Review

Therapeutic Potential of Medicinal Plants and Their Phytoconstituents in Diabetes, Cancer, Infection, Cardiovascular Diseases, Inflammation and Gastrointestinal Disorders

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Therapeutic Potential of Medicinal Plants and Their Phytoconstituents in Diabetes, Cancer, Infection, Cardiovascular Diseases, Inflammation and Gastrointestinal Disorders

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Abstract: Conditions like diabetes mellitus (DM), cancer, infection, inflammation, cardiovascular diseases (CVDs) as well as gastrointestinal (GI) disorders continue to have a major global impact on mortality and morbidity. Medicinal plants have been used since ancient times in ethnomedicine (e.g. Ayurveda, Unani, Traditional Chinese Medicine, European Traditional Medicine) including treatment of a wide range of disorders. Plants are a rich source of numerous and diverse phytoconstituents that have demonstrated antidiabetic, anticancer, antimicrobial, antihypertensive, antioxidant, antihyperlipidemic, cardioprotective, immunomodulatory and/or anti-inflammatory activity. The current review focuses on the 30 plants most commonly reported for use in treatment of DM, cancer, infection, CVDs, inflammation and gastrointestinal disorders, with a particular emphasis on their traditional uses, phytoconstituents, pharmacological properties and modes of action. Plants with antidiabetic potential include *Terminalia chebula*, *Zingiber officinale*, *Withania somnifera*, *Ocimum sanctum*, *Curcuma longa* and *Aframomum angustifolium*. Plants with anticancer potential include *Zingiber officinale, Aloe barbadensis, Annona muricata, Artocarpus heterophyllus* and *Azadirachta indica*. Those with antimicrobial potential include *Aframomum angustifolium, Aloe barbadensis, Capsicum frutescens* and *Centella asiatica. Those* with potential in CVDs include *Acacia Arabica, Allium cepa, Azadirachta indica* and *Catharanthus roseus.* Plants with anti-inflammatory potential include *Eriobotrya japonica, Aloe barbadensis* and *Ocimum sanctum* Whereas those with potential in GI disorders include *Musa paradisiaca* and *Aloe barbadensis.* Further studies are warranted to fully investigate the clinical therapeutic benefits of these and other plants considered in this review, and to unravel the mechanisms of action of their bioactive phytoconstituents at the molecular level.

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1. Introduction

Conditions like diabetes mellitus (DM), cancer, infection, inflammation, cardiovascular diseases (CVDs) as well as gastrointestinal (GI) disorders continue to have a major impact on mortality and morbidity worldwide, and in the case of chronic illnesses - often associated with multiple complications - can severely impact quality of life [1–3]. Many of the modern synthetic medicines that are used to manage the aforementioned diseases present limitations that restrict their use. This includes being associated with adverse side effects, triggering drug-interactions and/or hypersensitivity reactions [4–9]. Additionally, a significant proportion of the world's population can neither afford nor easily access synthetic medicines [10].

Medicinal plants, generally considered safer, more affordable and accessible than synthetic medicines, have historically served as useful therapeutic agents in ethnomedicine. According to the World Health Organization (WHO), more than 80% of the world's population still relies on traditional medicine obtained from plants to meet their basic medical needs. Over the past few decades, there has been a surge in global interest for medicinal plants as an alternative to synthetic medicines. Unlike the latter, which are based on a single chemical entity, medicines based on plant extracts contain various phytoconstituents (e.g. flavonoids, alkaloids, polyphenols, terpenoids). Interestingly, these have been demonstrated to exert their pharmacological activities by interacting simultaneously with numerous biological targets, thereby increasing the therapeutic potential [1,2,11]. Moreover, the discovery that some phytoconstituents are able to enhance the bioactivity of others within a plant extract, an effect called synergism, is another great incentive for the use of medicinal plants [12,13].

The purpose of this review is to explore the most common medicinal plants used in ethnomedicine, their phytoconstituents, pharmacological properties and mechanisms of actions, for the management of DM, cancer, infection, inflammation, CVDs and gastrointestinal disorders. This article also discusses advancements in medicinal plants research and the future potential of medicinal plants in human health disorders.

2. Methodology

A comprehensive literature search was conducted using multiple databases including Google Scholar, Science Direct, Scopus and PubMed. During the search, the terms "Medicinal plants", "Ethnomedicine", "Herbal medicine", "Plant-based treatment", "Phytoconstituents", "Pharmacological action" and "The role of medicinal plants in the management of diabetes, cancer, infection, inflammation and gastrointestinal disorders" were used. Although the search approach was not limited to any particular time period, 98% of the articles obtained were published between 2000-2022 and only 2% predated the year 2000. Over 800 articles were shortlisted. Following a preliminary screening, approximately 400 articles were retrieved for in-depth analysis, and 105 of them were considered for our investigation. The important findings were compiled, analyzed, and presented in this review. The names of all plants were authenticated using the plant list (www.theplantlist.org) and the world flora (www.worldfloraonline.org).

3. Medicinal Plants in Traditional Systems of Medicines

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The traditional knowledge/practice of using plants as medicines to cure and/or prevent disease among various ethnic communities is called ethnomedicine [14,15]. Medicinal plants have been used for centuries (mostly by those living in rural and/or remote communities) as part of traditional systems of medicines. These include Ayurveda, Unani, Traditional Chinese Medicine (TCM) and European Traditional Medicine [16–18].

Ayurveda is an ancient and widely popular medicinal practice, predominantly practiced in India but also frequently employed in other Southeast Asian countries (Bangladesh, Sri Lanka, Nepal, Pakistan) [19]. Over 20,000 medicinal plant species have been reported in India [20]. These include *Acacia arabica* (bark), *Aframomum angustifolium* (seeds), *Allium sativum* (leaves, cloves), *Azadirachta indica* (leaves), *Curcuma longa* (roots), *Momordica charantia* (fruits, leaves) (Table 1).

