guajava)*

Guava, a tropical fruit rich in vitamins A, C, and fiber, has shown great promise in the management of obesity and diabetes (Díaz-de-Cerio et al., 2017). The fruit's high fiber content helps regulate blood glucose levels by delaying carbohydrate absorption and improving insulin

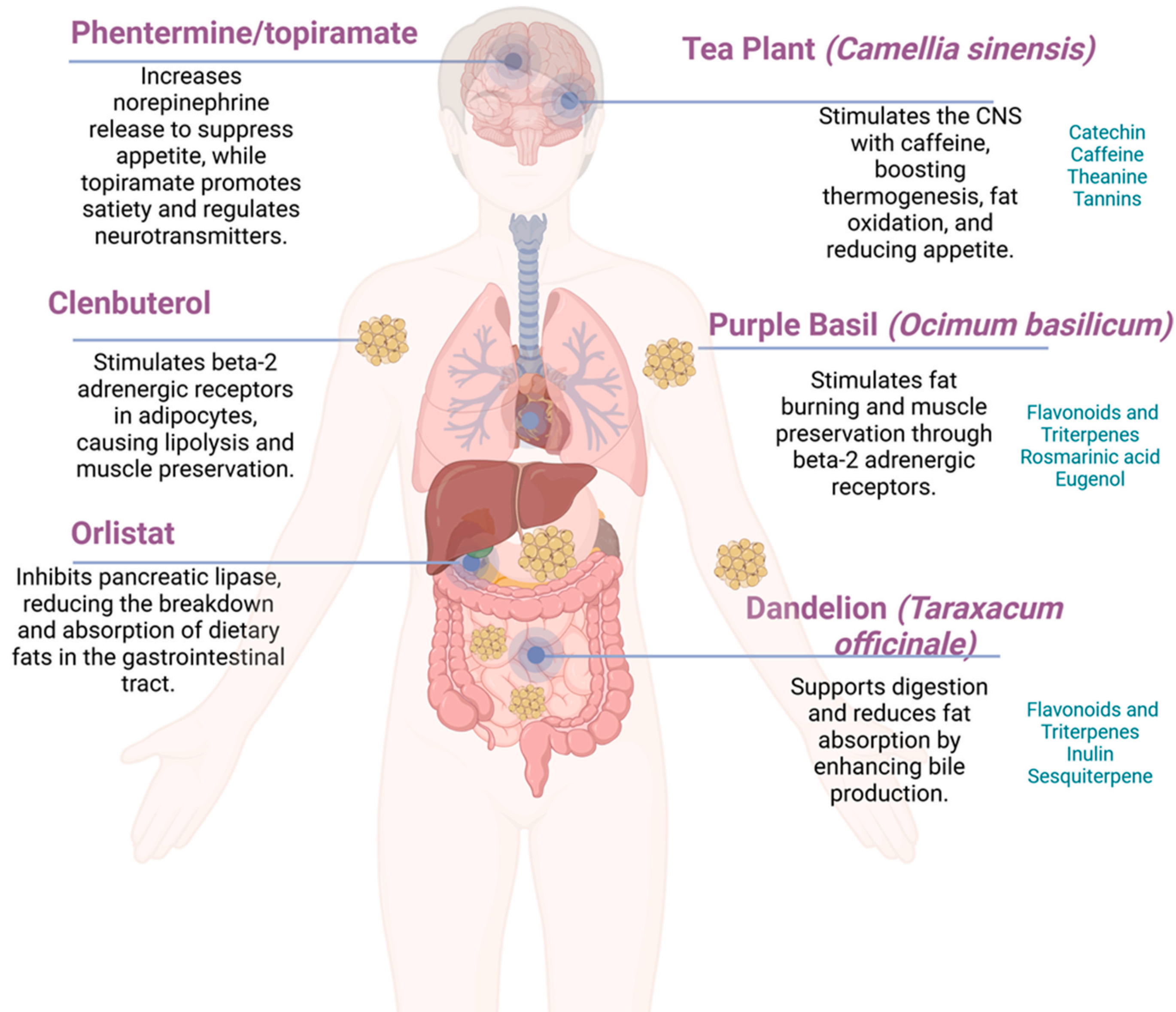

Fig. 2. Mechanisms of action of anti-obesity drugs and medicinal plants.

sensitivity Guava is also known for its low glycemic index, making it an ideal fruit for diabetic patients. The antioxidants found in guava, including flavonoids and carotenoids, help combat oxidative stress and reduce inflammation, which is a key factor in the development of insulin resistance and metabolic dysfunction (Kumar et al., 2021).

11. Neem tree *(Azadirachta indica)*

Neem has a long history of use in managing obesity and diabetes. The active compounds in neem, such as nimbolide and azadirachtin, are known to enhance insulin sensitivity and reduce blood sugar levels. Studies have shown that neem extract potentially helps modulate lipid metabolism, reducing the accumulation of visceral fat in obese individuals (Mazumder et al., 2021). Neem's anti-inflammatory properties also help reduce the chronic inflammation associated with obesity and insulin resistance, further supporting its role in managing diabetes (Yarmohammadi et al., 2021). Neem is often used as an adjunct in the treatment of type 2 diabetes.

12. Papaya leaf *(Carica papaya)*

Papaya leaf, rich in enzymes like papain, has been shown to support weight management and improve metabolic health. These enzymes aid digestion and nutrient absorption, making papaya leaf extract useful for promoting a healthy gut microbiome and preventing gastrointestinal disturbances often linked to obesity. Papain particularly has been shown to exert anti-obesity effect by influencing a downregulation of adipogenesis-related transcription factors, such as C/EBPα, SREBP and PPARγ (Kang et al., 2021). Additionally, papaya leaf contains flavonoids that exhibit antioxidant properties, helping to reduce oxidative stress and inflammation in individuals with type 2 diabetes (Nyakundi and Yang, 2023). The plant's ability to improve insulin sensitivity further supports its role in managing blood sugar levels.

13. Orange tree *(Citrus sinensis)*

Oranges, particularly known for their high vitamin C content, are a valuable fruit for managing obesity and diabetes. The fruit is low in calories and rich in dietary fiber, which helps regulate blood sugar levels by slowing glucose absorption in the intestines. The antioxidants, especially flavonoids such as hesperidin, found in oranges play a crucial role in reducing oxidative stress and improving insulin sensitivity (Aslan et al., 2024). Studies suggest that the high fiber content also aids in weight management by increasing satiety and reducing overall calorie intake (Bosch-Sierra et al., 2019). Furthermore, the polyphenolic compounds in oranges have been shown to reduce inflammation, which is a major contributing factor in the development of insulin resistance and metabolic dysfunction. Incorporating oranges into a balanced diet can help prevent and manage type 2 diabetes and support weight loss in obese individuals (Cardile et al., 2015).

Camellia sinensis: Green tea, from the *Theaceae* family, has long been revered as a medicinal plant in India, China, Japan, and Thailand (Lan et al., 2023). Its leaves are packed with polyphenolic compounds, especially catechins, which make up 60–80 % of its flavan-3-ols (Wang et al., 2024). This potent brew contains around Four thousand (4000) bioactive compounds, with polyphenols (mainly flavonoids) and alkaloids like caffeine, theophylline, and theobromine leading the charge. Among the most powerful compounds are catechins such as epigallocatechin (EGC), epigallocatechin gallate (EGCG), epicatechin (EC) and epicatechin gallate (ECG) which has been extensively studied for its beneficial effects in obesity and diabetes management (Ghosh et al., 2023). Green tea's anti-obesity powers come from its ability to boost fat oxidation, increase energy expenditure, and regulate fat metabolism as illustrated in Figs. 1 and 2. EGCG activates the sympathetic nervous system, stimulating thermogenesis and fat oxidation in brown adipose tissue as shown in Fig. 2, which leads to increased energy expenditure and reduced fat accumulation and absorption in the gut (Chakhtoura et al., 2023; Xu et al., 2023). Beyond that, catechins improve insulin sensitivity and reduce inflammation, fostering better metabolic health and weight management (Shahwan et al., 2022). In fact, research suggests EGCG can reduce body weight by up to 29 % in rats in just one week when injected into the peritoneum (Faria et al., 2020). Catechins also inhibit enzymes like α-amylase and lipase, which are crucial in lipid digestion and absorption (Koo and Noh, 2007). Additionally, the catechins in tea have been shown to suppress appetite by influencing neuropeptide expression and the hypothalamic regulation of hunger signals, mimicking the actions of anti-obesity medication Phentermine/Topiramate thus aiding in weight control as depicted in Fig. 2 (Lee et al., 2017). Green tea also enhances glucose metabolism and has shown potential in lowering postprandial blood glucose levels in individuals with type 2 diabetes. The anti-inflammatory properties of tea further contribute to reducing the systemic inflammation associated with insulin resistance and obesity as illustrated in Fig. 1. With mounting evidence of its benefits, green tea is poised to play a significant role in the prevention and treatment of obesity in the years to come.

14. Dandelion (Taraxacum officinale)

Dandelion, particularly its roots and leaves, is a potent plant used in obesity and diabetes management. It has diuretic properties that help reduce bloating and support fluid balance, aiding in weight management. Dandelion's high fiber content also assists in regulating blood sugar levels by slowing glucose absorption in the digestive system. Additionally, Fig. 1 depicts examples of the roles dandelion's bioactive compounds, such as taraxasterol and luteolin, potentially play to contribute to reducing inflammation, which plays a major role in insulin resistance and metabolic dysfunction (Kania-Dobrowolska and Baraniak, 2022). The plant mimics anti-obesity medication Orlistat that inhibits breakdown and absorption of dietary fat through the inhibition of pancreatic lipase by targeting fat absorption though the enhancement of bile secretion as shown in Fig. 2 (Chakhtoura et al., 2023). Dandelion has also been shown to improve insulin sensitivity and lower blood glucose, making it a promising natural remedy for managing type 2 diabetes.

This figure shows the mechanisms of anti-obesity drugs and medicinal plants. Phentermine/Topiramate suppresses appetite through norepinephrine release and promotes satiety. Tea Plant (Camellia sinensis) enhances thermogenesis, fat oxidation, and appetite reduction via caffeine and catechins. Clenbuterol stimulates −2 receptors in adipocytes to promote fat breakdown and muscle preservation. Orlistat inhibits pancreatic lipase, reducing fat absorption. Purple Basil (Ocimum basilicum) stimulates fat burning and muscle preservation through beta-2 receptors. Dandelion (Taraxacum officinale) supports digestion and reduces fat absorption by enhancing bile production.

15. Addressing infectious diseases with medicinal plant-based phytochemicals

Microorganisms cause infectious diseases, which are harmful to health and frequently spread through particular kinds of contact. These illnesses can spread to humans through insect bites, contact with infected people, places, animals, or environments. The common cold, giardiasis, malaria, influenza, measles, pneumonia, salmonella infections, tuberculosis, whooping cough (pertussis), rubella, shingles, onchocerciasis, candidiasis, aspergillosis, and clostridial infections are a few examples. Acquired immunodeficiency syndrome (AIDS) is another. These illnesses are caused by a variety of agents, including helminths, bacteria, fungi, viruses, and protozoa. The ongoing increase in antibiotic resistance and the negative side effects of synthetic medications, which have long been used to treat infectious diseases, should draw attention back to the value of traditional therapeutic methods and medicinal plants worldwide.

The use of plants for therapeutic and medicinal purposes to treat illnesses and enhance human health is known as herbal medicine, or phytomedicine. Phytochemicals, derived from the Greek word for "phyto" are secondary metabolites that plants produce that shield them from microbial infections. The medicinal properties of plants have been the subject of recent scientific research worldwide because of their potent therapeutic efficacy, antioxidant activity, low side effects, and affordability. Every plant produces phytochemicals that are good for human health (Babalola et al., 2024) and are rich dietary sources of vitamins, minerals, and other biomolecules that are essential for bodily maintenance. The metabolites of many plants show pharmacological effects. Plant metabolites are classified as primary or secondary metabolites because they are organic compounds. The human body needs primary metabolites, including proteins, nucleic acids, lipids, starch, and glucose, for growth and development. Many diseases can be effectively treated with secondary metabolites, which include alkaloids, saponins, flavonoids, steroids, glycosides, terpenoids, volatile oils, and tannins (Babalola et al., 2024; El-saadony et al., 2021; Parthasarathy et al., 2021).

Pharmacologically active substances are known as phytochemicals. Alkaloids, for instance, have diuretic, analgesic, antimalarial, and antispasmodic qualities. The anthelmintic, antiviral, antibacterial, antimalarial, anticancer, and anti-inflammatory properties of terpenoids are well-known. It has been demonstrated that glycosides have antibacterial and antifungal properties, and that flavonoids and phenols have antiallergic, antioxidant, and antibacterial qualities. Plant defense, antiviral, and anti-inflammatory properties are contributed by saponins (Timilsena et al., 2023; Kaushik et al., 2021). Many herbal medicines used today are still very important in treating a wide range of human ailments and are derived from plants, either directly or indirectly.

16. Mechanisms of antimicrobial action of key phytochemicals

16.1. Curcumin (from Curcuma longa, turmeric)

Curcumin, a polyphenol derived from *Curcuma longa* (turmeric), is well known for its broad range of medicinal benefits, which include antibacterial, anti-inflammatory, and antioxidant effects. Because of its broad-spectrum activity against pathogens such as bacteria, viruses, fungi, and parasites, its use in the fight against infectious diseases has garnered significant scientific attention. Recent research highlights the versatility of curcumin in treating infections and improving the effectiveness of antifungal and conventional antibiotics (Hussain et al., 2023). Curcumin's ability to damage microbial cell membranes is largely responsible for its antimicrobial qualities. Curcumin increases the permeability of the membrane by integrating into the lipid bilayer of pathogens. This results in the leakage of intracellular contents and the death of microbial cells. Moreover, curcumin prevents bacteria from using quorum sensing, a mechanism of cell-to-cell communication that controls pathogens such as *Staphylococcus aureus* virulence and biofilm formation. Curcumin inhibits coordinated bacterial behaviours, including the production of biofilms—protective structures that ward off pathogens from antibiotics and immune responses—by interfering with quorum sensing (Zheng et al., 2020; Hussain et al., 2023) Curcumin's antimicrobial activity is further enhanced by studies showing that it inhibits bacterial DNA gyrase, an enzyme essential for DNA replication leading to DNA fragmentation and disrupts membrane integrity (de Andrade Neto et al., 2021; Murtadlo et al., 2024; Zouine et al., 2024).

The efficacy of curcumin against a wide variety of bacterial infections is well-established. For instance, it has a notable and strong effect on *Helicobacter pylori* and *Escherichia coli*, particularly in gastrointestinal infections. Due to curcumin's bactericidal properties as well as its capacity to lessen gastric lining inflammation, *H. pylori*, a major cause of peptic ulcers and gastric cancer, has demonstrated susceptibility to curcumin. Furthermore, curcumin has been demonstrated to improve the effectiveness of traditional antibiotics against *Pseudomonas aeruginosa* and *Staphylococcus aureus* drug-resistant strains, indicating its potential for use in combination therapies (Hussain et al., 2023; Zouine et al., 2024). Apart from bacterial infections, curcumin has demonstrated potent antifungal properties. In patients with compromised immune systems, it is especially beneficial against *Candida albicans*, a fungus that causes infections ranging from oral thrush to systemic candidiasis (Lee et al., 2022; Leferman et al., 2023). In addition to causing fungal cell death through interference with the synthesis of fungal cell walls, curcumin has been shown in studies to reverse antifungal resistance when combined with antifungal medications such as fluconazole. For treating fungal infections that are challenging to treat, curcumin is a useful tool (Kannigadu and N'Da, 2021; Rajasekar et al., 2021). Curcumin has proven to have antiviral properties as well. Studies reveal that curcumin can prevent the growth of a number of viruses, including influenza and even SARS-CoV-2, the virus that causes COVID-19 (Rattis et al., 2021; Rajagopal et al., 2020; Valença et al., 2022). As an adjuvant treatment for viral infections, curcumin has demonstrated promise by blocking viral entry into host cells and causing disruptions in the assembly of viral proteins. Initial results are promising, but more clinical studies are needed to confirm its role in viral infections (Marín-Palma et al., 2021).

The low bioavailability of curcumin has hindered its therapeutic use despite its encouraging potential. Curcumin-loaded liposomes and nanoparticles are two examples of cutting-edge drug delivery technologies that have been the focus of recent research to improve curcumin's bioavailability. Curcumin is now a more attractive option for clinical applications due to these advancements that have greatly increased its systemic absorption and efficacy. The potential of curcumin's combined antimicrobial and anti-inflammatory properties to prevent infections and accelerate wound healing is being investigated in topical formulations for wound care, particularly in diabetic patients (Agharazi et al., 2022; Dehghani et al., 2020; Farooq et al., 2023; Sabet et al., 2021).

16.2. Cinnamaldehyde

Cinnamomum spp. contains a primary bioactive compound called cinnamonaldehyde, which is widely known for its strong antibacterial qualities. Its efficacy against various microbial infections, especially those resulting from Gram-negative bacteria, has been thoroughly studied. Because of its capacity to target microbial membranes and disrupt bacterial communication pathways, this compound has attracted interest in both food preservation and medicine. New insights into its therapeutic potential have been provided by recent studies that have clarified its mechanisms of action. Because it can damage microbial cell membranes, cinnamonaldehyde has antimicrobial properties (Chen et al., 2024; Shu et al., 2024). Due to the structural integrity of the lipid bilayer being compromised, there is an increase in permeability and leakage of vital intracellular contents in the bacterial cells, which ultimately leads to cell death (Zhang et al., 2022). Cinnamaldehyde also suppresses quorum sensing, a vital bacterial communication mechanism that controls virulence and the formation of biofilms (Chen et al., 2024; Topa et al., 2020). Cinnamaldehyde decreases bacterial virulence and stops the growth of biofilms, which are extremely resistant to antibiotics and the immune system, by obstructing quorum sensing (Barrio-Pujante et al., 2024; Li et al., 2023; Topa et al., 2020). Cinnamaldehyde is an effective antimicrobial agent because of these two processes, especially in clinical and food preservation settings.

Efficacy against a range of pathogens has been demonstrated by cinnamon aldehyde. The antimicrobial properties of cinnamon aldehyde against *Listeria monocytogenes*, a dangerous foodborne pathogen that can result in life-threatening infections, are among its most important uses. Cinnamaldehyde is a useful natural food preservative because studies have shown that it can stop *Listeria* from growing. As a result, food safety strategies that aim to prevent contamination now include it (Guan et al., 2023). *Staphylococcus aureus*, a common cause of foodborne illnesses and skin infections, is another important pathogen that cinnamaldehyde targets. *S. aureus* has been effectively inhibited by cinnamonaldehyde, as it damages the bacterium's cell membrane and prevents the formation of biofilms, which are crucial for the survival of the bacteria and the development of antibiotic resistance (Kim et al., 2022a,b). Cinnamaldehyde significantly decreased *S. aureus* adhesion and virulence, according to a recent study (Li et al., 2024), indicating that it may find use in clinical settings, particularly for wound care. *Escherichia coli* is another pathogen that causes a variety of gastrointestinal infections; cinnamaldehyde has also been found to be effective against it. Its compound value extends to the food and medical industries, as it inhibits the formation of biofilms and stops *E. coli* from growing (Pereira et al., 2021). Cinnamaldehyde can successfully lower *E. coli* contamination in a range of food matrices, increasing food safety and prolonging shelf life, according to recent research in food preservation (Alves et al., 2020).

Cinnamaldehyde's uses have grown beyond food preservation thanks to recent developments. Its use in antimicrobial films and coatings has gained traction in the healthcare industry. These coatings, which contain cinnamaldehyde, can lower the risk of infections linked to healthcare by inhibiting the growth of bacteria on surfaces and medical equipment (Worreth et al., 2022). Furthermore, topical applications of cinnamonaldehyde in wound care are being investigated. Its capacity to prevent biofilm formation can help treat infections brought on by bacteria resistant to antibiotics as well as chronic wounds (Qureshi et al., 2022). When combined with antibiotics, cinnamonaldehyde has also demonstrated synergistic effects. Studies indicate that the addition of cinnamonaldehyde to traditional antibiotics may increase their effectiveness by reducing the strength of bacterial defenses like membrane integrity and biofilm formation. According to Yin et al. (2023), the combination therapy approach presents a viable means of countering the increasing danger posed by antibiotic-resistant pathogens.

16.3. **Berberine (from** *Berberis* **species)**

Berberine is a well-known isoquinoline alkaloid that has been widely researched for antibacterial effects. Traditionally utilized in Ayurvedic and Chinese medicine for therapeutic purposes, recent study has confirmed its usefulness in combating a wide range of pathogenic diseases. It is isolated from numerous plants, including *Berberis vulgaris* (barberry), *Coptis chinensis* (Chinese goldthread), and *Hydrastis* *canadensis* (goldenseal), and has been used to treat bacterial, fungal, and parasite diseases (Warowicka et al., 2020). Berberine's antibacterial capabilities are demonstrated through a variety of ways, making it an effective tool against a wide range of infections. One of its principal routes of action is to break the bacterial cell membrane, resulting in depolarization and increased permeability. Zorić et al. (2017) found that this disruption causes the bacterial cell to lose critical ions and nutrients, thus impacting its survival. Furthermore, berberine has been shown to decrease nucleic acid synthesis by preventing DNA and RNA synthesis (Wan et al., 2020). This technique interrupts critical cellular activities, such as bacterial reproduction and transcription, eventually leading to microbial death. Berberine also targets certain bacterial enzymes, including DNA gyrase and topoisomerase IV, which are required for bacterial DNA replication. Berberine inhibits these enzymes, reducing the bacteria's capacity to reproduce and maintain genetic material, making it especially effective against resistant strains (Kosalec et al., 2022). Berberine's diverse mechanism of action makes it a possible alternative or adjuvant in the treatment of antibiotic-resistant illnesses.

Berberine has strong antibacterial properties against a variety of diseases, including Gram-positive and Gram-negative bacteria. Studies have shown that it is efficient against the primary bacterial species that cause human illnesses. Berberine has been demonstrated to decrease the growth of *Staphylococcus aureus*, including MRSA (Zhang et al., 2020). This is especially critical given the growing threat posed by antibiotic-resistant strains of *S. aureus*, which cause a wide range of infections, including skin problems and life-threatening disorders like pneumonia and sepsis. Berberine's capacity to damage bacterial cell membranes and inhibit DNA replication makes it a promising contender for treating MRSA (Kosalec et al., 2022). *E. coli*, a common source of urinary tract infections and gastrointestinal illnesses, is another pathogen that responds to berberine. The compound's membrane-disrupting capabilities are especially effective against *E. coli*, lowering its capacity to cling to host cells and manufacture toxins, therefore minimizing its pathogenicity. Recent investigations have shown that berberine can improve antibiotic efficacy against resistant *E. coli* strains (Cui et al., 2024; Seo et al., 2021; Meng et al., 2024). Berberine has also demonstrated potential in the treatment of tuberculosis (Mi et al., 2024). Mycobacterium tuberculosis, the bacterium that causes tuberculosis, is notoriously difficult to treat due to its complex cell wall and the advent of multidrug-resistant forms. Berberine's ability to block key enzymes like DNA gyrase provides a new path for tuberculosis treatment. According to recent studies, berberine could be an effective adjuvant in combination with traditional TB medications, perhaps decreasing treatment duration and enhancing outcomes (Ozturk et al., 2021). The alkaloid antifungal qualities have also been widely reported, with specific efficacy against *Candida albicans*, a frequent source of yeast infections. Berberine disrupts fungal cell membranes and inhibits mitochondrial function, limiting the ability of *Candida* to produce biofilms resistant to antifungal therapies (Gao et al., 2021; Huang et al., 2020; Xie et al., 2020). Berberine has also been proven to be effective against *Aspergillus* species (Moradi et al., 2024), which are another group of fungus that cause serious lung infections, particularly in immunocompromised persons. In addition to its antibacterial and antifungal characteristics, berberine provides antiparasitic activity. It is useful against protozoal infections like *Giardia lamblia* and *Entamoeba histolytica*, which cause gastrointestinal illnesses (Bhattacharyya, 2021). Berberine suppresses these parasites' growth and replication, providing a natural alternative to synthetic antiprotozoal medications. This has important implications for areas where parasite diseases are common, as berberine could be a viable and economical therapeutic option.

Recent research has investigated the use of berberine in combination therapies to increase its antibacterial properties. One area of particular interest is its ability to battle drug-resistant microorganisms. Berberine can improve the efficiency of conventional antibiotics by preventing biofilm formation and increasing bacterial membrane permeability, providing a technique for combating antibiotic resistance (Li et al., 2021). Berberine's antibacterial and anti-inflammatory characteristics may provide dual benefits in the treatment of gastrointestinal infections and inflammatory illnesses, according to clinical research (Lu et al., 2020). In addition to its direct antibacterial activities, berberine possesses immunomodulatory qualities, making it a useful tool for treating infections in people with weakened immune systems. Berberine enhances immunological responses, allowing the body to better protect itself against invading diseases while also targeting bacteria directly.

16.4. Allicin

Allicin, a sulphur-containing compound derived from garlic (*Allium sativum*), is well-known for its powerful broad-spectrum antibacterial activities. When garlic is crushed, an enzyme called alliinase converts alliin into the active component allicin. Allicin has long been recognized for its therapeutic applications in infectious disorders, a fact that modern scientific study has supported via a variety of investigations. This bioactive molecule has antibacterial properties against a variety of bacteria, fungi, and viruses, making it an attractive option for both therapeutic and preventive applications. Allicin has antibacterial properties through a variety of ways. It primarily disrupts bacterial cell wall formation by inhibiting enzymes required for cell wall production, such as transpeptidases and muramidases. These enzymes are essential for maintaining bacterial cell shape and integrity, and allicin inhibits them, resulting in cell wall weakening, leakage, and, ultimately, bacterial death. Furthermore, allicin damages bacterial membranes, causing increased permeability and loss of important intracellular components including ions and proteins. This membrane damage is an important part of its bactericidal action, as it works against both Gram-positive and Gram-negative bacteria (Senarathna and Gunathilaka, 2023). Another important function of allicin is its capacity to impair quorum sensing, a communication system utilized by bacteria to control collective activities such as biofilm formation and virulence factor synthesis. Allicin decreases bacterial pathogenicity by suppressing quorum sensing and preventing the production of biofilms, which are complex communities of bacteria resistant to antibiotics and the host immune system (Jikah and Edo, 2023; Snoussi et al., 2022). This makes allicin an effective weapon for fighting chronic illnesses and lowering the chance of bacterial resistance.

Allicin has shown broad-spectrum antibacterial action against a wide range of bacterial species. Research has demonstrated its efficacy against *Staphylococcus aureus*, particularly methicillin-resistant *Staphylococcus aureus* (MRSA), a renowned bacteria that causes difficult-to-treat skin infections and systemic problems. Allicin inhibits quorum sensing and disrupts cell membranes, dramatically reducing *S.aureus* growth and pathogenicity (Sheppard et al., 2018). This has resulted in ongoing research into allicin's potential application as a topical and systemic therapy for resistant bacterial infections. Allicin is also effective against Escherichia coli and Pseudomonas aeruginosa, two prominent Gram-negative organisms that cause urinary tract infections, gastrointestinal problems, and hospital-acquired infections. *Pseudomonas aeruginosa* is particularly resistant to antibiotics, and allicin's membrane-disrupting capabilities make it a promising treatment option for these infections. Recent research has demonstrated that allicin can suppress *P. aeruginosa* biofilm development, considerably lowering pathogenicity in both in vitro and in vivo models (Farrag et al., 2019). In addition to antibacterial activity, allicin contains antifungal characteristics. It is efficient against *Candida* species, which are common sources of fungal illnesses such oral thrush and vaginal yeast infections (Zainal et al., 2021). Allicin targets the fungal cell membrane, specifically ergosterol, which is an important component in fungal membrane stability. This disruption causes the loss of crucial membrane activities, resulting in cell death. Allicin's antifungal properties make it an important compound for the treatment of candidiasis and other fungal infections, particularly those that are resistant to traditional antifungal treatments. Allicin's antiviral capabilities are also notable. It has demonstrated efficacy against viruses such as herpes simplex virus (HSV). Allicin's capacity to interrupt viral replication, combined with its immunomodulatory properties, aids in the treatment of viral infections. In vitro experiments have shown that allicin inhibits HSV reproduction by interfering with viral entrance into host cells and lowering viral load (Horowitz, 2023).

The medicinal applications of allicin go beyond its direct antibacterial properties. Recent research has focused on its usage in combination medicines, in which allicin improves the efficacy of conventional antibiotics. Research suggests that allicin can enhance the effectiveness of antibiotics like ciprofloxacin and gentamicin against drug-resistant bacteria by disrupting membranes and reducing biofilm formation (Magryś et al., 2021). This opens up the possibility of using allicin as an adjuvant therapy in the treatment of multidrug-resistant illnesses, lowering antibiotic dosage and reducing adverse effects. In addition to its antibacterial properties, allicin's potential as an immunological booster has been investigated (Donma and Donma, 2020). Its capacity to influence immunological responses, such as increasing macrophage activity and the generation of pro-inflammatory cytokines, helps the body clear infections more efficiently. Allicin is a one-of-a-kind molecule in the battle against infectious diseases due to its dual action of direct antibacterial properties and immune system stimulation.

16.5. Thymol (from thyme and oregano)

Thymol is a natural monoterpenoid phenol found mostly in the essential oils of plants such as thyme (*Thymus vulgaris*) and oregano (*Origanum vulgare*). Thymol, known for its broad-spectrum antibacterial activity, has been used in traditional medicine as well as modern pharmaceutical uses. Its high antibacterial qualities have made it an important chemical in food preservation as well as medical formulations used to treat diseases caused by bacteria, fungus, or viruses. Thymol's antibacterial effect is mostly due to its capacity to damage the integrity of microbial cell membranes (Kowalczyk et al., 2020). This disturbance results in the leakage of essential intracellular components such as proteins, nucleic acids, and ions. Thymol undermines microbial cells' structural and functional integrity by increasing membrane permeability, eventually leading to cell death. Thymol also inhibits membrane-bound enzymes important for energy synthesis, such as ATPase, reducing cellular respiration and energy metabolism in pathogens (Liang et al., 2022). This inhibitor stops microbial cells from maintaining homeostasis, making them non-viable. Furthermore, thymol's lipophilicity allows it to integrate into lipid bilayers, disrupting bacterial membranes. This property is especially effective against Gram-positive and Gram-negative bacteria, as well as fungus. Combining the chemical with different antibacterial agents enhances its efficiency in multiple applications (Escobar et al., 2020).

Thymol has been proven to have excellent antibacterial properties against a variety of infections. For example, studies have shown that it is effective against *Staphylococcus aureus*, a Gram-positive bacterium that causes skin infections, pneumonia, and sepsis (Sasso et al., 2006). Thymol's propensity to break bacterial cell membranes makes it particularly efficient against *S. aureus*. This has sparked interest in thymol as a topical treatment for skin infections and wound dressings to combat resistant bacteria. Thymol has also been shown to be effective against *Escherichia coli*, a Gram-negative bacterium that is commonly connected with gastrointestinal infections and foodborne diseases. Thymol has been demonstrated to impede *E. coli* growth by breaking its outer membrane, which is necessary for the bacterium's survival in hostile settings (Sasso et al., 2006; Martínez et al., 2021). This makes thymol an important component in food safety and preservation since it inhibits the growth of *E. coli* in food products. Thymol is also effective against *Pseudomonas aeruginosa*, a Gram-negative bacterium noted for its multidrug resistance and potential to induce persistent infections, especially in immunocompromised persons. Thymol can greatly lower the development and virulence of *P. aeruginosa* by disrupting the bacterial membrane and blocking critical enzymes, making it a promising candidate for treating resistant infections (Liu et al., 2021).

Thymol also has potent antifungal properties. Its effectiveness against *Candida albicans*, a common fungal pathogen that causes oral and vaginal yeast infections, is well recognized (Jafri and Ahmad, 2020). Thymol targets the fungal cell membrane by altering its lipid components, particularly ergosterol, causing cell lysis and death. Given the growing resistance of *Candida* species to traditional antifungal treatments, thymol has emerged as a possible natural alternative (Kowalczyk et al., 2020). Furthermore, thymol has shown antifungal activity against *Aspergillus niger*, a mold species that can cause respiratory infections, especially in people with compromised immune systems (Nakasugi et al., 2021). Thymol inhibits spore germination and fungal growth, making it effective in preventing fungal contamination in food and agricultural products.

Thymol's antiviral activity, albeit less well studied than its antibacterial and antifungal effects, has showed promise against respiratory viruses. Notably, thymol has been studied for its ability to inhibit influenza viruses (Nandi and Khanna, 2022). Its antiviral mechanism is likely to involve disrupting viral envelopes and inhibiting viral replication. While additional research is needed to fully grasp its antiviral potential, thymol's broad-spectrum antibacterial capabilities make it a promising option for future antiviral therapeutics (Kachur and Suntres, 2020).

Because of its strong antibacterial characteristics, thymol is frequently employed in a variety of settings. It is a popular ingredient in mouthwashes because of its ability to treat oral infections including *Streptococcus mutans* and *Porphyromonas gingivalis*, which helps prevent dental caries and gingivitis. Thymol is also utilized in disinfectants and sanitizers, particularly in food preservation, where its activity against foodborne pathogens such as *Salmonella enterica* and *Listeria monocytogenes* protects the safety and longevity of perishable items (Coimbra et al., 2022). Furthermore, thymol's use in the pharmaceutical business is increasing. Recent research has looked into its potential as a natural preservative in pharmaceutical formulations, substituting synthetic preservatives that may have negative effects on human health. Topical preparations, wound dressings, and antimicrobial coatings are being explored for their efficacy against drug-resistant infections (Akermi et al., 2022).

16.6. Eugenol

Eugenol, a natural phenolic molecule derived mostly from cloves (*Syzygium aromaticum*), has potent antibacterial, antifungal, and antiviral effects. Eugenol, known for its fragrant properties and medicinal applications, has long been utilized in traditional medicine to combat a variety of infections (Ulanowska and Olas, 2021). Recent research has broadened its therapeutic potential by investigating its broad-spectrum antibacterial properties and mechanisms of action, with a special focus on its efficacy against drug-resistant infections. Eugenol's antibacterial activity stems mostly from its ability to destroy the structural integrity of microbial cell membranes. Eugenol increases membrane permeability by interacting with the cell membrane's lipid bilayer, resulting in the leaking of important intracellular components such as ions, proteins, and other metabolites (Nisar et al., 2021). This loss of key cellular components disables bacterial cells and finally leads to cell death. Furthermore, eugenol inhibits numerous membrane-bound enzymes required for bacterial viability. One of the primary targets is ATPase, an enzyme required for ATP generation that inhibits energy production in the cell. Eugenol drastically limits the pathogen's capacity to maintain metabolic processes by interfering with ATP generation, eventually leading to microbial death (Jeyakumar and Lawrence, 2021; Ulanowska and Olas, 2021). Furthermore, eugenol has been found to block bacterial protease activity, preventing the breakdown of proteins necessary for bacterial growth and replication (Bai et al., 2023).

Eugenol has shown strong antibacterial action against a wide range of pathogens, including both Gram-positive and Gram-negative bacteria. Recent investigations have demonstrated its efficacy against *Staphylococcus aureus,* a prevalent Gram-positive bacterium that causes skin infections, pneumonia, and septicemia. Eugenol's capacity to rupture the bacterial membrane has been shown to effectively reduce *S. aureus* growth, even antibiotic-resistant strains such as MRSA (Bezerra et al., 2022). This has made eugenol a promising chemical for the development of alternate treatments for resistant bacterial illnesses. Eugenol has been demonstrated to be effective against *Escherichia coli* and *Pseudomonas aeruginosa*, both of which are common causes of gastrointestinal and respiratory illnesses (Jeyakumar and Lawrence, 2021). Eugenol is an efficient antibacterial agent against these diseases because it disrupts the outer membrane and leaks cellular contents, which are frequently connected with biofilm development and resistance to conventional antibiotics (Ulanowska and Olas, 2021). Recent research has also looked into the synergistic effects of eugenol when combined with other antibiotics, which have increased its overall antibacterial efficacy (Jafri et al., 2020).