Unani traditional medicine was founded by Hippocrates (460–377 BC) and further developed by Arabian and Persian scientists in the Middle Ages, hence also called Greco-Arabian and Persian medicine [21]. Later introduced to India, it is now widely practiced in many Arabic and Asian countries and is a traditional medical practice recognised by the WHO [22]. Medicinal plants in Unani traditional medicine include *Acacia arabica* (bark), *Allium sativum* (roots), *Azadirachta indica* (leaves), *Centella asiatica* (leaves), *Cinnamomum verum* (leaves, bark), *Curcuma longa* (roots), *Lantana camara* (leaves), *Musa paradisiaca* (leaves, fruits), *Trigonella-foenum graecum* (leaves, seeds), *Withania somnifera* (roots), *Zingiber officinale* (roots) (Table 1) [23–27].

Traditional Chinese medicine (TCM) has long been employed to cure diseases in China, Japan, and other East and Southeast Asian countries with similar cultural traditions. TCM continues to be a significant part of the contemporary Chinese healthcare system, and it is becoming more well-recognized as a complementary and alternative medical practice worldwide [28]. Medicinal plants used in TCM include *Aconitum heterophyllum* (roots), *Allium cepa L.* (onion bulb), *Allium sativum* (leaves, cloves), *Aloe barbadensis* (leaves), *Annona muricata* (leaves, bark), *Artocarpus heterophyllus* (leaves, flowers, and fruits), *Azadirachta indica* (leaves, bark), *Capsicum frutescens* (leaves, fruits), *Catharanthus roseus* (leaves, root, and stem), *Cinnamomum verum* (leaves, bark), *Citrus aurantium* (leaves, fruits), *Citrus limon* (leaves, fruits), *Curcuma longa* (rhizome), *Emblica officinalis* (fruits), *Eriobotrya japonica* (leaves, seeds), *Hibiscus rosa-sinensis* (leaves, flowers, and roots), *Momordica charantia* (leaves, fruits, roots), *Musa paradisiaca* (leaves, peel), *Ocimum sanctum* (leaves, roots), *Punica granatum* (bark, fruits, and seeds), *Withania somnifera* (leaves, roots), *Zingiber officinale* (roots) (Table 1) [29,30].

Traditional European medicine has also a long history of use for the treatment of diseases and continues to be relevant in many European countries [31]. Popular traditional European medicinal plants include *Acacia arabica* (leaves, bark), *Aframomum angustifolium* (seeds), *Aloe barbadensis* (leaves), *Allium sativum* (leaves, cloves), *Capsicum frutescens* (leaves, fruits), *Centella asiatica* (leaves), *Cinnamomum verum* (leaves, bark), *Citrus limon* (fruits, peel), *Curcuma longa* (rhizome), *Emblica officinalis* (fruits), *Eriobotrya japonica* (leaves, seeds), *Gymnema sylvestre* (leaves), *Momordica charantia* (leaves, fruits, and roots), *Musa paradisiaca* (leaves, peel), *Ocimum sanctum* (leaves, stem, and roots), *Pterocarpus marsupium* (leaves, bark), *Punica granatum* (bark, fruits, and seeds), *Zingiber officinale* (root) (Table 1) [32–34].

4. Pharmacological Properties of Medicinal Plants

Medicinal plants traditionally used in ethnomedicine exhibit a wide range of pharmacological effects that have been demonstrated through scientific observation and testing [35,36]. These include antidiabetic, anticancer, antimicrobial, immunomodulatory, antioxidant, antihyperlipidemic, antihypertensive, cardioprotective, anti-inflammatory properties, as well as protective effects against GI disorders (Figure 1) [37–39]. The medicinal plants most commonly used in ethnomedicine for DM, cancer,

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infection, CVDs, inflammatory and GI disorders, along with their pharmacological actions are listed in Table 1.

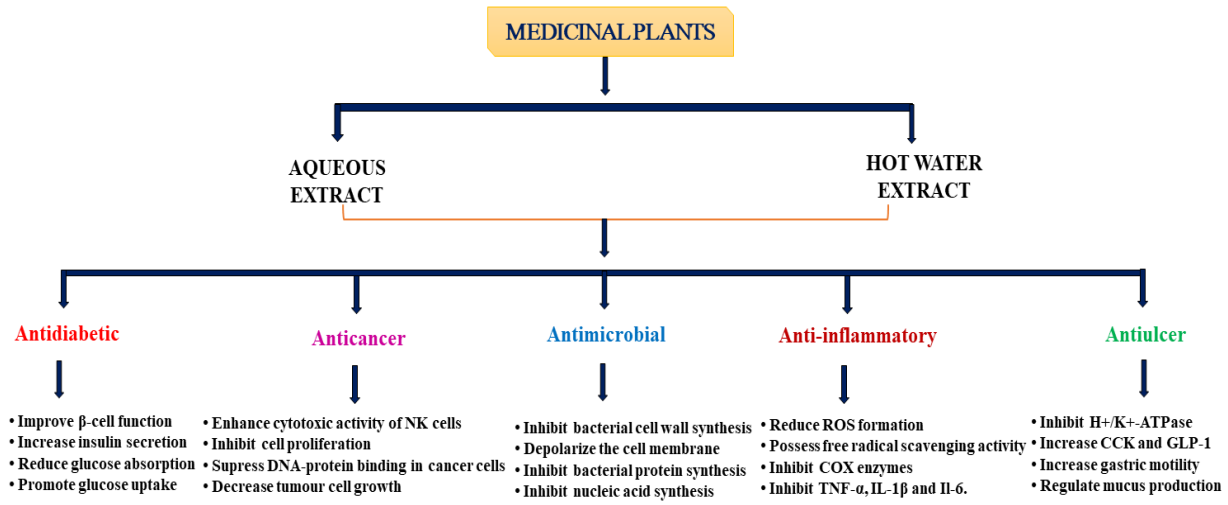

Figure 1. Schematic diagram illustrating the various pharmacological actions of medicinal plants: Medicinal plants exhibit their antidiabetic effects via improvement of β-cell function and insulin secretion; anticancer properties by inhibiting viral gene expression and cell wall proliferation; antimicrobial effects by inhibiting bacterial cell wall and protein synthesis; anti-inflammatory effect by inhibiting the COX enzyme in blood vessels and ROS formation, inducing free radical scavenging activity in inflamed cells via suppression of TNF-α, IL-1β and other inflammatory cytokines in adipose tissue; antiulcer properties by inhibiting H^+/K^+-ATPase, increasing CCK, GLP-1 and gastric motility, and regulating mucus production.