Eugenol's antifungal action is another key component of its medicinal promise. It has been demonstrated to be extremely powerful against fungal strains such as *Candida albicans*, which is a major cause of oral and vaginal yeast infections. Eugenol disrupts the fungal cell membrane, which inhibits the manufacture of ergosterol, a critical component of the fungal cell membrane, resulting in cell lysis (Didehdar et al., 2022). This makes eugenol an intriguing candidate for antifungal therapy, notably in the treatment of candidiasis, which is becoming increasingly resistant to standard antifungal medicines. Furthermore, eugenol has antifungal properties against *Aspergillus niger*, a mold species that can cause respiratory infections, especially in immunocompromised people (Ju et al., 2020). Eugenol, by breaking fungal cell membranes and preventing spore germination, can effectively suppress fungal growth and prevent infection spread. Its potential applications in agriculture and food safety are being researched, particularly for reducing fungal contamination in stored crops. Eugenol's antiviral properties have also received attention, particularly for its activity on enveloped viruses. Recent study has demonstrated that eugenol is effective against herpes simplex virus (HSV), which is a common cause of cold sores and genital herpes. Eugenol, by disrupting the viral envelope and interfering with viral replication, has the potential to drastically lower viral infectivity. While additional research is needed to completely understand its antiviral actions, using eugenol in topical preparations to treat HSV infections appears promise. Furthermore, some studies suggest that eugenol could have broader antiviral effects, especially against respiratory infections. Its capacity to suppress viral reproduction and damage viral membranes has generated attention in its potential as a natural antiviral drug, especially given the rising viral resistance to conventional treatments (Wani et al., 2021).

Eugenol's broad-spectrum antibacterial characteristics have led to its use in a variety of pharmaceutical and industrial applications. Eugenol is often used in dental care products, such as mouthwashes and toothpastes, because to its capacity to battle oral diseases like *Streptococcus mutans* (Laleman and Teughels, 2020). Its effectiveness in decreasing dental plaque formation and treating gingivitis has been well established, making it a common constituent in dental formulations (Rani et al., 2022; Kumar et al., 2023). Eugenol is also commonly utilized in the food sector as a natural preservative due to its antibacterial properties against foodborne infections (Gürbüz and Korkmaz, 2022). Its use into food packaging materials might inhibit the growth of spoilage organisms, hence increasing the shelf life of perishable products. Furthermore, eugenol has been investigated as a possible ingredient in pharmaceutical formulations, particularly topical creams and ointments used to treat fungal and bacterial skin infections (da Silva et al., 2022).

16.7. Gallic acid (from grapes, tea, and berries)

Gallic acid is a naturally occurring polyphenolic chemical found in many plants, including berries, grapes, tea leaves, and pomegranates. It has been extensively researched for its biological qualities, which include antibacterial, antioxidant, and anti-inflammatory activities. Recent research has increased emphasis on gallic acid's ability to act as a therapeutic agent, particularly in the treatment of infectious diseases, due to its role in disrupting bacterial and fungal growth and mitigating inflammatory responses caused by microbial infections. Gallic acid's antibacterial action stems mostly from its ability to damage microbial cell membranes. One of the key ways it accomplishes this is by causing oxidative stress within the microbial cell. This oxidative stress damages lipid structures in the microbial membrane, increasing permeability and resulting in the leakage of essential cellular contents (Tian et al., 2022; Flores-Maldonado et al., 2024). This membrane disruption reduces the pathogen's structural integrity and induces apoptosis, or programmed cell death, in bacterium and fungal cells. Gallic acid not only causes oxidative stress, but it also prevents bacterial biofilms from growing. Biofilms are organized populations of bacteria that stick to surfaces and are frequently resistant to drugs and immunological responses. These biofilms are especially harmful in persistent infections. Gallic acid inhibits bacterial growth by preventing biofilm formation, as well as the persistence of infections caused by resistant pathogens (Sang et al., 2024).

Gallic acid exhibits broad-spectrum antibacterial action against both Gram-positive and Gram-negative microorganisms. It has been proven to be effective against infections such as *Escherichia coli*, *Pseudomonas aeruginosa*, and *Bacillus subtilis* (Gobin et al., 2022; Keyvani-Ghamsari et al., 2023). Gallic acid was discovered to significantly reduce bacterial growth by increasing membrane permeability, which causes cytoplasmic content leakage and cell death (Flores-Maldonado et al., 2024). Furthermore, it was discovered that gallic acid has increased antimicrobial activity when combined with conventional antibiotics, potentially improving the efficacy of antibiotic treatments against resistant bacterial strains. Gallic acid synergistically and independently is particularly efficient against *Pseudomonas aeruginosa* (Keyvani-Ghamsari et al., 2023; Wang et al., 2021, a bacterium involved with a variety of hospital-acquired infections and resistant to numerous medications. The compound's capacity to both generate oxidative damage and inhibit biofilm formation has made it an intriguing option for treating difficult-to-treat bacterial illnesses. Gallic acid has significant antifungal effects. It has been demonstrated to limit the growth of fungus species including *Candida albicans* and *Aspergillus niger* (Liberato et al., 2022). Both of these fungi can cause infections. Gallic acid's antifungal mechanism is similar to its antibacterial effects: it breaks the fungal cell membrane via oxidative stress and lipid peroxidation, resulting in cellular lysis. Gallic acid's antioxidant capabilities contribute to its antifungal activity. Gallic acid, by lowering oxidative stress and neutralizing free radicals, can minimize the damage caused by fungal infections to host tissues, especially in chronic or systemic infections (Yang et al., 2020). Furthermore, it has shown the potential to be used as an adjunct to existing antimicrobial treatments, providing a synergistic effect that enhances the effectiveness of standard therapies (Gobin et al., 2022; Khoshi et al., 2024; Rhimi et al., 2020).

In addition to its antimicrobial and antifungal properties, gallic acid's strong antioxidant activity makes it particularly effective in managing infections accompanied by inflammation and oxidative stress. When the body is combating infections, reactive oxygen species (ROS) are created, which can cause tissue damage if not neutralized. Gallic acid, by scavenging ROS and lowering oxidative stress, serves to attenuate inflammation and prevent additional damage to host tissues during an infection (Yang et al., 2020). Recent study has focused on gallic acid's ability to alter immunological responses during infections. In a study on bacterial-induced oxidative stress, gallic acid was found to drastically reduce the levels of pro-inflammatory cytokines, therefore preventing excessive inflammation while simultaneously addressing the underlying infection (Keyvani-Ghamsari et al., 2023; Mohamed and Abd El-Twab, 2016). Gallic acid's broad-spectrum antibacterial activity, along with its antioxidant and anti-inflammatory properties, makes it a molecule of tremendous therapeutic potential. Its potential to increase the efficacy of conventional antibiotics and antifungal drugs implies that it could be used in combination therapy to treat resistant infections. Furthermore, as bacterial resistance to antibiotics increases, gallic acid presents a promising natural alternative for tackling this growing public health issue.

16.8. Gingerol from ginger

Gingerol, the major bioactive component of *Zingiber officinale* ginger), is widely known for its wide range of antibacterial capabilities. This chemical has been well researched for its potential to battle both Gram-positive and Gram-negative bacteria, fungus, and even some viruses. It is especially noteworthy for its therapeutic potential in respiratory and gastrointestinal diseases. Recent study has highlighted gingerol's involvement in altering bacterial metabolic processes, as well as its potential use in treating infections with antibiotic resistance (Bhaskar et al., 2020; Hayati et al., 2021). Gingerol's antibacterial effect originates from its ability to disrupt critical metabolic pathways within microbial cells. Table 2 highlights its mechanism of action as being able to suppress the synthesis of proteins and nucleic acids in bacteria, which are required for microbial growth and replication (Wang et al., 2020a, b). Gingerol causes cell death in pathogens by interrupting these mechanisms, making it an effective treatment for a variety of bacterial illnesses. Furthermore, gingerol's capacity to disrupt bacterial cell membranes, enhances its antibacterial activity by increasing permeability and generating intracellular leakage (Zhang et al., 2022). In addition to targeting bacterial activities, gingerol has been proven to have anti-biofilm effects. Gingerol prevents biofilm development by interrupting bacterial communication channels, also known as quorum sensing, preventing bacteria from coordinating the formation of these durable structures as illustrated in Fig. 3. This characteristic is especially useful for treating chronic infections produced by biofilm-forming bacteria such as *Pseudomonas aeruginosa* (Shukla et al., 2021).

Recent studies have demonstrated gingerol's efficacy against a wide range of bacterial pathogens, including Gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus subtilis*, as well as Gram-negative

Table 2
Phyto-compounds activities against Infections.

Compound	Primary Sources (Plants)	Other Sources	Mechanism of Action	Effectiveness	References
Curcumin	*Curcuma longa* (Turmeric)	*Curcuma aromatica*, *Curcuma zedoaria*, *Curcuma kwangsiensis*	Disrupts microbial membranes, increases permeability, inhibits biofilm formation, and quorum sensing.	Effective against *Escherichia coli*, *Staphylococcus aureus*, *Helicobacter pylori*, and *Candida albicans*. Enhances antibiotic efficacy in drug-resistant infections.	Patel et al. (2020); Lee et al. (2022); Murtadlo et al. (2024); Zheng et al. (2020)
Cinnamaldehyde	*Cinnamomum verum* (True Cinnamon)	*Cinnamomum cassia*, *Cinnamomum burmannii*, *Cinnamomum loureiroi*	Disrupts bacterial cell membranes and inhibits quorum sensing.	Active against *Listeria monocytogenes*, *Staphylococcus aureus*, and *E. coli*. Commonly used in food preservation.	Barrio-Pujante et al. (2024); Chen et al. (2024); Guan et al. (2023); Kim et al., 2022; Li et al. (2024); Peirera et al., 2024
Berberine	*Berberis vulgaris* (Barberry)	*Hydrastis canadensis* (Goldenseal), *Coptis chinensis* (Chinese Goldthread)	Disrupts bacterial membranes, inhibits DNA/RNA synthesis, and inhibits bacterial DNA gyrase.	Active against *Staphylococcus aureus* (including MRSA), *E. coli*, *Mycobacterium tuberculosis*, and fungi like *Candida albicans* and *Aspergillus*.	Huang et al. (2020); Kosalec et al. (2022); Sun et al. (2019); Xi et al., 2022; Zhang et al. (2020)
Allicin	*Allium sativum* (Garlic)	*Allium cepa* (Onion), *Allium porrum* (Leek), *Allium schoenoprasum*(Chive)	Interferes with cell wall synthesis, damages microbial membranes, and disrupts quorum sensing.	Effective against *Staphylococcus aureus*, *E. coli*, *Pseudomonas aeruginosa*, *Candida* species, and herpes simplex virus.	El-Saber Batiha et al. (2020); Jikah and Edo, 2023; Parthasarathy et al. (2021); Zainal et al. (2021)
Thymol	*Thymus vulgaris* (Thyme)	*Origanum vulgare* (Oregano), *Satureja hortensis* (Savory), *Thymus serpyllum*(Wild Thyme)	Disrupts microbial membranes, inhibits membrane-bound enzymes, disrupts cellular respiration.	Active against *Staphylococcus aureus*, *Salmonella enterica*, *Pseudomonas aeruginosa*, *Candida albicans*, and *Aspergillus niger*. Used in mouthwashes and disinfectants.	Jafri et al., 2020; Kowalczyk et al. (2020); Liu et al. (2021); Nandi and Khanna, 2022; Nakasugi et al. (2021);
Eugenol	*Syzygium aromaticum* (Cloves)	*Ocimum gratissimum*(African Basil), *Pimenta dioica* (Allspice), *Ocimum tenuiflorum* (Holy Basil)	Disrupts bacterial membranes, inhibits ATPase and protease enzymes, interferes with energy production.	Active against *Staphylococcus aureus*, *E. coli*, *Pseudomonas aeruginosa*, herpes simplex virus, and fungal strains like *Candida albicans* and *Aspergillus niger*.	Bezerra et al. (2022); Jafri et al. (2020); Jeyakumar and Lawrence, 2021; Ju et al. (2020)
Gallic Acid	*Vitis vinifera* (Grapes), *Vaccinium* spp. (Berries)	*Camellia sinensis*(Tea), *Punica granatum* (Pomegranate), *Quercus robur* (Oak)	Causes oxidative stress and membrane leakage, inhibits bacterial biofilm formation.	Effective against *E. coli*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, *Candida albicans*, and *Aspergillus niger*. Also reduces inflammation associated with infections.	Keyvani-Ghamsari et al. (2023); Liberato et al. (2022); Sang et al. (2024); Tian et al. (2022); Wang et al. (2021); Yang et al. (2020)
Gingerol	*Zingiber officinale* (Ginger)	*Zingiber zerumbet* (Shampoo Ginger), *Zingiber montanum* (Bitter Ginger), *Alpinia officinarum* (Lesser Galangal)	Inhibits protein and nucleic acid synthesis in bacterial cells.	Effective against Gram-positive and Gram-negative bacteria, respiratory viruses, and gastrointestinal pathogens.	Dos Santos et al. (2023); Hayati et al. (2021); Shukla et al. (2021); Lee et al. (2018)
Quercetin	*Fagopyrum esculentum* (Buckwheat)	*Allium cepa* (Onion), *Capparis spinosa* (Caper), *Morus alba* (Mulberry)	Inhibits DNA gyrase, damages bacterial cell walls, prevents viral replication.	Active against *Streptococcus pneumoniae*, *Helicobacter pylori*, *Mycobacterium tuberculosis*, herpes simplex virus, rhinoviruses, influenza, and fungal pathogens.	Janeczko et al. (2022); Kim et al. (2020); Rizky et al. (2022).
Azadirachtin	*Azadirachta indica* (Neem)	*Melia azedarach* (Chinaberry), *Melia dubia* (Malabar Neem), *Melia toosendan* (Chinese Toosendan)	Disrupts enzyme systems essential for microbial cell division and replication.	Effective against *Aspergillus* species, with potential against bacterial strains like *Staphylococcus aureus*and *Bacillus subtilis*. Works synergistically with other compounds.	Altayb et al. (2022); Hussain et al. (2023); Joshi and Prabhakar, 2021

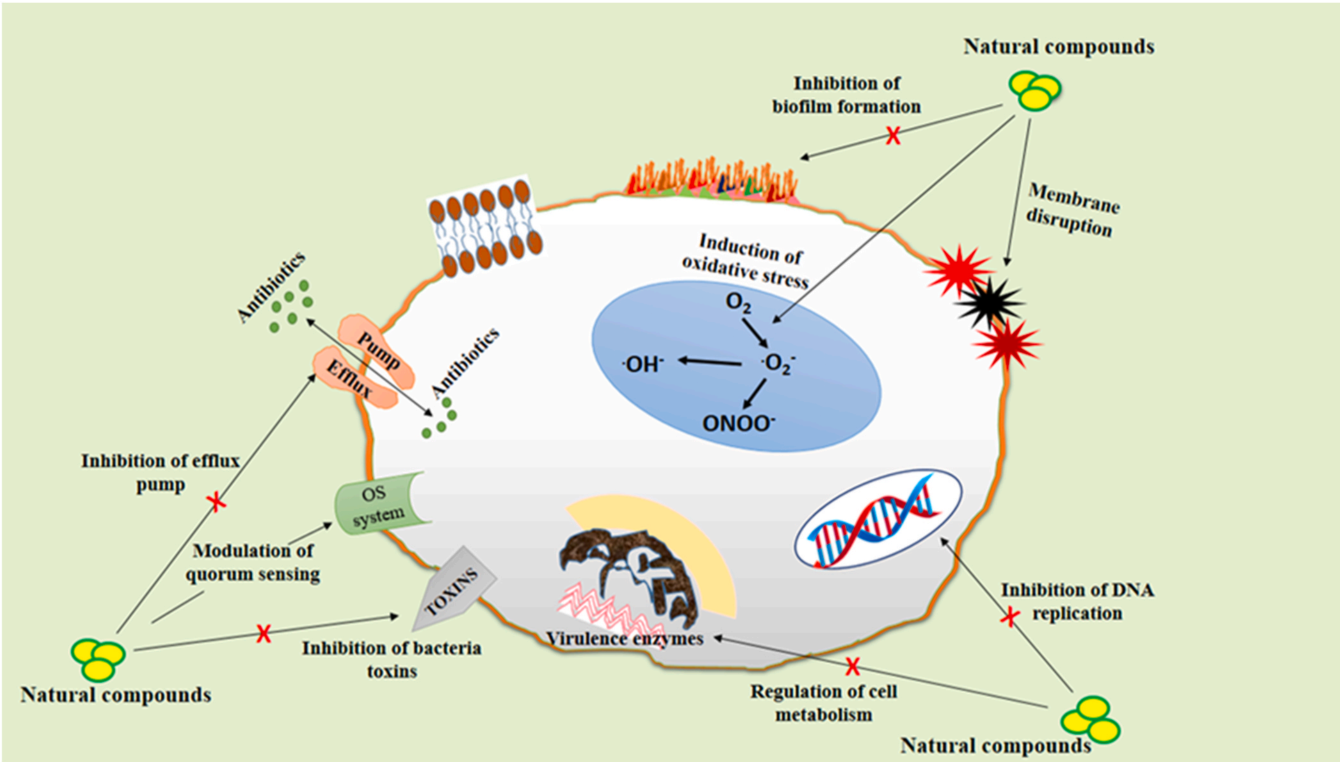

Fig. 3. Phytochemicals elicit its mechanisms against infection via numerous pathways including inhibition of biofilm formation, membrane disruption, imbibition of DNA replication, regulation of cell metabolism, inhibition of bacteria toxins, modulation of quorum sensing and inhibition of efflux pump.

bacteria such as *Escherichia coli* and *Salmonella typhi* (Dos Santos et al., 2023; Hughes et al., 2021; Wang et al., 2020a,b). Gingerol has showed potential as an alternative or complementary treatment for respiratory infections because of its capacity to target both bacterial and viral pathogens found in the respiratory system (Yücel et al., 2022). Another study looked into gingerol's usefulness in treating methicillin-resistant *Staphylococcus aureus* (MRSA), a hazardous infection that is resistant to several antibiotics. The researchers discovered that gingerol not only suppressed MRSA growth but also improved the efficacy of various antibiotics when used in combination therapy (Oyedemi et al., 2019). This makes gingerol a promising contender in the ongoing fight against antibiotic-resistant microorganisms. However, 6-gingerol, a derivative of gingerol has been said to have a less significant effect on biofilm formation in some organisms (Dos Santos et al., 2023; Wong and Chow, 2024). Further studies are needed to determine the reason for the inconsistency across microbial species.

Gingerol has considerable antifungal and antiviral properties in addition to its antibacterial activity. It has been proven to prevent the growth of fungi, including *Candida albicans*, which is a common source of fungal infections in people. Gingerol breaks the fungal cell membrane in the same way that it does bacterial cells, causing cell death and inhibiting fungal spread (Lee et al., 2018; Xi et al., 2022). Furthermore, gingerol's antiviral effects are gaining popularity, notably in the treatment of respiratory infections. Recent research on gingerol's capacity to prevent viral replication has yielded encouraging results in the treatment of influenza and respiratory syncytial virus infections. Gingerol decreases viral load and alleviates symptoms in infected persons by inhibiting viral enzymes and proteins required for reproduction (Hayati et al., 2021). This makes it a useful natural substance for treating viral outbreaks, particularly in cases where conventional antiviral medications are restricted or ineffective.