4.1. Type 2 Diabetes Mellitus (T2DM)

Type 2 Diabetes mellitus refers to a group of metabolic conditions characterized by prolonged hyperglycemia due to impaired production, secretion or action of insulin [40]. Many medicinal plants and their bioactive phytoconstituents are used as traditional cures for type 2 diabetes have demonstrated ameliorating effects on high blood glucose level, restoring β-cell function, improving glucose tolerance, and glucose uptake, increasing insulin secretion, and insulin sensitivity, mitigating diabetes-induced ROS formation, possess free radical scavenging activity, inhibiting hydrolytic and oxidative enzymes, aldose reductase, and α-glucosidase effects [5,40,49,155,157]. Examples of plants with antidiabetic properties include *Aframomum angustifolium* (seeds), *Curcuma longa* (roots), *Ocimum sanctum* (leaves, roots), *Terminalia chebula* (fruit), *Withania somnifera* (roots) and *Zingiber officinale* (roots) (Table 1) [55,89,119,134,142,149].

4.2. Cancer

The use of medicinal plants in cancer therapy is considered an alternative approach to conventional treatment, and one that is potentially safer and better tolerated [41]. Many phytoconstituents possess anticancer or cancer chemoprotective properties, for example controlling oncogenesis expression, carcinogen metabolism, or inhibiting protein and DNA synthesis in cancer cells [42]. Many studies have demonstrated that medicinal plants can inhibit cancer cell generation by reducing the ameliorated expression of NF-κB and TNF-α, thus reducing tumor volume and weight, as well as tumor burden and incidence [137,144]. Plants with anticancer activity include *Aloe barbadensis* (leaves), *Annona muricata*

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(leaves, fruits), *Artocarpus heterophyllus* (fruits, leaves), *Azadirachta indica* (leaves, bark), *Zingiber officinale* (roots) (Table 1) [137,144].

4.3. Infectious Diseases

Infectious diseases are currently a severe global health concern [43]. Many medicinal plants exhibit antimicrobial or antiviral activity, inhibiting bacterial cell wall and protein synthesis, viral gene expression or viral entry into host cells [44,45]. As drug-resistant microbes become increasingly prevalent, research into antimicrobial medicinal plants has gained renewed importance [46,47]. Studies have revealed that medicinal plants can effectively reduce the growth of certain pathogens, such as *Staphylococcus aureus*, *Salmonella typhimurium*, *Vibrio cholera*, and *Shigella dysenteriae* [76,80]. Plants with notable antimicrobial activity include *Aframomum angustifolium, Aloe barbadensis, Capsicum frutescens and Centella asiatica* (Table 1) [76,80].

4.4. Cardiovascular Diseases

Cardiovascular diseases, the leading cause of death worldwide, can also be managed using medicinal plants [48]. Plant-based products have a long history of use in traditional medicine for treating CVDs [49]. Plant extracts have shown cardioprotective and anti-hypertensive activity by stimulating peroxisome proliferator-activated receptor γ (PPARγ) and suppressing calcium influx, respectively [42]. They can ameliorate triglyceride, total cholesterol (TC), LDL- and HDL-cholesterol as well as total protein levels effectively. They have also been reported to reinstate blood supply by prompting the proliferation of new blood vessels as well as lower blood pressure [48–50]. Plants with protective effects against CVDs include *Acacia Arabica, Allium cepa, Azadirachta indica* and *Catharanthus roseus* (Table 1) [54,59,60,74,77].

4.5. Inflammatory Diseases

Many current analgesics, such as opiates and non-steroidal anti-inflammatory drugs (NSAIDs), present adverse side effects [5,6]. The use of medicinal plants for the treatment of inflammatory conditions may lead to fewer side effects [51]. Medicinal plants and their bioactive phytoconstituents have been reported to possess anti-inflammatory activity by restoring free radical scavenging, inhibiting hydrolytic and oxidative enzymes, and reducing aldose reductase activity [40]. Several studies have shown that medicinal plants can reduce inflammation by inhibiting various inflammatory markers. These plants act by suppressing the activation of NF-κB, decreasing the expression of nitric oxide (NO) and inducible nitric oxide synthase (iNOS), inhibiting cyclooxygenase-2 (COX-2), and reducing tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6) levels. Additionally, they can mitigate leukocyte adhesion and reduce the production of prostaglandin E2 [66,94,118]. Plants with anti-inflammatory effects include *Aloe barbadensis* Mill., *Eriobotrya japonica* and *Ocimum sanctum* (Table 1) [66,94,118].

4.6. Gastrointestinal Disorders

Plant-based medicines exert gastroprotective properties via mitigation of heartburn through inhibition of H^+/K^+-ATPase, alteration of GHR (ghrelin) sensitivity (which decreases hunger), increase in CCK and GLP-1 release, fasting leptin levels, gastric motility, suppression of abdominal pain causing L-type calcium channel, impediment of 5-HT3 receptors that lead to symptoms of dyspepsia, inhibiting α_2-adrenergic receptor, and regulation of mucus production [49]. Numerous medicinal plants are effective traditional remedies for GI disorders by reducing the ulcer index and gastric juice volume, increasing gastric juice pH and gastric wall mucus, reducing hyperemia and attenuating colon inflammation. Examples of plants with beneficial effects in GI disorders include *Aloe barbadensis* Mill. and *Musa paradisiaca* (Table 1) [66,114].

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Table 1. Pharmacological effects of medicinal plants commonly used in ethnomedicine for DM, cancer, infection, CVDs, inflammatory and GI disorders.

Medicinal plants	Parts	Ethnomedicinal uses	Form of extract	Experimental model	Pharmacological action	Dose	Duration	References(s)
1. *Acacia arabica*	Bark, leaves and seeds	Diabetes, leucorrhoea, diarrhea and dysentery, skin, stomach and tooth disorders	Hot water extract	High-fat-diet induced obese rats	Decreases blood glucose levels, improves glucose homeostasis and β-cell functions, increases insulin release, enhances glucose tolerance and glucose uptake	0.25 g/kg	9 days	[52,53]
			Chloroform extract	Streptozotocin (STZ)-induced diabetic rats	Reduces serum glucose, insulin resistance, TC, LDL-C, TG, MDA and increases plasma insulin, HDL-C	0.1, 0.2 g/kg	21 days	[54]

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2. *Aframomum angustifolium*	Seeds	Cardiovascular disease, diabetes, inflammation, stomachache, wound healing, snakebite, diarrhea	Ethanol extract	Bromate-induced Wister rats	Improves ALP (alkaline phosphate) activity, increases liver tissue, decreases Na^+ and increases K^+	0.75 g/kg	10 days	[55,56]y
3. *Allium cepa*	Onion skin and bulbs	Diabetes, bronchitis, hypertension, skin infections, swelling	Ethyl alcohol onion skin (EOS) extract	Sprague-Dawley (SD) rats	Lowers blood glucose, increases plasma insulin secretion and insulin sensitivity, improves glucose uptake, lowers cholesterol	0.5 g/kg	14 days	[4,57,58]
			Aqueous extract (Raw onion bulb)	STZ -induced diabetic mice	Improves oral glucose tolerance, reduces fasting blood glucose levels and	30 g/kg	-	[59,60]

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					reduces TC, LDL and increases HDL Levels			
4. *Allium sativum*	Leaves, flowers, cloves, and bulbs	Hypertension, diabetes, fever, dysentery, bronchitis, intestinal worms	Raw garlic extract	STZ -induced diabetic rats	Lowers serum glucose, reduces fasting blood glucose, cholesterol and triglyceride levels, reduces urinary protein levels and increases plasma insulin secretion and insulin sensitivity.	0.5 g/kg intraperitoneally (i.p.)	49 days	[4,61,62]
			Decoctions	STZ -induced diabetic mice	Reduces hyperphagia, polydipsia, and body weight	6.25% (by weight of the diet)	40 days	[63]

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5. *Aloe barbadensis* Mill. (Syn. *Aloe vera*)	Clear gel, green part of the leaf and yellow latex	Diabetes, dermatitis, headache, insect bites, viral infection, arthritis, gum sore, wound healing, inflammation and urine related problems	Gel Extract	Alloxan-induced Wistar albino diabetic rats	Decreases serum glucose, TG, TC, MDA levels, increases serum nitric oxide and total antioxidant capacity.	0.5 mL /day	42 days	[64,65]
			Ethanolic extract	TNBS-(Trinitrobenzenesulfonic acid)-induced Wister rats	Reduces hyperemia, attenuates colon inflammation, reduces the increased levels of TNF-α, IL-6, NO, MPO, and MPA.	0.2, 0.4 g/kg	7 days	[66]
6. *Annona muricata*	Leaves, bark, fruit, and seed	Fever, stomach pain, worms, diabetes and vomiting	Aqueous extract	STZ -induced diabetic rats	Reduces AST, ALT activity and lowers blood glucose, serum creatinine, MDA, nitrite and LDL-	0.1, 0.2 g/kg	28 days	[67]

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					cholesterol levels			
7. *Artocarpus heterophyllus*	Fruits, leaves and bark	Hypertension, diabetes, cancer, anemia, asthma, dermatosis and diarrhea	Ethyl acetate fraction	STZ -induced diabetic rats	Reduces fasting blood glucose, lowers serum glucose, cholesterol and TG levels.	0.02 g/kg	35 days	[68,69]
8. *Asparagus adscendes*	Dried rhizome	Diarrhea, gonorrhea, dysuria, weakness, lean and thinness, erectile dysfunction, diabetes, piles, cough and dysentery	Aqueous extract	3T3-L1 adipocytes cell	Increases glucose uptake	0.005 g/ml	---------	[70,71]
				BRIN-BD11 cells	Stimulates insulin secretion			
9. *Azadirachta indica*	Leaves, flowers, seeds, fruits, roots and bark	Diabetes, malaria, skin diseases, cardiovascular diseases, intestinal worms	Aqueous extract	STZ -induced diabetic rats and high-fat-diet-induced diabetic rats	Improves body weight, decreases blood glucose, lowers TC, TG, LDL, VLDL levels,	0.5 g/kg (b.w.) and 0.4 g/kg (b.w.)	14 days and 30 days	[4,58,72,73]

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					improves HDL levels, insulin sensitivity and glucose tolerance, increases insulin secretion, regenerates insulin, improves pancreatic β-cell functions, enhances glucose uptake, inhibits α-amylase and α-glucosidase activity.			
			Ethanol extract	STZ -induced diabetic rats	Reduces the total cholesterol, LDL- and VLDL-cholesterol, triglycerides, and total lipids	0.5 g/kg p.o. (per os)	7 days	[74]

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10. *Capsicum frutescens*	Fruit, seed and leaves	Diabetes, bronchitis, burning feet, arthritis, stomach ache, diarrhea and dysentery.	Dietary supplements	Alloxan-induced diabetic Wistar rats	Decreases AST, ALT, ALP , GGT, serum uric acid, creatinine, total cholesterol, fasting blood glucose levels, increases HDL cholesterol	1g and 2g/ 99 and 98 g of animal food	21 days	[75]
			Aqueous and methanol extracts	*Staphylococcus aureus, Salmonella typhimurium, Vibrio cholera, Escherichia coli, Pseudomonas aeruginosa, Shigella dysenteriae*	Lowers MIC, shows antibacterial activity against *Staphylococcus aureus, Salmonella typhimurium,* and *Vibrio cholera*.	10 g/100 and 60 mL	48h	[76]
11. *Catharanthus roseus*	Leaf, root, shoot and stem	Skin problems, (dermatitis, eczema, acne) and diabetes	Leaf powder suspension	STZ -induced diabetic Wistar rats	Improves body weight, decreases plasma glucose, TG, TC, LDL-C and	0.1 g/kg	60 days	[77]

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					VLDL-C levels, increases HDL-C			
			Dichloromethane: methanol extract (DCMM)	STZ -induced diabetic rats	Improves enzymatic activities of glycogen synthase, glucose 6-phosphate-dehydrogenase, succinate dehydrogenase, malate dehydrogenase, increases metabolization of glucose and normalizes increased lipid peroxidation.	0.5 g/kg	7 days	[78]
12. *Centella asiatica*	Leaves and stems	Inflammation, diabetes, dysentery, hysteron-epilepsy, leprosy,	Ethanol extract	STZ-induced obese diabetic Sprague Dawley rats	Lowers blood glucose levels, increases serum insulin levels, decreases	0.3 g/kg	28 days	[79]