Gingerol-rich ginger extracts have long been used in traditional medicine to alleviate nausea, vomiting, and inflammation, but recent research suggests that they can also be used to directly target infectious pathogens in the gastrointestinal tract. Furthermore, gingerol's potential for application in food preservation is being investigated because it effectively inhibits the growth of foodborne bacteria, extending shelf life and enhancing food safety. Its application in topical formulations for skin diseases, particularly those caused by resistant bacteria, is another area of active research, with potential for the development of antimicrobial creams and ointments (Ahmad et al., 2023). Recent research has also revealed that mixing gingerol with regular antibiotics can improve their efficacy, particularly against resistant strains (Ham et al., 2021). This could serve as a natural supplement to conventional antimicrobial medicines, lessening the risk of side effects while perhaps lowering the doses required of synthetic antibiotics. Furthermore, gingerol's broad-spectrum effect against bacteria, fungi, and viruses makes it an important compound in the search for innovative treatments for a variety of diseases.

16.9. *Quercetin (flavonoid found in plants like apples, onions, and green tea)*

Quercetin is a naturally occurring flavonoid present in many fruits, vegetables, and grains. It has received a lot of attention for its broad-spectrum health advantages, which include antibacterial, antioxidant, and anti-inflammatory qualities. Over the last few decades, research has consistently demonstrated quercetin's ability to resist bacterial, viral, and fungal infections, making it a significant bioactive molecule for infectious disease management. Quercetin's antibacterial effects are mediated by a number of mechanisms that target infections at various phases of growth and reproduction. One of its key routes of action against bacteria is the capacity to block DNA gyrase, an enzyme required for the supercoiling of bacterial DNA during replication (Nguyen and Bhattacharya, 2022) as illustrated in Fig. 3. This disruption prevents bacterial multiplication by interfering with essential replication pathways. Furthermore, quercetin disrupts the integrity of bacterial cell membranes and cell walls, increasing permeability and resulting in cell lysis and death.

Its antiviral properties are equally outstanding. Quercetin inhibits viral reproduction by attaching to viruses' surface proteins, preventing them from entering host cells. This mechanism has been notably noticed in its activity against respiratory viruses, where quercetin inhibits virus attachment to respiratory epithelial cells, hence lowering infection severity and dissemination and is illustrated further in Table 2 and Fig. 3 (Rizky et al., 2022). Furthermore, quercetin's antioxidant qualities shield host cells from viral-induced oxidative damage, boosting the body's ability to combat infections (Rizky et al., 2022). Several studies have shown quercetin's powerful antibacterial properties against a variety of infections. It is effective against both Gram-positive and Gram-negative bacteria, including Helicobacter pylori and Escherichia coli (Nguyen and Bhattacharya, 2022). In a study investigating its efficacy against *Mycobacterium tuberculosis*, the causal agent of tuberculosis, quercetin was found to suppress bacterial growth and improve the effects of conventional antibiotics (Pawar et al., 2020).

Quercetin's antiviral properties have been extensively researched in the context of respiratory infections. Notably, it has demonstrated strong action against rhinoviruses, which cause the common cold, as well as influenza viruses (Rizky et al., 2022). By inhibiting viral entry and replication, quercetin decreases the severity of symptoms and may shorten the length of sickness. Recent research reveals that quercetin may be effective in the treatment of herpes simplex virus (HSV) infections, both directly antivirally and by increasing the host's immune response to the virus (Kim et al., 2020). In addition to its antibacterial and antiviral effects, quercetin is effective against a variety of fungal infections. Its antifungal activity is especially strong against *Candida* species, which are common sources of fungal infections in people. Quercetin damages these fungi's cell membranes, resulting in the release of crucial cellular contents and fungal death (Janeczko et al., 2022). This makes it a good candidate for treating candidiasis and other fungal infections, especially as resistance to traditional antifungal drugs grows.

Given its broad-spectrum antibacterial activity, quercetin is being investigated as a potential complement or alternative in the treatment of infectious disorders, particularly in circumstances when conventional medications are ineffective. Its ability to improve the efficacy of antibiotics and antiviral medications emphasizes its medicinal potential. Furthermore, quercetin's antioxidant and anti-inflammatory properties protect tissues from infection-induced damage and boost the immune system. In the future, quercetin could play an important role in the development of new antimicrobial medicines, either as a standalone treatment or in combination with existing antibiotics. Its natural prevalence in common meals makes it an appealing choice for infection prevention methods in susceptible groups.

16.10. Azadirachtin (A Tetranortriterpenoid)

Azadirachtin, a bioactive molecule derived from the neem tree (*Azadirachta indica*), has received widespread interest due to its pesticidal abilities. However, new study has revealed its promise as an antibacterial agent, extending its application beyond pest control to infectious disease treatment. While it has been widely used for its insecticidal properties, the revelation that it can prevent the growth of microorganisms, notably fungus, opens up new possibilities for its application in infection control. Azadirachtin acts as an antibacterial by inhibiting key enzyme systems involved in cell proliferation and reproduction (Joshi and Prabhakar, 2021).

Recent research has demonstrated azadirachtin's capacity to target fungal pathogens such as *Aspergillus* specie, which are known to cause invasive fungal infections (Zenat et al., 2024; de Castro e Silva et al., 2019). Azadirachtin's potency against these pathogens is of great importance, considering the growing concern about antifungal resistance. Its ability to prevent fungal spore formation and proliferation has made it an attractive candidate for future study and clinical development. Another study found that azadirachtin had synergistic effects when mixed with other phytochemicals, implying that it can function in concert with other natural components to increase antimicrobial efficacy (Hussain et al., 2023). Interestingly, azadirachtin's antibacterial properties extend to specific bacterial types, particularly Gram-positive bacteria. Although its antibacterial potential is less evident than its antifungal characteristics, studies have shown minimal action against pathogens including *Staphylococcus aureus* and *Bacillus subtilis* (Mwendwa et al., 2023). However, its true potential rests in its combination use with other antimicrobial drugs.

Azadirachtin, which has been shown to be active against both fungal and bacterial infections, is emerging as a promising chemical. Its traditional use in pest management suggests that it has potential in agricultural applications for managing plant infections, which can indirectly benefit human health by lowering foodborne illnesses. Furthermore, combining azadirachtin with chemicals that have broad-spectrum antibacterial properties, such as curcumin or allicin, could lead to the development of powerful, natural medicinal medicines for treating resistant infections.

16.11. Synergistic effects and dual management potential of medicinal plants

The synergistic effects of combining multiple medicinal plants have emerged as a promising strategy in the management of complex diseases. Synergy occurs when the interaction between bioactive compounds results in an enhanced therapeutic effect greater than the sum of the effects of individual components. This is particularly important in herbal medicine, where the diversity of bioactive compounds can target different biological pathways, improving the overall efficacy of treatment. Many medicinal plants contain compounds like flavonoids, terpenoids, and polyphenols, each with distinct actions. However, when used in combination, these compounds can exert additive or even synergistic effects, providing greater anti-inflammatory, antioxidant, and antimicrobial benefits (Liu et al., 2022; Sapkota et al., 2022). Interestingly, some of the medicinal plants investigated in this study, provide a unique advantage by offering dual benefits, addressing both obesity and infectious diseases simultaneously. These plants are rich in bioactive compounds that not only aid in weight management but also possess antimicrobial properties, making them highly valuable for holistic disease management. For example, *Curcuma longa* (Turmeric) is a well-known medicinal plant due to its active compound, curcumin as discussed earlier. Curcumin is highly effective in managing obesity through its ability to activate AMP-activated protein kinase (AMPK), a crucial enzyme that promotes fat oxidation and regulates energy balance. At the same time, curcumin's potent anti-inflammatory properties can reduce levels of pro-inflammatory cytokines, such as TNF-α and IL-6, which are often elevated in both obesity and infectious diseases. Moreover, curcumin has demonstrated antimicrobial effects, effectively combating bacterial, viral, and fungal infections, making it a powerful dual-action agent in managing both conditions (Zheng et al., 2020; Varì et al., 2021; Hussain et al., 2023). *Zingiber officinale* (Ginger) is another plant with significant dual benefits. The active compounds in ginger, particularly gingerols, play a critical role in lipid metabolism, helping to prevent fat accumulation and improve insulin sensitivity. This makes ginger effective for managing obesity. Additionally, ginger's strong antimicrobial properties have been widely studied, with evidence showing its ability to inhibit the growth of pathogens such as *Escherichia coli* and *Helicobacter pylori*, further supporting its use in the management of infectious diseases. More so, the combination of its metabolic and antimicrobial effects makes ginger a versatile agent for addressing both obesity and infections simultaneously (Seo et al., 2021; Hughes et al., 2021; Dos Santos et al., 2023). *Camellia sinensis* (Green Tea) is also rich in catechins, particularly EGCG, which has been shown to boost thermogenesis and enhance fat oxidation, thereby aiding in weight loss. Furthermore, green tea exhibits notable antimicrobial properties. Studies have demonstrated its ability to inhibit the growth of various bacteria, including *Streptococcus mutans*, and its antiviral effects against influenza viruses. These combined properties of green tea make it an excellent candidate for managing obesity while simultaneously offering protection against infectious agents (Batta, 2020; Gao et al., 2021; Moslemifard et al., 2020; Lin et al., 2020). Additionally, *Allium sativum* (Garlic) is widely recognized for its primary bioactive compound, allicin, which exhibits potent antimicrobial properties. Allicin has been shown to combat a wide range of pathogens, including bacteria, viruses, and fungi. Beyond its antimicrobial role, garlic's ability to improve metabolic parameters such as cholesterol levels and blood pressure links it closely to obesity management. More importantly, garlic's dual action in modulating both metabolic and immune responses enhance its potential as a comprehensive therapeutic agent for both obesity and infectious diseases (Anaeigoudari et al., 2021; El-Saber Batiha et al., 2020; Sheppard et al., 2018; Shi et al., 2019). *Nigella sativa* (Black Seed) contains thymoquinone, a bioactive compound with dual-action benefits. Thymoquinone has been found to improve lipid profiles and reduce body weight by enhancing insulin sensitivity, which is critical in the management of obesity. Thymoquinone also demonstrates broad-spectrum antimicrobial activity, effectively inhibiting pathogens such as *Staphylococcus aureus* and viruses like hepatitis C. These properties make *Nigella sativa* a promising candidate for addressing both metabolic disorders and infectious diseases, offering a natural and holistic approach to treatment (Fatima Shad et al., 2021; Habib et al., 2020). Furthermore, *Moringa oleifera* (Drumstick Tree) is another plant known for its rich antioxidant profile, particularly quercetin and chlorogenic acid, both of which have been shown to promote fat reduction and improve glucose metabolism. At the same time, *Moringa oleifera* has demonstrated strong antimicrobial properties against pathogens such as Escherichia coli and Salmonella. These dual properties make it an effective plant for managing obesity-related complications as well as combating infections, highlighting its value in integrative therapy (Redha et al., 2021; Adji et al., 2022). In addition, *Panax ginseng* (Ginseng) stands out due to its active components known as ginsenosides, which are effective in enhancing fat oxidation and improving insulin sensitivity, thus promoting weight loss. Moreover, ginseng has been extensively studied for its immunomodulatory effects, helping to bolster the immune system against infections, particularly respiratory infections. Its role in both enhancing metabolic health and strengthening the body's defense mechanisms makes it a valuable plant for dual management of obesity and infectious diseases (Ghosh et al., 2020; Valdés-González et al., 2023; You et al., 2022).

17. Conclusion

Medicinal plants present a promising complementary solution for managing both obesity and infectious diseases. Their ability to target multiple biological pathways with lower toxicity than synthetic drugs positions them as valuable adjuncts in modern healthcare. This review has explored the dual role of medicinal plants in managing both obesity and infectious diseases, focusing on bioactive compounds like curcumin, gingerols, allicin, and others. These compounds exhibit diverse mechanisms, such as enhancing fat metabolism, suppressing appetite, regulating insulin sensitivity, and reducing inflammation, all of which contribute to weight management. Additionally, their potent antimicrobial properties have been demonstrated through the inhibition of bacterial, fungal, and viral growth, making them effective against pathogens like *Escherichia coli*, *Candida albicans*, and *Staphylococcus aureus*. The combined use of these plants has shown synergistic effects, amplifying their therapeutic potential. As interest in integrative medicine grows, the natural and sustainable qualities of these plants could play a vital role in developing holistic health strategies. However, more clinical trials are necessary to validate their efficacy and optimize their use in therapeutic settings, particularly in combating drug-resistant infections and chronic diseases. With further research, medicinal plants could become essential components in addressing complex health challenges.

CRediT authorship contribution statement

Ezichi Favour Ofoezie: Writing – review & editing, Writing – original draft, Methodology, Conceptualization. **Chinwendu Angela Ogbonna:** Supervision, Investigation. **Ezinne Tiffany George:** Writing – original draft, Validation. **Chioma Juliet Anunobi:** Writing – review & editing, Investigation. **Sandra C. Olisakwe:** Writing – review & editing. **Simeon Babarinde:** Writing – review & editing, Project administration. **Chidera Godson Chukwuemeka:** Writing – review & editing, Resources. **Uzochukwu Eric Ogbonna:** Software, Resources. **Chibuzo Collette Amafili:** Writing – review & editing, Visualization, Resources. **Justina Onyinyechi Omaba:** Project administration. **Henry Nnaemeka Ogbonna:** Writing – original draft, Visualization, Supervision, Software.

Funding sources

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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.

References

Adji, A.S., Atika, N., Kusbijantoro, Y.B., Billah, A., Putri, A., Handajani, F., 2022. A review of leaves and seeds Moringa oleifera extract: the potential Moringa oleifera as antibacterial, anti-inflammatory, antidiarrhoeal, and antiulcer approaches to bacterial gastroenteritis. Open Access Macedonian J. Med. Sci. 10 (F), 305–313. https://doi.org/10.3889/oamjms.2022.8894.

Agharazi, M., Gazerani, S., Huntington, M.K., 2022. Topical turmeric ointment in the treatment of diabetic foot ulcers: a randomized, placebo-controlled study. Int. J. Low. Extrem. Wounds, 15347346221143222. https://doi.org/10.1177/15347346221143222. Advance online publication.

Ahda, M., Jaswir, I., Khatib, A., Ahmed, Q.U., Syed Mohamad, S.N.A., 2023. *A review on Cosmos caudatus* as A potential medicinal plant based on pharmacognosy, phytochemistry, and pharmacological activities. Int. J. Food Prop. 26 (1), 344–358. https://doi.org/10.1080/10942912.2022.2158862.

Ahmad, N., Khali d, M.S., Khan, M.F., Ullah, Z., 2023. Beneficial effects of topical 6-gingerol loaded nanoemulsion gel for wound and inflammation management with their comparative dermatokinetic. J. Drug Deliv. Sci. Technol. 80, 104094. https://doi.org/10.1016/j.jddst.2022.104094.

Akermi, S., Smaoui, S., Fourati, M., Elhadef, K., Chaari, M., Chakchouk Mtibaa, A., Mellouli, L., 2022. In-depth study of *Thymus vulgaris* essential oil: towards understanding the antibacterial target mechanism and toxicological and pharmacological aspects. BioMed Res. Int., 3368883 https://doi.org/10.1155/2022/3368883, 2022.

Alasmari, K.M., Zeid, I.M.A., Al-Attar, A.M., 2020. Medicinal properties of Arabica coffee (Coffea arabica) oil: an Overview. Adv. Life Sci. 8 (1), 20–29. https://doi.org/10.62940/als.v8i1.1024.

Ali, M.Y., Sina, A.A., Khandker, S.S., Neesa, L., Tanvir, E.M., Kabir, A., Khalil, M.I., Gan, S.H., 2020. Nutritional composition and bioactive compounds in tomatoes and their impact on human health and disease: a review. Foods 10 (1), 45. https://doi.org/10.3390/foods10010045.

Alobaida, M., Alrumayh, A., Oguntade, A.S., Al-Amodi, F., Bwalya, M., 2021. Cardiovascular safety and superiority of anti-obesity medications. Diabetes, Metab. Syndrome Obes. Targets Ther. 14, 3199–3208. https://doi.org/10.2147/DMSO.S311359.

Altayb, H.N., Yassin, N.F., Hosawi, S., et al., 2022. *In-vitro* and *in-silico* antibacterial activity of *Azadirachta indica* (Neem), methanolic extract, and identification of Beta.d-Mannofuranoside as a promising antibacterial agent. BMC Plant Biol. 22, 262. https://doi.org/10.1186/s12870-022-03650-5.

Alves, D., Cerqueira, M.A., Pastrana, L.M., Sillankorva, S., 2020. Entrapment of a phage cocktail and cinnamaldehyde on sodium alginate emulsion-based films to fight food contamination by Escherichia coli and Salmonella Enteritidis. Food Res. Int. 128, 108791. https://doi.org/10.1016/j.foodres.2019.108791.

Amini, M.R., Salavatizadeh, M., Kazeminejad, S., Javadi, F., Hajiaqaei, M., Askari, G., Hekmatdoost, A., 2024. The effects of Garcinia cambogia (hydroxycitric acid) on serum leptin concentrations: a systematic review and meta-analysis of randomized controlled trials. Compl. Ther. Med., 103060 https://doi.org/10.1016/j.ctim.2024.103060.

Anaeigoudari, A., Safari, H., Khazdair, M.R., 2021. Effects of *Nigella sativa, Camellia sinensis*, and *Allium sativum* as food additives on metabolic disorders, a literature review. Front. Pharmacol. 12, 762182. https://doi.org/10.3389/fphar.2021.762182.

Ansari, B., Behl, T., Pirzada, A.S., Khan, H., 2022. *Caralluma edulis* (Apocynaceae): a comprehensive review on its traditional uses, phytochemical profile and pharmacological effects. Curr. Top. Med. Chem. 22 (18), 1501–1514. https://doi.org/10.2174/1568026622666220527092825.

Anwar, R., Rabail, R., Rakha, A., Bryla, M., Roszko, M., Aadil, R.M., Kieliszek, M., 2022. Delving the role of *Caralluma fimbriata*: an edible wild plant to mitigate the biomarkers of metabolic syndrome. Oxid. Med. Cell. Longev. 2022, 5720372. https://doi.org/10.1155/2022/5720372.

Anwar, Rimsha, Rabail, Roshina, Rakha, Allah, Bryla, Marcin, Roszko, Marek, Aadil, Rana Muhammad, Kieliszek, Marek, 2022. Delving the role of Caralluma fimbriata: an edible wild plant to mitigate the biomarkers of metabolic syndrome. Oxid. Med. Cell. Longev. 17, 5720372. https://doi.org/10.1155/2022/5720372, 2022.

Aslan, M.N., Sukan-Karaçağıl, B., Acar-Tek, N., 2024. Roles of citrus fruits on energy expenditure, body weight management, and metabolic biomarkers: a comprehensive review. Nutr. Rev. 82 (9), 1292–1307. https://doi.org/10.1093/nutrit/nuad116.

Aziz, M.A., Millat, M.S., Akter, T., Hossain, M.S., Islam, M.M., Mohsin, S., et al., 2023. A comprehensive review on clinically proven medicinal plants in the treatment of overweight and obesity, with mechanistic insights. Heliyon 9 (2), e13493. https://doi.org/10.1016/j.heliyon.2023.e13493.

Azlan, A., Sultana, S., Huei, C.S., Razman, M.R., 2022. Antioxidant, anti-obesity, nutritional and other beneficial effects of different chili pepper: a review. Molecules 27 (3), 898. https://doi.org/10.3390/molecules27030898.

Babalola, O.O., Iwaloye, O., Ottu, P.O., Aturamu, P.O., Olawale, F., 2024. Biological activities of African medicinal plants in the treatment of erectile dysfunction: a mechanistic perspective. Horm. Mol. Biol. Clin. Invest. 44 (4), 357–370. https://doi.org/10.1515/hmbci-2022-0090.

Bai, J., Li, J., Chen, Z., Bai, X., Yang, Z., Wang, Z., Yang, Y., 2023. Antibacterial activity and mechanism of clove essential oil against foodborne pathogens. Lwt 173, 114249. https://doi.org/10.1016/j.lwt.2022.114249.

Balkrishna, A., Sharma, S., Maity, M., Tomer, M., Singh, R., Gohel, V., Dev, R., Sinha, S., Varshney, A., 2023. Divya-WeightGo combined with moderate aerobic exercise remediates adiposopathy, insulin resistance, serum biomarkers, and hepatic lipid accumulation in high-fat diet-induced obese mice. Biomed. pharmacother. 163, 114785. https://doi.org/10.1016/j.biopha.2023.114785.

Barrio-Pujante, A., Bleriot, I., Blasco, L., Fernández-Garcia, L., Pacios, O., Ortiz-Cartagena, C., Cuenca, F.F., Oteo-Iglesias, J., Tomás, M., 2024. Regulation of anti-phage defense mechanisms by using cinnamaldehyde as a quorum sensing inhibitor. Front. Microbiol. 15, 1416628. https://doi.org/10.3389/fmicb.2024.1416628.

Basu, T., Selman, A., Reddy, A.P., Reddy, P.H., 2023. Current status of obesity: protective role of catechins. Antioxidants 12 (2), 474. https://doi.org/10.3390/antiox12020Biomed.Pharmacother.474.

Batiha, G.E., Teibo, J.O., Shaheen, H.M., Babalola, B.A., Teibo, T.K.A., Al-Kuraishy, H.M., Al-Garbeeb, A.I., Alexiou, A., Papadakis, M., 2024. Therapeutic potential of Lawsonia inermis Linn: a comprehensive overview. N. Schmied. Arch. Pharmacol. 397 (6), 3525–3540. https://doi.org/10.1007/s00210-023-02735-8.

Batta, A., 2020. Green tea treats and prevents infectious diseases. Sch. Int J. Biochem 3 (10), 211–214. https://doi.org/10.36348/sijb.2020.v03i10.002.

Bezerra, S.R., Bezerra, A.H., de Sousa Silveira, Z., Macedo, N.S., Dos Santos Barbosa, C. R., Muniz, D.F., Sampaio Dos Santos, J.F., Melo Coutinho, H.D., Bezerra da Cunha, F. A., 2022. Antibacterial activity of eugenol on the IS-58 strain of Staphylococcus aureus resistant to tetracycline and toxicity in Drosophila melanogaster. Microb. Pathog. 164, 105456. https://doi.org/10.1016/j.micpath.2022.105456.

Bhaskar, A., Kumari, A., Singh, M., Kumar, S., Kumar, S., Dabla, A., Chaturvedi, S., Yadav, V., Chattopadhyay, D., Prakash Dwivedi, V., 2020. [6]-Gingerol exhibits potent anti-mycobacterial and immunomodulatory activity against tuberculosis. Int. Immunopharmacol. 87, 106809. https://doi.org/10.1016/j.intimp.2020.106809.

Bhattacharyya, S., 2021. Herbal, nutritional, and traditional remedies for giardiasis: phytochemicals as drug candidates. Neglected Tropical Diseases and Phytochemicals in Drug Discovery 135–169. https://doi.org/10.1002/9781119617143.ch4.

Bosch-Sierra, N., Marqués-Cardete, R., Gurrea-Martínez, A., Grau-Del Valle, C., Morillas, C., Hernández-Mijares, A., Bañuls, C., 2019. Effect of fibre-enriched orange juice on postprandial glycaemic response and satiety in healthy individuals: an acute, randomised, placebo-controlled, double-blind, crossover study. Nutrients 11 (12), 3014. https://doi.org/10.3390/nu11123014.

Brown, L., 2023. Dietary supplements claimed to aid in weight loss. SA Pharmacist's Assist. 23 (3), 27–30.

Cardile, V., Graziano, A.C., Venditti, A., 2015. Clinical evaluation of Moro (Citrus sinensis (L.) Osbeck) orange juice supplementation for the weight management. Nat. Prod. Res. 29 (23), 2256–2260. https://doi.org/10.1080/14786419.2014.1000897.

Chakhtoura, M., Haber, R., Ghezzawi, M., Rhayem, C., Tcheroyan, R., Mantzoros, C.S., 2023. Pharmacotherapy of obesity: an update on the available medications and drugs under investigation. EClinicalMed. 58, 101882. https://doi.org/10.1016/j.eclinm.2023.101882.

Chen, Y., Wu, R., Chen, W., Liu, Y., Liao, X., Zeng, B., et al., 2021. Curcumin prevents obesity by targeting TRAF4-induced ubiquitylation in m6A-dependent manner. EMBO Rep. 22 (5), e52146. https://doi.org/10.15252/embr.202052146.

Chen, X., Liu, P., Luo, X., Huang, A., Wang, G., 2024. Study on the antibacterial activity and mechanism of Cinnamaldehyde against Methicillin-resistant Staphylococcus aureus. Eur. Food Res. Technol. 250 (4), 1069–1081. https://doi.org/10.1007/s00217-023-04446-z.

Coimbra, A., Carvalho, F., Duarte, A.P., Ferreira, S., 2022. Antimicrobial activity of Thymus zygis essential oil against Listeria monocytogenes and its application as food preservative. Innov. Food Sci. Emerg. Technol. 80, 103077. https://doi.org/10.1016/j.ifset.2022.103077.

Cui, X.D., Liu, X.K., Ma, X.Y., Li, S.H., Zhang, J.K., Han, R.J., et al., 2024. Restoring colistin sensitivity in colistin-resistant Salmonella and Escherichia coli: combinatorial use of berberine and EDTA with colistin. mSphere e00182–24. https://doi.org/10.1128/msphere.00182-24.

da Silva, T.N., Cardoso, S.A., Barradas, T.N., 2022. Nanostructured pharmaceutical formulations for topical application of clove oil and eugenol. In: Clove (Syzygium Aromaticum). Academic Press, pp. 363–403. https://doi.org/10.1016/B978-0-323-85177-0.00019-7.

Davkova, I., Zhivikj, Z., Kukić-Marković, J., Karanfilova, I.C., Stefkov, G., Kulevanova, S., Karapandzova, M., 2024. Natural products in the management of obesity. Arch. Pharm. (Weinh.) 74 (Notebook 3), 298–315. https://doi.org/10.5937/arhfarm74-50438.

de Andrade Neto, J.B., de Farias Cabral, V.P., Nogueira, L.F.B., da Silva, C.R., Sa, L.G.D. A.V., da Silva, A.R., et al., 2021. Anti-MRSA activity of curcumin in planktonic cells and biofilms and determination of possible action mechanisms. Microb. Pathog. 155, 104892. https://doi.org/10.1016/j.micpath.2021.104892.

de Castro e Silva, P., Pereira, L.A.S., de Rezende, É.M., dos Reis, M.V., Lago, A.M.T., Carvalho, G.R., et al., 2019. Production and efficacy of neem nanoemulsion in the control of Aspergillus flavus and Penicillium citrinum in soybean seeds. Eur. J. Plant Pathol. 155 (4), 1105–1116. https://doi.org/10.1007/s10658-019-01838-4.

Dehghani, S., Dalirfardouei, R., Jafari Najaf Abadi, M.H., Ebrahimi Nik, M., Jaafari, M.R., Mahdipour, E., 2020. Topical application of curcumin regulates the angiogenesis in diabetic-impaired cutaneous wound. Cell Biochem. Funct. 38 (5), 558–566. https://doi.org/10.1002/cbf.3500.

del Río-Celestino, M., Font, R., 2020. The health benefits of fruits and vegetables. Foods 9 (3), 369. https://doi.org/10.3390/foods9030369.

Díaz-de-Cerio, E., Rodríguez-Nogales, A., Algieri, F., Romero, M., Verardo, V., Segura-Carretero, A., Duarte, J., Galvez, J., 2017. The hypoglycemic effects of guava leaf (Psidium guajava L.) extract are associated with improving endothelial dysfunction in mice with diet-induced obesity. Food Res. Int. 96, 64–71. https://doi.org/10.1016/j.foodres.2017.03.019.

Didehdar, M., Chegini, Z., Shariati, A., 2022. Eugenol: a novel therapeutic agent for the inhibition of Candida species infection. Front. Pharmacol. 13, 872127. https://doi.org/10.3389/fphar.2022.872127.

Dilokthornsakul, P., Rattanachaisit, N., Thimkorn, P., Pongpattanawut, S., Dilokthornsakul, W., Dhippayom, T., 2024. Clinical effects of Hibiscus sabdariffa Linn. on obesity treatment: a systematic review and meta-analysis of randomized controlled trials. Compl. Ther. Med., 103063 https://doi.org/10.1016/j.ctim.2024.103063.

Donma, M.M., Donma, O., 2020. The effects of allium sativum on immunity within the scope of COVID-19 infection. Med. Hypotheses 144, 109934. https://doi.org/10.1016/j.mehy.2020.109934.

Dos Santos, E.A.R., Tadielo, L.E., Schmiedt, J.A., Possebon, F.S., Pereira, M.O., Pereira, J. G., dos Santos Bersot, L., 2023. Effect of ginger essential oil and 6-gingerol on a multispecies biofilm of Listeria monocytogenes, Salmonella Typhimurium, and Pseudomonas aeruginosa. Braz. J. Microbiol. 54 (4), 3041–3049. https://doi.org/10.1007/s42770-023-01075-2.

Duranova, H., Valkova, V., Gabriny, L., 2022. Chili peppers (Capsicum spp.): the spice not only for cuisine purposes: an update on current knowledge. Phytochem. Rev. 21 (4), 1379–1413. https://doi.org/10.1007/s11101-021-09789-7.

El-Gendy, Y.A., Hadad, G., Abo-El-Matty, D., Ramadan, A., 2024. Biochemical evaluation of some compounds used for treatment of obesity. Records Pharmaceut. Biomed. Sci. 8 (1), 106–122. https://doi.org/10.21608/rpbs.2024.367914.

El-Saadony, M.T., Zabermawi, N.M., Zabermawi, N.M., Burollus, M.A., Shafi, M.E., Alagawany, M., et al., 2021. Nutritional aspects and health benefits of bioactive plant compounds against infectious diseases: a review. Food Rev. Int. 39 (4), 2138–2160. https://doi.org/10.1080/87559129.2021.1944183.

El-Saber Batiha, G., Magdy Beshbishy, A.G., Wasef, L., Elewa, Y.H., Al-Sagan A, A., Abd El-Hack, M.E., et al., 2020. Chemical constituents and pharmacological activities of garlic (Allium sativum L.): a review. Nutrients 12 (3), 872. https://doi.org/10.3390/nu12030872.

Escobar, A., Perez, M., Romanelli, G., Blustein, G., 2020. Thymol bioactivity: a review focusing on practical applications. Arab. J. Chem. 13 (12), 9243–9269. https://doi.org/10.1016/j.arabjc.2020.11.009.

Faria, A., Pereira-Wilson, C., Negrão, R., 2020. The Relevance of Polyphenols in Obesity Therapy. MONTEIRO, ROSÁRIO.; MARTINS, MARIA JOÃO. Understanding Obesity: from its Causes to Impact on Life. Bentham Books imprint, Porto, pp. 271–307. https://doi.org/10.2174/97898114426361200100l4.

Farooq, M.A., Ali, S., Sulayman, R., Hassan, A., Tahir, H.M., Shahzad, H., et al., 2023. Therapeutic applications of garlic and turmeric for the diabetic wound healing in mice. J. Burn Care Res. 44 (4), 800–809. https://doi.org/10.1093/jbcr/irac169.

Farrag, H.A., Hosny, A.E.D.M., Hawas, A.M., Hagras, S.A., Helmy, O.M., 2019. Potential efficacy of garlic lock therapy in combating biofilm and catheter-associated infections; experimental studies on an animal model with focus on toxicological aspects. Saudi Pharm. J. 27 (6), 830–840. https://doi.org/10.1016/j.jsps.2019.05.004.

Fatima Shad, K., Soubra, W., Cordato, D.J., 2021. The role of thymoquinone, a major constituent of Nigella sativa, in the treatment of inflammatory and infectious diseases. Clin. Exp. Pharmacol. Physiol. 48 (11), 1445–1453. https://doi.org/10.1111/1440-1681.13553.

Firdaus, M.D., Artanti, N., Hanafi, M., 2021. Phytochemical constituents and in vitro antidiabetic and antioxidant properties of various extracts of Kenikir (Cosmos caudatus) leaves. Pharmacogn. J. 13 (4). https://doi.org/10.5530/pj.2021.13.114.

Flores-Maldonado, O., Dávila-Aviña, J., González, G.M., Becerril-García, M.A., Ríos-López, A.L., 2024. Antibacterial activity of gallic acid and methyl gallate against emerging non-fermenting bacilli. Folia Microbiol. 1–9. https://doi.org/10.1007/s12223-024-01182-z.

Fuloria, S., Mehta, J., Chandel, A., Sekar, M., Rani, N.N.I.M., Begum, M.Y., et al., 2022. A comprehensive review on the therapeutic potential of Curcuma longa Linn. in relation to its major active constituent curcumin. Front. Pharmacol. 13, 820806. https://doi.org/10.3389/fphar.2022.820806.

Gao, S., Zhang, S., Zhang, S., 2021. Enhanced in vitro antimicrobial activity of amphotericin B with berberine against dual-species biofilms of Candida albicans and Staphylococcus aureus. J. Appl. Microbiol. 130 (4), 1154–1172. https://doi.org/10.1111/jam.14872.

Garg, S.K., Shukla, A., Choudhury, S., 2021. Green coffee beans. In: Nutraceuticals. Academic Press, pp. 725–748. https://doi.org/10.1016/B978-0-12-821038-3.00042-2.

Gawron-Gzella, A., Chanaj-Kaczmarek, J., Cielecka-Piontek, J., 2021. Yerba mate—a long but current history. Nutrients 13 (11), 3706. https://doi.org/10.3390/nu13113706.

Gerber, T., Nunes, A., Moreira, B.R., Maraschin, M., 2023. Yerba mate (Ilex paraguariensis A. St.-Hil.) for new therapeutic and nutraceutical interventions: a review of patents issued in the last 20 years (2000–2020). Phytother Res. 37 (2), 527–548. https://doi.org/10.1002/ptr.7632.

Ghosh, R., Bryant, D.L., Farone, A.L., 2020. Panax quinquefolius (North American Ginseng) polysaccharides as immunomodulators: current research status and future directions. Molecules 25 (24), 5854. https://doi.org/10.3390/molecules25245854.

Ghosh, S., Manchala, S., Raghunath, M., Sharma, G., Singh, A.K., Sinha, J.K., 2021. Role of phytomolecules in the treatment of obesity: targets, mechanisms and limitations. Curr. Top. Med. Chem. 21 (10), 863–877. https://doi.org/10.2174/1568026621666210305101804.

Ghosh, A., Majumder, S., Samadder, R., Sarkar, S., Nandi, S., Subba, P., et al., 2023. Study of in vitro antioxidant and antibacterial potential of different tea clones. Pharmacol. Res. Modern Chinese Med. 9, 100312. https://doi.org/10.1016/j.prmcm.2023.100312.

Gobin, M., Proust, R., Lack, S., Duciel, L., Des Courtils, C., Pauthe, E., et al., 2022. A combination of the natural molecules gallic acid and carvacrol eradicates P. aeruginosa and S. aureus mature biofilms. Int. J. Mol. Sci. 23 (13), 7118. https://doi.org/10.3390/ijms23137118.

Guan, P., Wang, X., Dong, Z., Song, M., Zhu, H., Suo, B., 2023. Cinnamaldehyde inactivates Listeria monocytogenes at a low temperature in ground pork by disturbing the expression of stress regulatory genes. Food Biosci. 51, 102277. https://doi.org/10.1016/j.fbio.2022.102277.

Gürbüz, M., Korkmaz, B.İ.O., 2022. The anti-campylobacter activity of eugenol and its potential for poultry meat safety: a review. Food Chem. 394, 133519. https://doi.org/10.1016/j.foodchem.2022.133519.

Gutiérrez-Cuevas, J., López-Cifuentes, D., Sandoval-Rodriguez, A., García-Bañuelos, J., Armendariz-Borunda, J., 2024. Medicinal plant extracts against cardiometabolic risk factors associated with obesity: molecular mechanisms and therapeutic targets. Pharmaceuticals 17 (7), 967. https://doi.org/10.3390/ph17070967.

Gwaltney-Brant, S.M., 2021. Nutraceuticals in hepatic diseases. In: Nutraceuticals. Academic Press, pp. 117–129. https://doi.org/10.1016/B978-0-12-821038-3.00008-2.

Habib, M.A., Afroze, M., Islam, M.F., Sajid, M., Chowdhury, A.I., Ahmed, N., 2020. Nigella sativa: a traditional remedy for the prevention of non-communicable and communicable diseases. Sch Int J Tradit Complement Med 3 (7), 149–156. https://doi.org/10.36348/sijtcm.2020.v03i07.004.