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		rheumatism, dizziness, hemorrhoids, diarrhea, tuberculosis, skin lesions and asthma.			lipid metabolism			
			Methanol, acetone and chloroform extract	*Shigella dysenteriae*	Inhibits *Shigella dysenteriae*	0.001 g/mL	-	[80]
13. *Cinnamomum verum*	Leaves, bark, flowers, fruits and roots	Diabetes, bacterial infection, inflammation and cancer.	Lyophilized aqueous extract	Alloxan-diabetic rats	Improves body weight, food intake (FI) and food efficiency ratio (FER), lowers FBG, TC, LDL-C, TG levels and induces HDL-C levels.	0.2, 0.4, 0.6, 1.2 g/kg	30 days	[81]
			Cinnamon powder	STZ-induced Sprague-Dawley diabetic rats	Increases CYP2D1 enzyme activity, hepatic clearance, and decreases fasting blood glucose.	0.3 g/kg	14 days	[82]

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14. *Citrus aurantium*	Peel, flower, leaf, fruit and fruit juice	Diabetes, insomnia, indigestion, and heartburn	Ethanol extract	High fat diet-induced obese C57BL/6 mice and Alloxan-induced diabetic rats	Decreases body weight, adipose tissue weight, and serum cholesterol levels, decreases blood glucose, TG, TCH, LDL and VLDL levels, increases HDL, and insulin secretion from β-cells.	0.1 g/kg/day and 0.3, 0.5 g/kg b.w.	56 days and 21 days	[4,83,84]
15. *Citrus limon*	Fruit, stem, leaves juice and peel	Scurvy, sore throats, phlegm, fevers, cough, rheumatism, hypertension and diabetes	Hexane extract	Alloxan-induced diabetic rats and 3T3L1-adipocytes cells	Reduces blood glucose levels, increases insulin secretion, enhances glucose utilization, inhibits α-amylase	0.01 g/kg and 0.00056 g/ml	4 days and 48	[4,85,86]

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					activity, increases PPARγ, (Peroxisome Proliferator Activated Receptors Gamma), GLUT4 (Glucose Transporter 4), DGAT-1 (diacylglycerol o-acyltransferase 1) levels, decreases IL-6, and restores triglyceride adipocytes.			
			Dietary supplements	Atherogenic diet-fed rabbits	Increases total cholesterol and ApoB100 (apolipoproteins), decreases LDL levels.	5 cc (cubic centimeter) lemon juice and 1 g powder	60 days	[87]

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16. Curcuma *longa*	Rhizome (underground stem)	Biliary disorders, anorexia, cough, diabetic wounds, hepatic disorders, rheumatism and sinusitis	Dietary supplement	STZ-induced diabetic rats	Decreases blood cholesterol, triglyceride, phospholipids, renal cholesterol and triglyceride levels	0.5% (Curcumin containing diet)	56 days	[88,89]
			Suspension	STZ-induced diabetic rats	Decreases plasma glucose, body weight, diabetic proteinuria, polyuria, lipid peroxidation, increases serum creatinine, blood urea nitrogen and GSH, SOD, and catalase activities.	0.015 and 0.03 g/kg, p.o.	14 days	[90]

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17. *Eriobotrya japonica*	Leaves and seeds	Headache, low back pain, phlegm, asthma, dysmenorrhoea, cough, chronic bronchitis diabetes and skin diseases	Ethanolic and methanolic extract	Otsuka Long-Evans Tokushima fatty (OLETF) rats, male KK-A(y) diabetic mice and Streptozotocin-induced diabetic mice	Decreases blood glucose, improves glucose tolerance, reduces insulin resistance, lowers HbA1c, TG, TC, increases GLUT4 (glucose transporter 4), PPARα (peroxisome proliferator activated receptor α), decreases body weight, increases insulin and leptin levels, enhances ApoA-1 (apolipoprotein A-1) levels.	8 g/kg and 0.5 or 1.0 g/kg	28 days	[4,91,92]

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			Aqueous extract	Spontaneously hypertensive rats (SHR)	Reduces degree of tissue deterioration, abnormal architecture and interstitial spaces, decreases the size of H9c2 cells, inhibits Ang-II-induced cardiac hypertrophy, attenuates gene expression and decreases body weight.	0.1, 0.3 g/kg	56 days	[93]
			Methanolic extract	LPS (lipopolysaccharide)-induced mice	Reduces NF-κB activation, NO and iNOS expression, inhibits COX-2 TNF-α and IL-6.	0.25, 0.5 g/kg p.o.	24 h	[94]
18. *Gymnema sylvestre*	Leaves	Anti-periodic, stomachic, laxative,	Aqueous extract	Alloxan-induced diabetic rats	Reduces blood glucose, TC and TG levels,	0.4, 0.6, 0.8 g/kg	30 days	[95]

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		diuretic, cough remedy, snakebite, biliousness, parageusia, and furunculosis			increases HDL-C levels.			
			Ethanol extract	High-fat-fed Albino rats	Decreases TG, TC, VLDL, LDL, increases HDL lipoprotein fraction.	0.025, 0.05, 0.1 g/kg p.o.	14 days	[96]
			Aqueous extract	Carrageenan-induced Wistar rats	Increases γ-glutamyl transpeptidase, reduces lipid peroxidation and inhibits paw edema moderately.	0.2, 0.4, 0.6 g/kg p.o.		[97]
19. *Harungana madagascariensis*	Bark and leaves	Gastrointestinal disorders, cardiovascular disorders, malaria, leprosy, anemia, tuberculosis, fever, angina, nephrosis, dysentery,	Ethanolic extract	Alloxan-induced diabetic rats	Reduces blood glucose levels, edema formation, edema size and MDA, SOD and CAT activities, increases GSH levels.	0.025, 0.05, 0.1 g/kg i.p.	3 days	[98]
			Aqueous extract	Isoproterenol (ISO)-induced Wistar rats	Reduces heart weight and the	0.2, 0.4 g/kg p.o.	7 days	[99]