Ham, S.Y., Kim, H.S., Jo, M.J., Lee, J.H., Byun, Y., Ko, G.J., Park, H.D., 2021. Combined treatment of 6-gingerol analog and tobramycin for inhibiting Pseudomonas aeruginosa infections. Microbiol. Spectr. 9 (2), e0019221. https://doi.org/10.1128/Spectrum.00192-21.

Hayati, R.F., Better, C.D., Denis, D., Komarudin, A.G., Bowolaksono, A., Yohan, B., Sasmono, R.T., 2021. [6]-Gingerol inhibits chikungunya virus infection by suppressing viral replication. BioMed Res. Int. 2021 (1), 6623400. https://doi.org/10.1155/2021/6623400.

He, L., Su, Z., Wang, S., 2024. The anti-obesity effects of polyphenols: a comprehensive review of molecular mechanisms and signal pathways in regulating adipocytes. Front. Nutr. 11, 1393575. https://doi.org/10.3389/fnut.2024.1393575.

Horowitz, J.R., 2023. Black Garlic Extract as an Antiviral for Herpes Simplex Virus-2 in Lung Cells. https://doi.org/10.4236/abb.2024.151005.

Huang, X., Zheng, M., Yi, Y., Patel, A., Song, Z., Li, Y., 2020. Inhibition of berberine hydrochloride on Candida albicans biofilm formation. Biotechnol. Lett. 42, 2263–2269. https://doi.org/10.1007/s10529-020-02938-6.

Hughes, T., Azim, S., Ahmad, Z., 2021. Inhibition of Escherichia coli ATP synthase by dietary ginger phenolics. Int. J. Biol. Macromol. 182, 2130–2143. https://doi.org/10.1016/j.ijbiomac.2021.05.168.

Hussain, S., Javed, W., Tajammal, A., Khalid, M., Rasool, N., Riaz, M., et al., 2023. Synergistic antibacterial screening of Cymbopogon citratus and Azadirachta indica: phytochemical profiling and antioxidant and hemolytic activities. ACS Omega 8 (19), 16600–16611. https://doi.org/10.1021/acsomega.2c06785.

Islam, A.A., Osman, M.B., Mohamad, M.B., Islam, A.M., 2021. Vegetable mesta (Hibiscus sabdariffa L. var sabdariffa): a potential industrial crop for Southeast Asia. In: Roselle. Academic Press, pp. 25–42. https://doi.org/10.1016/B978-0-323-85213-5.00016-0.

Islam, A.S., Sultana, H., Refat, M.N.H., Farhana, Z., Kamil, A.A., Rahman, M.M., 2024. The global burden of overweight-obesity and its association with economic status, benefiting from STEPs survey of WHO member states: a meta-analysis. Preventive Med. Rep., 102882 https://doi.org/10.1016/j.pmedr.2024.102882.

Izquierdo-Vega, J.A., Arteaga-Badillo, D.A., Sánchez-Gutiérrez, M., Morales-González, J. A., Vargas-Mendoza, N., Gómez-Aldapa, C.A., et al., 2020. Organic acids from Roselle (Hibiscus sabdariffa L.)—a brief review of its pharmacological effects. Biomedicines 8 (5), 100. https://doi.org/10.3390/biomedicines8050100.

Jabczyk, M., Nowak, J., Hudzik, B., Zubelewicz-Szkodzińska, B., 2021. Curcumin and its potential impact on microbiota. Nutrients 13 (6), 2004. https://doi.org/10.3390/nu13062004.

Jafri, H., Ahmad, I., 2020. Thymus vulgaris essential oil and thymol inhibit biofilms and interact synergistically with antifungal drugs against drug resistant strains of Candida albicans and Candida tropicalis. J. Mycol. Med. 30 (1), 100911. https://doi.org/10.1016/j.mycmed.2019.100911.

Jafri, H., Banerjee, G., Khan, M.S.A., Ahmad, I., Abulreesh, H.H., Althubiani, A.S., 2020. Synergistic interaction of eugenol and antimicrobial drugs in eradication of single and mixed biofilms of Candida albicans and Streptococcus mutans. AMB Express 10, 1–9. https://doi.org/10.1186/s13568-020-01123-2.

Janeczko, M., Gmur, D., Kochanowicz, E., Górka, K., Skrzypek, T., 2022. Inhibitory effect of a combination of baicalein and quercetin flavonoids against Candida albicans strains isolated from the female reproductive system. Fungal Biol. 126 (6–7), 407–420. https://doi.org/10.1016/j.funbio.2022.05.002.

Janson, B., Prasomthong, J., Malakul, W., Boonsong, T., Tunsophon, S., 2021. Hibiscus sabdariffa L. calyx extract prevents the adipogenesis of 3T3-L1 adipocytes, and obesity-related insulin resistance in high-fat diet-induced obese rats. Biomed. Pharmacother. 138, 111438. https://doi.org/10.1016/j.biopha.2021.111438.

Jayawardena, R., Francis, T.V., Abhayaratna, S., et al., 2021. The use of *Caralluma fimbriata* as an appetite suppressant and weight loss supplement: a systematic review and meta-analysis of clinical trials. BMC Complement Med. Ther. 21, 279. https://doi.org/10.1186/s12906-021-03450-8.

Jeyakumar, G.E., Lawrence, R., 2021. Mechanisms of bactericidal action of Eugenol against Escherichia coli. J. Herb. Med. 26, 100406. https://doi.org/10.1016/j.hermed.2020.100406.

Jikah, A.N., Edo, G.I., 2023. Mechanisms of action by sulphur compounds in Allium sativum. A review. Pharmacol. Res. Modern Chinese Med., 100323 https://doi.org/10.1016/j.prmcm.2023.100323.

Joshi, M., Prabhakar, B., 2021. Azadirachta indica (neem) in various infectious diseases. Herbal Med.: Back to the Future: Volume 4, Infectious Diseases 4, 128. https://doi.org/10.2174/9789811458712121040007.

Ju, J., Xie, Y., Yu, H., Guo, Y., Cheng, Y., Zhang, R., Yao, W., 2020. Synergistic inhibition effect of citral and eugenol against Aspergillus Niger and their application in bread preservation. Food Chem. 310, 125974. https://doi.org/10.1016/j.foodchem.2019.125974.

Kachur, K., Suntres, Z., 2020. The antibacterial properties of phenolic isomers, carvacrol and thymol. Crit. Rev. Food Sci. Nutr. 60 (18), 3042–3053. https://doi.org/10.1080/10408398.2019.1675585.

Kamelnia, E., Mohebbati, R., Kamelnia, R., El-Seedi, H.R., Boskabady, M.H., 2023. Anti-inflammatory, immunomodulatory and anti-oxidant effects of *Ocimum basilicum* L. and its main constituents: a review. Iranian J. Basic Med. Sci. 26 (6), 617–627. https://doi.org/10.22038/IJBMS.2023.67466.14783.

Kang, Y.M., Kang, H.A., Cominguez, D.C., Kim, S.H., An, H.J., 2021. Papain ameliorates lipid accumulation and inflammation in high-fat diet-induced obesity mice and 3T3-L1 adipocytes via AMPK activation. Int. J. Mol. Sci. 22 (18), 9885. https://doi.org/10.3390/ijms22189885.

Kania-Dobrowolska, M., Baraniak, J., 2022. Dandelion (*Taraxacum officinale* L.) as a source of biologically active compounds supporting the therapy of Co-existing diseases in metabolic syndrome. Foods 11 (18), 2858. https://doi.org/10.3390/foods11182858.

Kannigadu, C., N'Da, D.D., 2021. Recent advances in the synthesis and development of curcumin, its combinations and formulations and curcumin-like compounds as anti-infective agents. Curr. Med. Chem. 28 (27), 5463–5497. https://doi.org/10.2174/0929867328666210111102916.

Kaushik, B., Sharma, J., Kumar, P., Shourie, A., 2021. Phytochemical properties and pharmacological role of plants: secondary metabolites. Biosci. Biotechnol. Res. Asia 18 (1), 23. https://doi.org/10.13005/bbra/2894.

Keyvani-Ghamsari, S., Rahimi, M., Khorsandi, K., 2023. An update on the potential mechanism of gallic acid as an antibacterial and anticancer agent. Food Sci. Nutr. 11 (10), 5856–5872. https://doi.org/10.1002/fsn3.3615.

Khantamat, O., Dukaew, N., Karinchai, J., Chewonarin, T., Pitchakarn, P., Temviriyanukul, P., 2020. Safety and bioactivity assessment of aqueous extract of Thai Henna (*Lawsonia inermis* Linn.) Leaf. J. Toxicol. Environ. Health, Part A 84 (7), 298–312. https://doi.org/10.1080/15287394.2020.1866129.

Khoshi, M.A., Keyvani-Ghamsari, S., Khorsandi, K., 2024. Gallic acid synergistically enhances the antibacterial activity of azithromycin in MRSA. Int. Microbiol. 1–8. https://doi.org/10.1007/s10123-024-00579-7.

Kim, Y.J., Kim, K.Y., Kim, M.S., Lee, J.H., Lee, K.P., Park, T., 2008. A mixture of the aqueous extract of Garcinia cambogia, soy peptide and L: -carnitine reduces the accumulation of visceral fat mass in rats rendered obese by a high fat diet. Gene Nutr. 2 (4), 353–358. https://doi.org/10.1007/s12263-007-0070-1.

Kim, C.H., Kim, J.E., Song, Y.J., 2020. Antiviral activities of quercetin and isoquercitrin against human herpesviruses. Molecules 25 (10), 2379. https://doi.org/10.3390/molecules25102379.

Kim, Y., Kim, S., Cho, K.H., Lee, J.H., Lee, J., 2022a. Antibiofilm activities of cinnamaldehyde analogs against Uropathogenic Escherichia coli and Staphylococcus aureus. Int. J. Mol. Sci. 23 (13), 7225. https://doi.org/10.3390/ijms23137225.

Kim, Y., Kim, S., Cho, K.H., Lee, J.H., Lee, J., 2022b. Antibiofilm activities of cinnamaldehyde analogs against Uropathogenic Escherichia coli and Staphylococcus aureus. Int. J. Mol. Sci. 23 (13), 7225. https://doi.org/10.3390/ijms23137225.

Koo, S.I., Noh, S.K., 2007. Green tea as inhibitor of the intestinal absorption of lipids: potential mechanism for its lipid-lowering effect. J. Nutr. Biochem. 18 (3), 179–183. https://doi.org/10.1016/j.jnutbio.2006.12.005.

Kosalec, I., Jembrek, M.J., Vlainić, J., 2022. The spectrum of berberine antibacterial and antifungal activities. In: Promising Antimicrobials from Natural Products. Springer International Publishing, Cham, pp. 119–132. https://doi.org/10.1007/978-3-030-83504-0_7.

Kosmalski, M., Deska, K., Bąk, B., Różycka-Kosmalska, M., Pietras, T., 2023. Pharmacological support for the treatment of obesity—present and future. Healthcare 11 (3), 433. https://doi.org/10.3390/healthcare1103043.

Kowalczyk, A., Przychodna, M., Sopata, S., Bodalska, A., Fecka, I., 2020. Thymol and thyme essential oil—new insights into selected therapeutic applications. Molecules 25 (18), 4125. https://doi.org/10.3390/molecules25184125.

Kudo, M., Gao, M., Hayashi, M., Kobayashi, Y., Yang, J., Liu, T., 2024. Ilex paraguariensis A. St.-Hil. improves lipid metabolism in high-fat diet-fed obese rats and suppresses intracellular lipid accumulation in 3T3-L1 adipocytes via the AMPK-dependent and insulin signaling pathways. Food Nutr. Res. 68. https://doi.org/10.29219/fnr.v68.10307.

Kumar, M., Tomar, M., Amarowicz, R., Saurabh, V., Nair, M.S., Maheshwari, C., Sasi, M., Prajapati, U., Hasan, M., Singh, S., Changan, S., Prajapat, R.K., Berwal, M.K., Satankar, V., 2021. Guava (*Psidium guajava* L.) leaves: nutritional composition, phytochemical profile, and health-promoting bioactivities. Foods 10 (4), 752. https://doi.org/10.3390/foods10040752.

Kumar, M., Kaushik, D., Kaur, J., Proestos, C., Oz, F., Oz, E., et al., 2022. A critical review on obesity: herbal approach, bioactive compounds, and their mechanism. Appl. Sci. 12 (16), 8342. https://doi.org/10.3390/app12168342.

Kumar, G., Rajula, M.P., Rao, K.S., Ravishankar, P.L., Albar, D.H., Bahammam, M.A., et al., 2023. Antimicrobial efficacy of blended essential oil and chlorhexidine against periodontal pathogen (P. gingivalis)–An in vitro study. Niger. J. Clin. Pract. 26 (5), 625–629. https://doi.org/10.4103/njcp.njcp_787_22.

Laleman, I., Teughels, W., 2020. Novel natural product-based oral topical rinses and toothpastes to prevent periodontal diseases. Periodontology 84 (1), 102–123. https://doi.org/10.1111/prd.12339, 2000.

Lan, C., Sun, J., Zhao, B., 2023. Origin, history and species of tea. In: Tea Polyphenols, Oxidative Stress and Health Effects (In 2 Volumes), vol. 1.

Lee, M.S., Shin, Y., Jung, S., Kim, Y., 2017. Effects of epigallocatechin-3-gallate on thermogenesis and mitochondrial biogenesis in brown adipose tissues of diet-induced obese mice. Food Nutr. Res. 61 (1), 1325307. https://doi.org/10.1080/16546628.2017.1325307.

Lee, J.H., Kim, Y.G., Choi, P., Ham, J., Park, J.G., Lee, J., 2018. Antibiofilm and antivirulence activities of 6-gingerol and 6-shogaol against Candida albicans due to hyphal inhibition. Front. Cell. Infect. Microbiol. 8, 299. https://doi.org/10.3389/fcimb.2018.00299.

Lee, Y.S., Chen, X., Widiyanto, T.W., Orihara, K., Shibata, H., Kajiwara, S., 2022. Curcumin affects function of Hsp90 and drug efflux pump of Candida albicans. Front. Cell. Infect. Microbiol. 12, 944611. https://doi.org/10.3389/fcimb.2022.944611.

Leferman, C.E., Stoica, L., Tiglis, M., Stoica, B.A., Hancianu, M., Ciubotaru, A.D., et al., 2023. Overcoming drug resistance in a clinical C. albicans strain using photoactivated curcumin as an adjuvant. Antibiotics 12 (8), 1230. https://doi.org/10.3390/antibiotics12081230.

Li, X., Song, Y., Wang, L., Kang, G., Wang, P., Yin, H., Huang, H., 2021. A potential combination therapy of berberine hydrochloride with antibiotics against multidrug-resistant Acinetobacter baumannii. Front. Cell. Infect. Microbiol. 11, 660431. https://doi.org/10.3389/fcimb.2021.660431.

Li, S., You, J., Wang, Z., Liu, Y., Wang, B., Du, M., Zou, T., 2021. Curcumin alleviates high-fat diet-induced hepatic steatosis and obesity in association with modulation of gut microbiota in mice. Food Res. Int. 143, 110270. https://doi.org/10.1016/j.foodres.2021.110270.

Li, S., Zhou, S., Yang, Q., Liu, Y., Yang, Y., Xu, N., et al., 2023. Cinnamaldehyde decreases the pathogenesis of Aeromonas hydrophila by inhibiting quorum sensing and biofilm formation. Fishes 8 (3), 122. https://doi.org/10.3390/fishes8030122.

Li, J., Lu, T., Chu, Y., Zhang, Y., Zhang, J., Fu, W., et al., 2024. Cinnamaldehyde targets SarA to enhance β-lactam antibiotic activity against methicillin-resistant Staphylococcus aureus. Mlife 3 (2), 291–306. https://doi.org/10.1002/mlf2.12121.

Liang, S., Hu, X., Wang, R., Fang, M., Yu, Y., Xiao, X., 2022. The combination of thymol and cinnamaldehyde reduces the survival and virulence of Listeria monocytogenes on autoclaved chicken breast. J. Appl. Microbiol. 132 (5), 3937–3950. https://doi.org/10.1111/jam.15496.

Liberato, I., Lino, L.A., Souza, J.K., Neto, J.B., Sá, L.G., Cabral, V.P., et al., 2022. Gallic acid leads to cell death of Candida albicans by the apoptosis mechanism. Future Microbiol. 17 (8), 599–606. https://doi.org/10.2217/fmb-2021-0139.

Lin, Y.C., Lu, H.F., Chen, J.C., Huang, H.C., Chen, Y.H., Su, Y.S., et al., 2020. Purple-leaf tea (Camellia sinensis L.) ameliorates high-fat diet induced obesity and metabolic disorder through the modulation of the gut microbiota in mice. BMC complementary Med. Therapies 20, 1–12. https://doi.org/10.1186/s12906-020-03171-4.

Liu, T., Kang, J., Liu, L., 2021. Thymol as a critical component of Thymus vulgaris L. essential oil combats Pseudomonas aeruginosa by intercalating DNA and inactivating biofilm. Lwt 136, 110354. https://doi.org/10.1016/j.lwt.2020.110354.

Liu, Y., Liu, C., Kou, X., Wang, Y., Yu, Y., Zhen, N., et al., 2022. Synergistic hypolipidemic effects and mechanisms of phytochemicals: a review. Foods 11 (18), 2774. https://doi.org/10.3390/foods11182774.

López-Ortega, O., Moreno-Corona, N.C., Cruz-Holguin, V.J., Garcia-Gonzalez, L.D., Helguera-Repetto, A.C., Romero-Valdovinos, M., et al., 2022. The immune response in adipocytes and their susceptibility to infection: a possible relationship with infectobesity. Int. J. Mol. Sci. 23 (11), 6154. https://doi.org/10.3390/ijms23116154.

Lu, M., Chen, C., Lan, Y., Xiao, J., Li, R., Huang, J., et al., 2020. Capsaicin—the major bioactive ingredient of chili peppers: bio-efficacy and delivery systems. Food Funct. 11 (4), 2848–2860. https://doi.org/10.1039/d0fo00351d.

Magryś, A., Olender, A., Tchórzewska, D., 2021. Antibacterial properties of *Allium sativum* L. against the most emerging multidrug-resistant bacteria and its synergy with antibiotics. Arch. Microbiol. 203, 2257–2268. https://doi.org/10.1007/s00203-021-02248-z.

Maiztegui, B., Villagarcía, H.G., Román, C.L., Flores, L.E., Prieto, J.M., Castro, M.C., Massa, M.L., Schinella, G.R., Francini, F., 2023. Dietary supplementation with Yerba mate (*Ilex paraguariensis*) infusion increases IRS-1 and PI3K mRNA levels and enhances insulin sensitivity and secretion in rat pancreatic islets. Plants 12 (14), 2620. https://doi.org/10.3390/plants12142620.

Marín-Palma, D., Tabares-Guevara, J.H., Zapata-Cardona, M.I., Flórez-Álvarez, L., Yepes, L.M., Rugeles, M.T., Zapata-Builes, W., Hernandez, J.C., Taborda, N.A., 2021. Curcumin inhibits in vitro SARS-CoV-2 infection in vero E6 cells through multiple antiviral mechanisms. Molecules 26 (22), 6900. https://doi.org/10.3390/molecules26226900.

Martínez, A., Manrique-Moreno, M., Klaiss-Luna, M.C., Stashenko, E., Zafra, G., Ortiz, C., 2021. Effect of essential oils on growth inhibition, biofilm formation and membrane integrity of Escherichia coli and Staphylococcus aureus. Antibiotics 10 (12), 1474. https://doi.org/10.3390/antibiotics10121474.

Mazumder, T., Mamun, I.P., Zaman, M.S., Islam, A.K.M.K., Chowdhury, S., Reza, M.S., Hussain, M.S., 2021. Comparative lipid and uric acid suppressing properties of four common herbs in high fat-induced obese mice with their total phenolic and flavonoid index. Biochem. Biophys. Rep. 26, 100990. https://doi.org/10.1016/j.bbrep.2021.100990.

Meng, J., Ding, J., Wang, W., Gu, B., Zhou, F., Wu, D., et al., 2024. Reversal of gentamicin sulfate resistance in avian pathogenic Escherichia coli by matrine combined with berberine hydrochloride. Arch. Microbiol. 206 (7), 292. https://doi.org/10.1007/s00203-024-04021-4.

Mi, J., Wu, X., Liang, J., 2024. The advances in adjuvant therapy for tuberculosis with immunoregulatory compounds. Front. Microbiol. 15, 1380848. https://doi.org/10.3389/fmicb.2024.1380848.

Mohajan, D., Mohajan, H.K., 2023. Obesity and its related diseases: a new escalating alarming in global health. J. Innov. Med. Res. 2 (3), 12–23. https://doi.org/10.56397/JIMR/2023.03.04.

Mohamed, H.M., Abd El-Twab, S.M., 2016. Gallic acid attenuates chromium-induced thyroid dysfunction by modulating antioxidant status and inflammatory cytokines. Environ. Toxicol. Pharmacol. 48, 225–236. https://doi.org/10.1016/j.etap.2016.08.019.

Moradi, M.S., Kamkar, S., Sharifzadeh, A., Hassan, J., Shokri, H., Abbasi, J., 2024. The in vitro effect of berberine sulfate and berberine chloride on the growth and aflatoxin production by Aspergillus flavus and Aspergillus parasiticus. Iran. J. Vet. Med. 18 (2), 223–232. https://doi.org/10.32598/IJVM.18.2.1005399.

Moshawih, S., Cheema, M.S., Ahmad, Z., Zakaria, Z.A., Hakim, M.N., 2017. A comprehensive review on Cosmos caudatus (Ulam raja): pharmacology, ethnopharmacology, and phytochemistry. Int. Res. J. Edu. Sci. 1 (1), 14–31.

Moslemifard, M., Ghadimi, R., Kamalinejad, M., Shirafkan, H., Mozaffarpur, S.A., 2020. Hospital diet for COVID-19, an acute respiratory infectious disease: an evidence-based Protocol of a Clinical Trial. Caspian J. Intern. Med. 11 (Suppl. 1), 466. https://doi.org/10.22088/cjim.11.0.466.

Moutawalli, A., Benkhouili, F.Z., Doukkali, A., Benzeid, H., Zahidi, A., 2023. The biological and pharmacologic actions of Lawsonia inermis L. Phytomedicine 3 (3), 100468. https://doi.org/10.1016/j.phyplu.2023.100468.

Murtadlo, A.A.A., Ansori, A.N.M., Kharisma, V.D., 2024. A mini review of Curcuma longa: antimicrobial properties. J. Med. Chem. Sci. 7 (1), 215–221. https://doi.org/10.26655/JMCHEMSCI.2024.1.20.

Murugesu, S., Perumal, V., Balan, T., Fatinathan, S., Selvarajoo, P.D., Rozali, M.A.B., Aziz, N.I.A., 2020. A review of Cosmos caudatus as A promising antidiabetic plant. Malaysian J. Med. Health Sci. 16 (4).

Mwendwa, P.K., Karanja, A.W., Maingi, J.M., 2023. Endophytic Bacillus aerophilus from the leaves of Azadirachta indica as a potential biocontrol against Staphylococcus aureus. J. Adv. Microbiol. 23 (10), 116–127. https://doi.org/10.9734/jamb/2023/v23i10762.

Nakasugi, L.P., Silva Bomfim, N., Romoli, J.C.Z., Botião Nerilo, S., Veronezi Silva, M., Rocha Oliveira, G.H., Machinski, Jr M., 2021. Antifungal and antiaflatoxigenic activities of thymol and carvacrol against Aspergillus flavus. Saúde e Pesquisa 14 (1). https://doi.org/10.17765/2176-9206.2021v14n1.e7727.

Nandi, T., Khanna, M., 2022. Anti-viral activity of thymol against influenza A virus. EC Microbiology 18, 98–103.

Negi, H., Gupta, M., Walia, R., Khataibeh, M., Sarwat, M., 2021. Medicinal plants and natural products: more effective and safer pharmacological treatment for the management of obesity. Curr. Drug Metabol. 22 (12), 918–930. https://doi.org/10.2174/1389200222666210729114456.

Nguyen, T.L.A., Bhattacharya, D., 2022. Antimicrobial activity of quercetin: an approach to its mechanistic principle. Molecules 27 (8), 2494. https://doi.org/10.3390/molecules27082494.

Nisar, M.F., Khadim, M., Rafiq, M., Chen, J., Yang, Y., Wan, C.C., 2021. Pharmacological properties and health benefits of eugenol: a comprehensive review. Oxid. Med. Cell. Longev. 2021 (1), 2497354. https://doi.org/10.1155/2021/2497354.

Noreen, S., Khan Naizi, M., Tufail, T., Hassan, F., Awuchi, C.G., 2023. Nutraceutical, functional, and therapeutic properties of Garcinia cambogia: a review. Int. J. Food Prop. 26 (1), 729–738. https://doi.org/10.1080/10942912.2023.2178458.

Nyakudya, T.T., Tshabalala, T., Dangarembizi, R., Erlwanger, K.H., Ndhlala, A.R., 2020. The potential therapeutic value of medicinal plants in the management of metabolic disorders. Molecules 25 (11), 2669. https://doi.org/10.3390/molecules25112669.

Nyakundi, B.B., Yang, J., 2023. Uses of papaya leaf and seaweed supplementations for controlling glucose homeostasis in diabetes. Int. J. Mol. Sci. 24 (7), 6846. https://doi.org/10.3390/ijms24076846.

Okamoto, H., Ino, S., Nihei, N., Ikuta, N., Ueno, C., Itoi, A., Yoshikawa, Y., Terao, K., Sakamoto, N., 2019. Anti-obesity effects of α-cyclodextrin-stabilized 4-methylthio-3-butenyl isothiocyanate from daikon (*Raphanus sativus* var. *longipinnatus*) in mice. J. Clin. Biochem. Nutr. 65 (2), 99–108. https://doi.org/10.3164/jcbn.19-11.

Oyedemi, B.O., Kotsia, E.M., Stapleton, P.D., Gibbons, S., 2019. Capsaicin and gingerol analogues inhibit the growth of efflux-multidrug resistant bacteria and R-plasmids conjugal transfer. J. Ethnopharmacol. 245, 111871. https://doi.org/10.1016/j.jep.2019.111871.

Ozturk, M., Chia, J.E., Hazra, R., Saqib, M., Maine, R.A., Guler, R., et al., 2021. Evaluation of berberine as an adjunct to TB treatment. Front. Immunol. 12, 656419. https://doi.org/10.3389/fimmu.2021.656419.

Paluch, E., Okińczyc, P., Zwyrzykowska-Wodzińska, A., Szperlik, J., Żarowska, B., Duda-Madej, A., et al., 2021. Composition and antimicrobial activity of Ilex leaves water extracts. Molecules 26 (24), 7442. https://doi.org/10.3390/molecules26247442.

Panossian, A.G., Efferth, T., Shikov, A.N., Pozharitskaya, O.N., Kuchta, K., Mukherjee, P. K., et al., 2021. Evolution of the adaptogenic concept from traditional use to medical systems: pharmacology of stress-and aging-related diseases. Med. Res. Rev. 41 (1), 630–703. https://doi.org/10.1002/med.21743.

Parthasarathy, A., Borrego, E.J., Savka, M.A., Dobson, R.C., Hudson, A.O., 2021. Amino acid–derived defense metabolites from plants: a potential source to facilitate novel antimicrobial development. J. Biol. Chem. 296. https://doi.org/10.1016/j.jbc.2021.100438.

Patel, S.S., Acharya, A., Ray, R.S., Agrawal, R., Raghuwanshi, R., Jain, P., 2020. Cellular and molecular mechanisms of curcumin in prevention and treatment of disease. Crit. Rev. Food Sci. Nutr. 60 (6), 887–939. https://doi.org/10.1080/10408398.2018.1552244.

Pawar, A., Jha, P., Chopra, M., Chaudhry, U., Saluja, D., 2020. Screening of natural compounds that targets glutamate racemase of Mycobacterium tuberculosis reveals the anti-tubercular potential of flavonoids. Sci. Rep. 10 (1), 949. https://doi.org/10.1038/s41598-020-57658-8.

Pereira, W.A., Pereira, C.D.S., Assunção, R.G., da Silva, I.S.C., Rego, F.S., Alves, L.S., et al., 2021. New insights into the antimicrobial action of Cinnamaldehyde towards Escherichia coli and its effects on intestinal colonization of mice. Biomolecules 11 (2), 302. https://doi.org/10.3390/biom11020302.

Pham, D.C., Shibu, M.A., Mahalakshmi, B., Velmurugan, B.K., 2020. Effects of phytochemicals on cellular signaling: reviewing their recent usage approaches. Crit. Rev. Food Sci. Nutr. 60 (20), 3522–3546. https://doi.org/10.1080/10408398.2019.1699014.

Piché, M.E., Tchernof, A., Després, J.P., 2020. Obesity Phenotypes, diabetes, and cardiovascular diseases. Circ. Res. 126 (11), 1477–1500. https://doi.org/10.1161/CIRCRESAHA.120.316101.

Qureshi, K.A., Mohammed, S.A., Khan, O., Ali, H.M., El-Readi, M.Z., Mohammed, H.A., 2022. Cinnamaldehyde-Based Self-Nanoemulsion (CA-SNEDDS) accelerates wound healing and exerts antimicrobial, antioxidant, and anti-inflammatory effects in rats' skin burn model. Molecules 27 (16), 5225. https://doi.org/10.3390/molecules27165225.

Rahman, H.A., Sahib, N.G., Saari, N., Abas, F., Ismail, A., Mumtaz, M.W., Hamid, A.A., 2017. Anti-obesity effect of ethanolic extract from Cosmos caudatus Kunth leaf in lean rats fed a high fat diet. BMC Compl. Alternative Med. 17, 1–17. https://doi.org/10.1186/s12906-017-1640-4.

Rahman, M.M., Islam, M.R., Shohag, S., Hossain, M.E., Rahaman, M.S., Islam, F., et al., 2022. The multifunctional role of herbal products in the management of diabetes and obesity: a comprehensive review. Molecules 27 (5), 1713. https://doi.org/10.3390/molecules27051713.

Rajagopal, K., Varakumar, P., Baliwada, A., Byran, G., 2020. Activity of phytochemical constituents of Curcuma longa (turmeric) and Andrographis paniculata against coronavirus (COVID-19): an in silico approach. Future J. Pharmac. sci. 6, 1–10. https://doi.org/10.1186/s43094-020-00126-x.

Rajasekar, V., Darne, P., Prabhune, A., Kao, R.Y., Solomon, A.P., Ramage, G., et al., 2021. A curcumin-sophorolipid nanocomplex inhibits Candida albicans filamentation and biofilm development. Colloids Surf. B Biointerfaces 200, 111617. https://doi.org/10.1016/j.colsurfb.2021.111617.

Rani, N., Singla, R.K., Narwal, S., Tanushree, Kumar, N., Rahman, M.M., 2022. Medicinal plants used as an alternative to treat gingivitis and periodontitis. Evid. base Compl. Alternative Med. 2022 (1), 2327641. https://doi.org/10.1155/2022/2327641.

Rao, A., Briskey, D., Dos Reis, C., Mallard, A.R., 2021. The effect of an orally-dosed Caralluma Fimbriata extract on appetite control and body composition in overweight adults. Sci. Rep. 11 (1), 6791. https://doi.org/10.1038/s41598-021-86108-2.

Rattis, B.A., Ramos, S.G., Celes, M.R., 2021. Curcumin as a potential treatment for COVID-19. Front. Pharmacol. 12, 675287. https://doi.org/10.3389/fphar.2021.675287.

Redha, A.A., Perna, S., Riva, A., Petrangolini, G., Peroni, G., Nichetti, M., et al., 2021. Novel insights on anti-obesity potential of the miracle tree, Moringa oleifera: a systematic review. J. Funct.Foods 84, 104600. https://doi.org/10.1016/j.jff.2021.104600.

Rhimi, W., Aneke, C.I., Annoscia, G., Otranto, D., Boekhout, T., Cafarchia, C., 2020. Effect of chlorogenic and gallic acids combined with azoles on antifungal susceptibility and virulence of multidrug-resistant Candida spp. and Malassezia furfur isolates. Med. Mycol. 58 (8), 1091–1101. https://doi.org/10.1093/mmy/myaa010.

Rizky, W.C., Jihwaprani, M.C., Mushtaq, M., 2022. Protective mechanism of quercetin and its derivatives in viral-induced respiratory illnesses. The Egyptian J. Bronchol. 16 (1), 58. https://doi.org/10.1186/s43168-022-00162-6.

Sabet, S., Rashidinejad, A., Melton, L.D., McGillivray, D.J., 2021. Recent advances to improve curcumin oral bioavailability. Trends Food Sci. Technol. 110, 253–266. https://doi.org/10.1016/j.tifs.2021.02.006.

Saglam, K., Sekerler, T., 2024. A compherensive review of the anti-obesity properties of medicinal plants. Pharmedicine J. 1 (2), 46–67. https://doi.org/10.62482/pmj.10.

Saito, M., Matsushita, M., Yoneshiro, T., Okamatsu-Ogura, Y., 2020. Brown adipose tissue, diet-induced thermogenesis, and thermogenic food ingredients: from mice to men. Front. Endocrinol. 11, 222. https://doi.org/10.3389/fendo.2020.00222.

Sang, H., Jin, H., Song, P., Xu, W., Wang, F., 2024. Gallic acid exerts antibiofilm activity by inhibiting methicillin-resistant Staphylococcus aureus adhesion. Sci. Rep. 14 (1), 17220. https://doi.org/10.1038/s41598-024-68279-w.

Sapkota, B.K., Khadayat, K., Aryal, B., Bashyal, J., Jaisi, S., Parajuli, N., 2022. LC-HRMS-based profiling: antibacterial and lipase inhibitory activities of some medicinal plants for the remedy of obesity. Sci. Pharm. 90 (3), 55. https://doi.org/10.3390/scipharm90030055.

Saqib, S., Ullah, F., Naeem, M., Younas, M., Ayaz, A., Ali, S., Zaman, W., 2022. *Mentha*: nutritional and health attributes to treat various ailments including cardiovascular diseases. Molecules 27 (19), 6728. https://doi.org/10.3390/molecules27196728.

Sasso, M.D., Culici, M., Braga, P.C., Guffanti, E.E., Mucci, M., 2006. Thymol: inhibitory activity on Escherichia coli and Staphylococcus aureus adhesion to human vaginal cells. J. Essent. Oil Res. 18 (4), 455–461. https://doi.org/10.1080/10412905.2006.9699140.

Scaria, B., Sood, S., Raad, C., Khanafer, J., Jayachandiran, R., Pupulin, A., et al., 2020. Natural health products (NHP's) and natural compounds as therapeutic agents for the treatment of cancer; mechanisms of anti-cancer activity of natural compounds and overall trends. Int. J. Mol. Sci. 21 (22), 8480. https://doi.org/10.3390/nu12092499.

Scazzocchio, B., Minghetti, L., D'Archivio, M., 2020. Interaction between gut microbiota and curcumin: a new key of understanding for the health effects of curcumin. Nutrients 12 (9), 2499.

Senarathna, S.D.U., Gunathilaka, M.D.T.L., 2023. Garlic and cloves as promising antibacterial agents against cariogenic bacteria-A mini review. Sri Lankan J. Appl. Sci. 2 (1), 44–50. https://sljoas.uwu.ac.lk/index.php/sljoas/article/view/68.

Seo, S.H., Fang, F., Kang, I., 2021. Ginger (Zingiber officinale) attenuates obesity and adipose tissue remodeling in high-fat diet-fed C57BL/6 mice. Int. J. Environ. Res. Publ. Health 18 (2), 631. https://doi.org/10.3390/ijerph18020631.

Shahwan, M., Alhumaydhi, F., Ashraf, G.M., Hasan, P.M., Shamsi, A., 2022. Role of polyphenols in combating Type 2 Diabetes and insulin resistance. Int. J. Biol. Macromol. 206, 567–579. https://doi.org/10.1016/j.ijbiomac.2022.03.004.

Shaik Mohamed Sayed, U.F., Moshawih, S., Goh, H.P., Kifli, N., Gupta, G., Singh, S.K., et al., 2023. Natural products as novel anti-obesity agents: insights into mechanisms of action and potential for therapeutic management. Front. Pharmacol. 14, 1182937. https://doi.org/10.3389/fphar.2023.1182937.

Shanbhag, P., 2024. Evaluating Garcinia cambogia: a comprehensive analysis of its effectiveness. Int. J. Health Med. Innov. (IJHMI) 1 (1). https://journals.gaftim.com/index.php/IJHMI/article/view/372.