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		bleeding, piles syphilis, gonorrhea and parasitic skin diseases			ratio of heart weight to body weight, reduces serum LDH, AST, ALT, MDA levels, myocytes degeneration, edema and inflammation, increases myocardial GSH levels			
			Ethanolic extract	Cyclophosphamide-induced rats	Decreases MDA levels, AST, ALT, ALP activities and total bilirubin content	0.5 and 1.0 %	14 days	[100]
20. *Lantana camara*	Leaves	Cancers, chicken pox, asthma, eczema, rashes, boils, cold, sore throat, fever,	Methanolic extract	STZ-induced diabetic rats	Reduces blood glucose levels and improves body weight, HbA1c profile, glucose tolerance and	0.1, 0.2 g/kg	21 days	[4,101,102]

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		headaches, toothaches and malaria			regeneration of liver cells			
			Ethanolic extract (70%) and n-butanol and aqueous fraction	Alloxan-and streptozotocin-induced diabetic rats	Lowers blood glucose, TC, and TG levels, SGOT (Serum glutamic oxaloacetic transaminase,) SGPT (Serum glutamate pyruvate transaminase), SALP (serum alkaline phosphatase), LPO levels, increases SOD, CAT, GPx levels	0.8, 0.2, and 0.4 g/kg	28 days and 21 days	[103,104]
			Methanolic extract and ethanolic extract	Neostigmine-induced mice and Alloxan-induced diabetic Albino Wistar rats	Decreases intestinal transit and reduces defecations, decreases blood glucose,	0.125, 0.25, 0.5, 1 g/kg i.p. and 0.6, 0..8, 1 g/kg b.w	10 days and 21 days	[105,106]

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					creatinine and uric acid, improves body weight			
21. *Momordica charantia*	Fruits, vines, leaves and roots	Asthma, tumors, diabetes, skin infections, GI disorders and hypertension	Ethanolic extract	Alloxan-induced type 2 diabetic rats	Increases insulin release, inhibits glucose absorption, improves oral glucose tolerance, FBG, plasma insulin and elevates intestinal motility.	0.5 g/kg	15 days	[107–109]
			Aqueous extract	STZ-induced male Sprague-Dawley rats/mice	Reduces blood glucose, increases antioxidant enzyme activities in cardiac tissues (SOD, GSH, CAT), and decreases hydroxyproline and size of	1.5g/kg	28 days	[110,111]

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					cardiomyocytes			
22. *Musa paradisiaca*	Stalk, peel, pulp, roots, stem and leaf	Diarrhoea, dysentery, intestinal lesions in ulcerative colitis, diabetes, sprue, uremia, nephritis, gout, hypertension, wound healing, inflammation, headache and cardiac diseases	Ethanolic extracts, hexane and chloroform fractions	STZ-induced diabetic rats	Lowers blood sugar levels	0.1, 0.5 g/kg	3 days	[112]
			Dietary supplement	Hypercholesterolemia-induced rats	Increases HDL and reduces TG, TC, LDL levels, reduces plasma lipid peroxidation (LPO), AST, ALT and ALP, inhibits MDA production	100, 200 g/kg	21 days	[113]
			Methanolic extract	Ulcer-induced albino mice	Reduces ulcer index and gastric juice volume, increases gastric juice pH and gastric wall mucus.	0.1 g/kg	7 days	[114]

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			Hydro-ethanolic extract	Nicotinamide (NA)/ STZ-induced diabetic rats	Decreases elevated fasting serum glucose, post-prandial serum glucose, TC, TG, LDL-C, VLDL-C levels, increases serum insulin, liver glycogen, HDL-cholesterol, homeostasis model assessment-insulin resistance (HOMA-IS), and HOMA-β cell function, improves elevated cardiovascular risk indices.	0.1 g/kg/day	28 days	[115]
23. *Ocimum sanctum*	Leaves, stem, flower, root,	Catarrhal bronchitis, bronchial	Petroleum ether extract (OSSO;	Cholesterol-fed male albino rabbits	Decreases serum cholesterol,	0.8 g/kg bw/day	28 days	[116]

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	seeds and whole plant	asthma, dysentery, dyspepsia, skin diseases, chronic fever, hemorrhage, helminthiasis and ringworm	*Ocimum sanctum* Linn. seed oil)		triacylglycerol, LDL and VLDL-cholesterol, decreases lipid peroxidation, increases GSH levels			
			Hexane extract	High fat-fed diet male Wistar rats	Lowers serum lipids (TC, LDL-C, atherogenic index), and attenuates hyperlipidemia (AST, ALP, LDH, CK-MB).	4.45 g/kg day	21 days	[117]
			Petroleum ether extract	Mediator-induced paw edema rats	Reduces paw edema, prevents edema formation, delays diarrhea, increases vascular permeability	3.0 mL/kg		[118]

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			Ethanolic extract	STZ- induced diabetic rats	Improves oral glucose tolerance, reduces blood glucose elevation and glucose absorption, promotes gastrointestinal motility and decreases disaccharide activity and serum glucose, increases liver glycogen and circulating insulin.	1.25 g/kg bw	28 days	[119]
24. *Plantago ovata*	Seeds and husks	Constipation, diarrhea, hemorrhoids, irritable bowel syndrome, weight loss, obesity, high	Hot water extract	STZ- induced diabetic rats	Improves glucose tolerance, suppresses post-prandial blood glucose, reduces glucose	0.5 g/kg	28 days	[120]

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		cholesterol and diabetes			absorption, increases motility and reduces atherogenic lipids and non-esterified fatty acids (NEFA).			
25. *Pterocarpus marsupium*	Bark and leaves	Diarrhea, diabetes, chest and body pain, pyrosis, boils, sores, inflammation and toothache	Ethanolic extract	Gabapentin-induced diabetic Wistar albino rats	Reduces blood glucose, TG, TC, LDL levels, increases HDL and total protein levels.	0.1, 0.2 g/kg	21 days	[121,122]
			Methanolic extract	STZ-induced-NIDDM (non-insulin dependent diabetes mellitus) rats	Decreases blood glucose, improves pancreatic β-cell functions, increases insulin secretion, improves glucose uptake	0.75 g/kg	6 days	[4,123]
			Aqueous extract	STZ-induced neonatal rats	Decreases FBG, postprandial blood glucose	0.1, 0.2 g/kg	28 days	[124]

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					and TNF-α levels, improves body weight.			
26. *Punica granatum*	Fruit, bark, roots and seed	Dysentery, diarrhea, piles, bronchitis, bilious affection and intestinal worms	Aqueous extract	Alloxan-induced diabetic Wistar rats	Improves insulin secretion, and action, increases insulin mRNA expression, reduces FBG levels, ameliorates glucose uptake	0.1, 0.2, 0.35 g/kg	21 days	[125]
			Hydro-ethanolic extract	High lipid diet-fed male Wistar rats	Decreases body weight, serum triglycerides, cholesterol, LDL, ALP, ALT and AST levels, increases HDL levels.	0.05, 0.1, 0.2, 0.3 g/kg	23 days	[126]
			Methanolic extract	Castor oil-treated Wistar rats	Reduces fecal droppings, propulsion of charcoal meal,	0.1, 0.2, 0.4, 0.6 g/kg	7 days	[127]

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					intestinal motility			
27. *Swertia chirayita*	Leaves, stems and roots	Fever, skin disorders, intestinal worms, malaria and diabetes	Aqueous extract and methanolic extract	BRIN-BD11 cells, 3T3-L1 adipocytes cells and Swiss albino rats	Stimulates insulin secretion, increases basal cellular glucose transport and insulin action, lowers blood glucose levels, improves glucose uptake, inhibits α-amylase and α-glucosidase	0.001 g/ml and 0.25 g/kg	-	[4,128,129]
28. *Terminalia arjuna*	Bark	Diabetes, cirrhosis, anemia, cardiovascular and viral diseases	Aqueous extract, ethanolic extract	BRIN-BD11 cells, 3T3-L1 cells, high-fat-diet Albino Wistar rats	Increases insulin secretion and glucose uptake, lowers blood glucose levels, decreases body weight and MDA, improves blood	0.005 g/ml, 0.1 g/kg	21 days-	[5,130–132]

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					urea and serum creatinine levels, increases SOD and GSH			
			Ethanolic extract	STZ-induced diabetic rats	Reduces serum TNF-α, IL-6, TC, TG, LDL-C, MDA levels and increases HDL-C levels.	0.5 g/kg	30 days	[133]
29. *Terminalia chebula*	Fruit	Diabetes, constipation and dementia	Ethanolic extract	STZ-induced diabetic rats	Lowers blood glucose and glycosylated hemoglobin levels, normalizes decreased number of secretory granules in pancreatic β-cells	0.2 g/kg	30 days	[134,135]
			Methanolic extract	High fat-fed male albino Wistar rats	Reduces total cholesterol, TG, LDL, VLDL	0.2, 0.4, 0.6 g/kg	30 days	[136]

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					and serum glucose levels.			
			Ethanolic extract	DMBA (7,12-dimethylbenzanthracene)-induced mammary carcinoma Sprague Dawley rats	Decreases tumor volume, tumor weight and tumor burden and tumor incidence, lowers LPO, increases SOD, CAT, GSH and GPx levels.	0.2, 0.5 g/kg	30 days	[137]
30. *Trigonella-foenum graecum*	Leaves and seeds	Diabetes, fever, abdominal colic, indigestion and baldness	Ethanolic extract	Alloxan-induced diabetic rats	Lowers blood glucose, serum cholesterol, SGOT and SGPT levels	0.05 g/100 g b.w.	48 days	[138]
			Aqueous extract	STZ-induced diabetic rats	Decreases blood glucose, glycated hemoglobin, TC and TG levels, increases HDL-C., improves body weight.	0.44, 0.87, 1.74 g/kg	42 days	[139]

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			Ethanolic extract	Hypercholesterolemic rats	Reduces plasma and hepatic cholesterol levels	30 or 50g	28 days	[140]
			Aqueous extract	Male NMRI (Naval Medical Research Institute) rats	Reduces yeast-induced hyperthermia and edema	1 g/kg	7 days	[141]
31. *Zingiber officinale*	Root	Stomach ache, nausea, diarrhea, vomiting, joint and muscle pain, inflammatory diseases	Aqueous extract	STZ-induced diabetic rats	Lowers serum glucose, cholesterol and TG levels, as well as urine protein levels	0.5 g/kg i.p.	49 days	[142]
			Ethanolic extract	Focal cerebral ischemic Wistar rats	Improves cognitive function and neuronal density, decreases brain infarct volume	0.2 g/kg	21 days	[143]
			Ethanolic extract	Ethionine-induced hepatoma Wistar albino rats	Reduces the elevated expression of NF-κB and TNF-α	0.1 g/kg	56 days	[144]

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32. *Emblica officinalis*	Fruit, seed, leaves, root, bark and flowers	Inflammation, diabetes, cough, chronic diarrhea, fever	Hydromethanolic extract	STZ-induced type 2 diabetic rats	Decreases fasting blood glucose levels, serum creatinine, urea, SGOT, SGPT, lipid profile and LPO, increases insulin levels, GSH, GPx, SOD, CAT levels	0.1, 0.2, 0.3, 0.4 g/kg b.w.	45 days	[145]
			Ethyl-acetate extract	Ovariectomy-induced female albino rats	Decreases total cholesterol, VLDL and LDL, increases HDL levels	0.1 g/kg	126 days	[146]
33. *Hibiscus rosa-sinensis*	Leaves and roots	Diabetes, cough, diarrhea, dysentery, pain	Ethanolic extract	STZ-induced Long Evans rats	Reduces glucose absorption and disaccharidase enzyme activity, increases GI motility,	0.25, 0.5 g/kg	28 days	[147]

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					improves glucose tolerance, decreases blood glucose levels, increases plasma insulin and hepatic glycogen, lowers TG, TC, LDL, and increases HDL levels			
			2% Carboxymethyl cellulose (CMC) extract (Vehicle)	Isoproterenol (ISO)-induced Wistar rats	Decreases myocardial TBARS, increases SOD, catalase and GSH content, lowers blood glucose levels and glucose absorption, increases insulin secretion,	0.125, 0.25, 0.5 g/kg	28 days	[5,148]