Sheppard, J.G., McAleer, J.P., Saralkar, P., Geldenhuys, W.J., Long, T.E., 2018. Allicin-inspired pyridyl disulfides as antimicrobial agents for multidrug-resistant Staphylococcus aureus. Eur. J. Med. Chem. 143, 1185–1195. https://doi.org/10.1016/j.ejmech.2017.10.018.

Shi, X.E., Zhou, X., Chu, X., Wang, J., Xie, B., Ge, J., et al., 2019. Allicin improves metabolism in high-fat diet-induced obese mice by modulating the gut microbiota. Nutrients 11 (12), 2909. https://doi.org/10.3390/nu11122909.

Shin, M.K., Yang, S.M., Han, I.S., 2020. Capsaicin suppresses liver fat accumulation in high-fat diet-induced NAFLD mice. Anim. Cell Syst. 24 (4), 214–219. https://doi.org/10.1080/19768354.2020.1810771.

Shu, C., Ge, L., Li, Z., Chen, B., Liao, S., Lu, L., et al., 2024. Antibacterial activity of cinnamon essential oil and its main component of cinnamaldehyde and the underlying mechanism. Front. Pharmacol. 15, 1378434. https://doi.org/10.3389/fphar.2024.1378434.

Shukla, A., Parmar, P., Patel, B., Goswami, D., Saraf, M., 2021. Breaking bad: better call gingerol for improving antibiotic susceptibility of Pseudomonas aeruginosa by inhibiting multiple quorum sensing pathways. Microbiol. Res. 252, 126863. https://doi.org/10.1016/j.micres.2021.126863.

Singh, M., Thrimawithana, T., Shukla, R., Adhikari, B., 2022. Inhibition of enzymes associated with obesity by the polyphenol-rich extracts of Hibiscus sabdariffa. Food Biosci. 50, 101992. https://doi.org/10.1016/j.fbio.2022.101992.

Slavin, J.L., Lloyd, B., 2012. Health benefits of fruits and vegetables. Adv. Nutrition (Bethesda, Md 3 (4), 506–516. https://doi.org/10.3945/an.112.002154.

Snoussi, M., Noumi, E., Hajlaoui, H., Bouslama, L., Hamdi, A., Saeed, M., et al., 2022. Phytochemical profiling of Allium subhirsutum L. aqueous extract with antioxidant, antimicrobial, antibiofilm, and anti-quorum sensing properties: in vitro and in silico studies. Plants 11 (4), 495. https://doi.org/10.3390/plants11040495.

Sudhakar, M., Sasikumar, S.J., Silambanan, S., Natarajan, D., Ramakrishnan, R., Nair, A. J., Kiran, M.S., 2020. Chlorogenic acid promotes development of brown adipocyte-like phenotype in 3T3-L1 adipocytes. J. Funct.Foods 74, 104161. https://doi.org/10.1016/j.jff.2020.104161.

Sun, T., Li, X.D., Hong, J., Liu, C., Zhang, X.L., Zheng, J.P., et al., 2019. Inhibitory effect of two traditional Chinese medicine monomers, berberine and matrine, on the quorum sensing system of antimicrobial-resistant Escherichia coli. Front. Microbiol. 10, 2584. https://doi.org/10.3389/fmicb.2019.02584.

Tian, Q., Wei, S., Su, H., Zheng, S., Xu, S., Liu, M., et al., 2022. Bactericidal activity of gallic acid against multi-drug resistance Escherichia coli. Microb. Pathog. 173, 105824. https://doi.org/10.1016/j.micpath.2022.105824.

Timilsena, Y.P., Phosanam, A., Stockmann, R., 2023. Perspectives on saponins: food functionality and applications. Int. J. Mol. Sci. 24 (17), 13538. https://doi.org/10.3390/ijms241713538.

Tomar, M., Rao, R.P., Dorairaj, P., Koshta, A., Suresh, S., Rafiq, M., et al., 2019. A clinical and computational study on anti-obesity effects of hydroxycitric acid. RSC Adv. 9 (32), 18578–18588. https://doi.org/10.1039/C9RA01345H.

Topa, S.H., Palombo, E.A., Kingshott, P., Blackall, L.L., 2020. Activity of cinnamaldehyde on quorum sensing and biofilm susceptibility to antibiotics in Pseudomonas aeruginosa. Microorganisms 8 (3), 455. https://doi.org/10.3390/microorganisms8030455.

Ulanowska, M., Olas, B., 2021. Biological properties and prospects for the application of eugenol—a review. Int. J. Mol. Sci. 22 (7), 3671. https://doi.org/10.3390/ijms22073671.

Valdés-González, J.A., Sánchez, M., Moratilla-Rivera, I., Iglesias, I., Gómez-Serranillos, M.P., 2023. Immunomodulatory, anti-inflammatory, and anti-cancer properties of ginseng: a pharmacological update. Molecules 28 (9), 3863. https://doi.org/10.3390/molecules28093863.

Valença, H.D.M., e Silva, C.P., de Brito Gitirana, L., Valença, S.S., Lanzetti, M., 2022. Beneficial effects of Ilex paraguariensis in the prevention of obesity-associated metabolic disorders in mice. Phytother Res. 36 (2), 1032–1042. https://doi.org/10.1002/ptr.7377.

Van Schaik, L., Kettle, C., Green, R., Irving, H.R., Rathner, J.A., 2021. Effects of caffeine on brown adipose tissue thermogenesis and metabolic homeostasis: a review. Front. Neurosci. 15, 621356. https://doi.org/10.3389/fnins.2021.621356.

Varì, R., Scazzocchio, B., Silenzi, A., Giovannini, C., Masella, R., 2021. Obesity-associated inflammation: does curcumin exert a beneficial role? Nutrients 13 (3), 1021. https://doi.org/10.3390/nu13031021.

Wan, J.J., Brown, R.S., Kielian, M., 2020. Berberine chloride is an alphavirus inhibitor that targets nucleocapsid assembly. mBio 11 (3), 10–1128. https://doi.org/10.1128/mBio.01382-20.

Wang, X., Shen, Y., Thakur, K., Han, J., Zhang, J.G., Hu, F., Wei, Z.J., 2020a. Antibacterial activity and mechanism of ginger essential oil against Escherichia coli and Staphylococcus aureus. Molecules 25 (17), 3955. https://doi.org/10.3390/molecules25173955.

Wang, X., Shen, Y., Thakur, K., Han, J., Zhang, J.G., Hu, F., Wei, Z.J., 2020b. Antibacterial activity and mechanism of ginger essential oil against Escherichia coli and Staphylococcus aureus. Molecules 25 (17), 3955. https://doi.org/10.3390/molecules25173955.

Wang, J., Xing, H., Qu, L., 2021. Inhibitory effect of gallic acid on Pseudomonas aeruginosa biofilm. Chinese J. Primary Med. Pharm. 1555–1559. https://doi.org/10.3760/cma.issn1008-6706.2021.10.025.

Wang, Y., Alkhalidy, H., Liu, D., 2021. The emerging role of polyphenols in the management of type 2 diabetes. Molecules 26 (3), 703. https://doi.org/10.3390/molecules26030703.

Wang, Y., Li, Z., He, J., Zhao, Y., 2024. Quercetin regulates lipid metabolism and fat accumulation by regulating inflammatory responses and glycometabolism pathways: a review. Nutrients 16 (8), 1102. https://doi.org/10.3390/nu16081102.

Wani, A.R., Yadav, K., Khursheed, A., Rather, M.A., 2021. An updated and comprehensive review of the antiviral potential of essential oils and their chemical constituents with special focus on their mechanism of action against various influenza and coronaviruses. Microb. Pathog. 152, 104620. https://doi.org/10.1016/j.micpath.2020.104620.

Warowicka, A., Nawrot, R., Goździcka-Józefiak, A., 2020. Antiviral activity of berberine. Arch. Virol. 165, 1935–1945. https://doi.org/10.1007/s00705-020-04706-3.

Werner, J., 2021. Capsaicinoids–properties and mechanisms of pro-health action. Analytical methods in the determination of bioactive compounds and elements in food 193–225. https://doi.org/10.1007/978-3-030-61879-7_8.

Wong, Y.Y., Chow, Y.L., 2024. Exploring the potential of spice-derived phytochemicals as alternative antimicrobial agents. eFood 5 (1), e126. https://doi.org/10.1002/efd2.126.

Worreth, S., Bieger, V., Rohr, N., Astasov-Frauenhoffer, M., Töpper, T., Osmani, B., Braissant, O., 2022. Cinnamaldehyde as antimicrobial in cellulose-based dental appliances. J. Appl. Microbiol. 132 (2), 1018–1024. https://doi.org/10.1111/jam.15283.

Xi, K.Y., Xiong, S.J., Li, G., Guo, C.Q., Zhou, J., Ma, J.W., et al., 2022. Antifungal activity of ginger rhizome extract against Fusarium solani. Horticulturae 8 (11), 983. https://doi.org/10.3390/horticulturae8110983.

Xie, Y., Liu, X., Zhou, P., 2020. In vitro antifungal effects of berberine against Candida spp. in planktonic and biofilm conditions. Drug Des. Dev. Ther. 87–101. https://doi.org/10.2147/DDDT.S230857.

Xu, X.Y., Zhao, C.N., Li, B.Y., Tang, G.Y., Shang, A., Gan, R.Y., et al., 2023. Effects and mechanisms of tea on obesity. Crit. Rev. Food Sci. Nutr. 63 (19), 3716–3733. https://doi.org/10.1080/10408398.2021.1992748.

Yang, K., Zhang, L., Liao, P., Xiao, Z., Zhang, F., Sindaye, D., et al., 2020. Impact of gallic acid on gut health: focus on the gut microbiome, immune response, and mechanisms of action. Front. Immunol. 11, 580208. https://doi.org/10.3389/fimmu.2020.580208.

Yarmohammadi, F., Mehri, S., Najafi, N., Salar Amoli, S., Hosseinzadeh, H., 2021. The protective effect of Azadirachta indica (neem) against metabolic syndrome: a review. Iranian J. Basic Med. Sci. 24 (3), 280–292. https://doi.org/10.22038/ijbms.2021.48965.11218.

Yasmin, R., Gogoi, S., Bora, J., Chakraborty, A., Dey, S., Ghaziri, G., et al., 2023. Novel insight into the cellular and molecular signalling pathways on cancer preventing effects of Hibiscus sabdariffa: a review. J. Cancer Preven. 28 (3), 77. https://doi.org/10.15430/JCP.2023.28.3.77.

Yildiz, E., Guldas, M., Ellergezen, P., Acar, A.G., Gurbuz, O., 2020. Obesity-associated pathways of anthocyanins. Food Sci. Technol. https://doi.org/10.1590/fst.39119.

Yin, L., Gou, Y., Dai, Y., Wang, T., Gu, K., Tang, T., et al., 2023. Cinnamaldehyde restores ceftriaxone susceptibility against multidrug-resistant Salmonella. Int. J. Mol. Sci. 24 (11), 9288. https://doi.org/10.3390/ijms24119288.

You, L., Cha, S., Kim, M.Y., Cho, J.Y., 2022. Ginsenosides are active ingredients in Panax ginseng with immunomodulatory properties from cellular to organismal levels. J. Ginseng Res. 46 (6), 711–721. https://doi.org/10.1016/j.jgr.2021.12.007.

Youl, O., Konaté, S., Sombié, E., Boly, R., Kaboré, B., Koala, M., Zoungrana, A., Savadogo, S., Tahita, C., Valea, I., Tinto, H., Hilou, A., Traoré-Coulibaly, M., 2024. Phytochemical analysis and antimicrobial activity of *Lawsonia inermis* leaf extracts from Burkina Faso. Am. J. Plant Sci. 15, 552–576. https://doi.org/10.4236/ajps.2024.157038.

Yuca, H., 2022. Capsicum Annuum L. In *Novel Drug Targets with Traditional Herbal Medicines: Scientific And Clinical Evidence*. Springer International Publishing, Cham, pp. 95–108. https://doi.org/10.1007/978-3-031-07753-1_7.

Yücel, Ç., Karatoprak, G.Ş., Açıkara, Ö.B., Akkol, E.K., Barak, T.H., Sobarzo-Sánchez, E., et al., 2022. Immunomodulatory and anti-inflammatory therapeutic potential of gingerols and their nanoformulations. Front. Pharmacol. 13, 902551. https://doi.org/10.3389/fphar.2022.902551.

Zainal, M., Zain, N.M., Amin, I.M., Ahmad, V.N., 2021. The antimicrobial and antibiofilm properties of allicin against Candida albicans and Staphylococcus aureus–A therapeutic potential for denture stomatitis. The Saudi dental journal 33 (2), 105–111. https://doi.org/10.1016/j.sdentj.2020.01.008.

Zhang, X., Sun, X., Wu, J., Wu, Y., Wang, Y., Hu, X., Wang, X., 2020. Berberine damages the cell surface of methicillin-resistant Staphylococcus aureus. Front. Microbiol. 11, 621. https://doi.org/10.3389/fmicb.2020.00621.

Zhang, L., Qin, M., Yin, J., Liu, X., Zhou, J., Zhu, Y., Liu, Y., 2022. Antibacterial activity and mechanism of ginger extract against Ralstonia solanacearum. J. Appl. Microbiol. 133 (4), 2642–2654. https://doi.org/10.1111/jam.15733.

Zhang, Z., Zhao, Y., Chen, X., Li, W., Li, W., Du, J., Wang, L., 2022. Effects of cinnamon essential oil on oxidative damage and outer membrane protein genes of Salmonella enteritidis cells. Foods 11 (15), 2234. https://doi.org/10.3390/foods11152234.

Zheng, D., Huang, C., Huang, H., Zhao, Y., Khan, M.R.U., Zhao, H., Huang, L., 2020. Antibacterial mechanism of curcumin: a review. Chem. Biodivers. 17 (8), e2000171. https://doi.org/10.1002/cbdv.202000171.

Zhu, Z., 2022. Beyond thermal sensation: roles of transient receptor potential vanilloid subfamily member 1 and spicy food in cardiometabolic diseases. Cardiol. Discovery 2 (1), 1–5. https://doi.org/10.1097/CD9.0000000000000047.

Zorić, N., Kosalec, I., Tomić, S., et al., 2017. Membrane of *Candida albicans* as a target of berberine. BMC Compl. Alternative Med. 17, 268. https://doi.org/10.1186/s12906-017-1773-5.

Zouine, N., El Ghachtouli, N., Soumya, E.L., Koraichi, S.I., 2024. A comprehensive review on medicinal plant extracts as antibacterial agents: factors, mechanism insights and future prospects. Scientific African, e02395. https://doi.org/10.1016/j.sciaf.2024.e02395.

Zulfiqar, S., Marshall, L.J., Boesch, C., 2022. Hibiscus sabdariffa inhibits α-glucosidase activity in vitro and lowers postprandial blood glucose response in humans. Human Nutrition & Metabolism 30, 200164. https://doi.org/10.1016/j.hnm.2022.200164.

Further reading

Abdul Rahman, H., Saari, N., Abas, F., Ismail, A., Mumtaz, M.W., Abdul Hamid, A., 2017. Anti-obesity and antioxidant activities of selected medicinal plants and phytochemical profiling of bioactive compounds. Int. J. Food Prop. 20, 2616–2629. https://doi.org/10.1080/10942912.2016.1247098.

Ahmad Khan, M.S., Ahmad, I., 2019. Chapter 1 - Herbal Medicine: Current Trends and Future Prospects. In: Ahmad Khan, M.S., Ahmad, I., Chattopadhyay, D. (Eds.), New Look to Phytomedicine, pp. 3–13. https://doi.org/10.1016/B978-0-12-814619-4.00001-X. Academic Press.

Chung, Sangwon, Park, Soo Hyun, Park, Jae Ho, Hwang, Jin-Taek, 2021. Anti-obesity effects of medicinal plants from Asian countries and related molecular mechanisms: a review. Rev. Cardiovasc. Med. 22 (4), 1279–1293. https://doi.org/10.31083/j.rcm2204135.

Gaur, R., Bao, G.H., 2021. Chemistry and pharmacology of natural catechins from Camellia sinensis as anti-MRSA agents. Curr. Top. Med. Chem. 21 (17), 1519–1537. https://doi.org/10.2174/1568026621666210524100632.

Lu, Q., Fu, Y., Li, H., 2022. Berberine and its derivatives represent as the promising therapeutic agents for inflammatory disorders. Pharmacol. Rep. 74 (2), 297–309. https://doi.org/10.1007/s43440-021-00348-7.

Mousavi, S.M., Sheikhi, A., Varkaneh, H.K., Zarezadeh, M., Rahmani, J., Milajerdi, A., 2018. Effect of Nigella sativa supplementation on obesity indices: a systematic review and meta-analysis of randomized controlled trials. Compl. Ther. Med. 38, 48–57. https://doi.org/10.1016/j.ctim.2018.04.003.

Özen, İ., Demir, A., Bahtiyari, M.İ., Wang, X., Nilghaz, A., Wu, P., et al., 2024. Multifaceted applications of thymol/carvacrol-containing polymeric fibrous structures. Adv. Ind. Eng. Polymer Res. 7 (2), 182–200. https://doi.org/10.1016/j.aiepr.2023.09.001.

Yan, Y.Q., Fu, Y.J., Wu, S., Qin, H.Q., Zhen, X., Song, B.M., et al., 2018. Anti-influenza activity of berberine improves prognosis by reducing viral replication in mice. Phytother Res. 32 (12), 2560–2567. https://doi.org/10.1002/ptr.6196.

Yanai, H., Adachi, H., Hakoshima, M., Katsuyama, H., 2023. Postprandial hyperlipidemia: its pathophysiology, diagnosis, atherogenesis, and treatments. Int. J. Mol. Sci. 24 (18), 13942. https://doi.org/10.3390/ijms241813942.

Yang, X., Rai, R., Huu, C.N., Nitin, N., 2019. Synergistic antimicrobial activity by light or thermal treatment and lauric arginate: membrane damage and oxidative stress. Appl. Environ. Microbiol. 85 (17), e0103319. https://doi.org/10.1128/AEM.01033-19.

Yang, R., Miao, J., Shen, Y., Cai, N., Wan, C., Zou, L., et al., 2021. Antifungal effect of cinnamaldehyde, eugenol and carvacrol nanoemulsion against Penicillium digitatum and application in postharvest preservation of citrus fruit. Lwt 141, 110924. https://doi.org/10.1016/j.lwt.2021.110924.

Zhu, W., Dai, Y., Huang, M., Li, J., 2021. Efficacy of ginger in preventing postoperative nausea and vomiting: a systematic review and meta-analysis. J. Nurs. Scholarsh. 53 (6), 671–679. https://doi.org/10.1111/jnu.12691.