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					improves glucose tolerance, and inhibits DPP-IV activity.			
34. *Withania somnifera*	Roots and leaves	Diabetes, cough and cold, insomnia, leprosy, bronchitis, asthma, tumors, tubercular glands, arthritis, nervous disorders	Ethanolic extract	STZ-induced diabetic rats	Decreases blood glucose, AST, ALT, ALP, LDH (lactate dehydrogenase) serum lipid, TC, TG and LDL-C levels, increases serum HDL-C, total protein and albumin levels.	0.2 g/kg	56 days	[149,150]
			Root powder	Hypercholesteremic induced rats	Reduces total cholesterol, TC, TG, LDL-C, VLDL-C, MDA levels, increases HDL-C, catalase, SOD, and TAA	0.75, 1.5 gm/rat/day	-	[151]

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					content and inhibits HMG-CoA reductase.			
35. *Aconitum heterophyllum*	Tuberous roots	Diarrhea, diabetes, cough, rheumatism, dyspepsia, stomach ache, fever, digestive and nervous system disorders.	Methanolic extract	Diet-induced obese rats	Increases HDL-C, LCAT, and ApoA1, decreases TC, TG, ApoB, LDL-C, and HMGR levels.	0.2, 0.4 g/kg	28 days	[152]
			Ethanolic and chloroform extract	Cotton-pellet-induced rats, and high-fat high cholesterol diet obese rats	Decreases cotton pellet weight and blood glucose TC, TG and LDL levels, increases HDL-C levels	0.225, 0.45, 0.9 g/kg p.o and 0.2, 0.3 g/kg.	28 days	[153,154]

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5. Phytoconstituents from Medicinal Plants and Their Therapeutic Mechanisms of Action

Medicinal plants contain numerous phytoconstituents, also referred to as phytochemicals, phytomolecules or bio-nutrients. These are organic substances that are synthesized naturally by plants to protect them against environmental challenges and attack from herbivores or microbial pathogens [44,155,156]. Phytoconstituents find commercial uses as biofuels, enzymes, preservatives, flavors, fragrances, and are found in numerous plant-based cosmeceutical and medicinal products. They can be extracted from different plant parts (e.g. roots, stem, leaves, flowers, seeds) using various extraction methods (Table 2) [157–159]. They belong to diverse classes of molecular structures, and many are biologically active. Their potential to interact with human biological targets is exploited for therapeutic purposes [18,44,155,156,160]. Indeed, many current drug classes (e.g. penicillins, opiates, taxanes, *Vinca* alkaloids and artemisinin derivatives) derive from bioactive phytoconstituents [36,161]. Unlike synthetic medicines, which use a single active ingredient to target a single biological target, medicinal plants display pleiotropic effects. This means that their numerous phytoconstituents are able to exert an overall effect by interacting with multiple targets/pathways [51].

5.1. Type 2 Diabetes Mellitus

T2DM is a chronic disease that significantly contributes to morbidity and mortality worldwide. It is often associated with complications like retinopathy, neuropathy, coronary heart disease, and stroke [162,163]. Notably, metformin, a widely used antidiabetic medication, is derived from the plant *Galega officinalis* and has been utilized for its therapeutic potential in enhancing insulin sensitivity [164]. Additionally, several other antidiabetic drugs are also derived from natural sources, highlighting the important role of plant-based compounds in the treatment of T2DM. Other phytoconstituents with antidiabetic activity include kaempferol, quercetin, catechin, allicin, alliin, diosgenin, L-leucine, marsupin, curcubitanes triterpenoids, azadiradione, gedunin and pterostilbene [5,43,52,58,71,191,213]. These compounds were observed to lower blood glucose levels through multiple mechanisms, including the reduction of α-glucosidase activity, enhancement of insulin sensitivity, and the elevation of intracellular calcium, which stimulates insulin secretion. [165,166].

For example, compounds cucurbitane triterpenoids activate GLUT4 translocation to the cell membrane, improves AMP-activated protein kinase activity, inhibits dipeptidyl peptidase IV (DPP-IV) activity, enhances glucose uptake and fatty acid oxidation, decreases triglyceride and low-density lipoprotein levels, increases high-density lipoprotein levels, reduces oxidative stress, heals pancreatic impairment, modifies pancreatic β-cells through increasing size, area, and numbers. Other examples of phytoconstituents with antidiabetic properties include diosgenin, which increases free radical scavenging/antioxidant activity, and limonoids azadiradione and gedunin, which inhibits α-amylase and α-glucosidase (Table 2) (Figure 2) [167,168].

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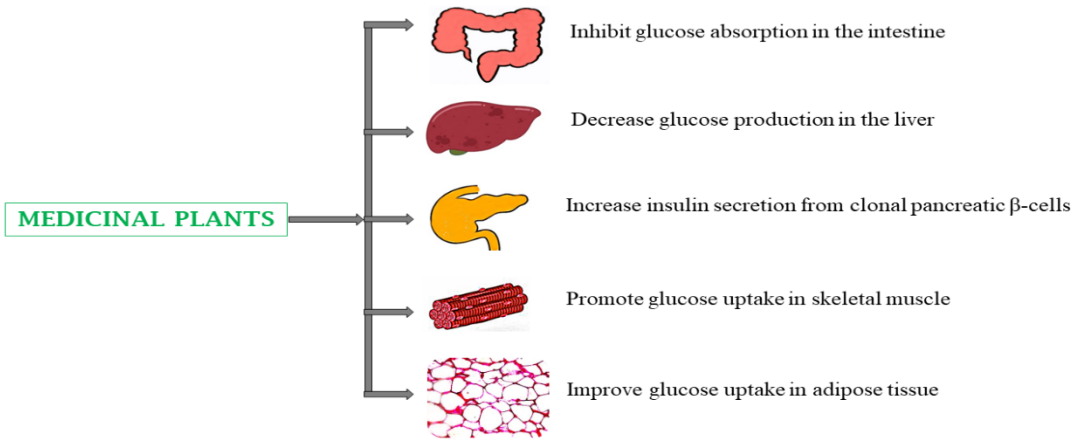

Figure 2. Schematic diagram illustrating the organ/tissue targeted by antidiabetic medicinal plants. Medicinal plants reduce glucose absorption in the small intestine, and glucose production in the liver; increase insulin secretion from pancreatic β-cells; and promote glucose uptake in skeletal muscle and adipose tissue.

5.2. Cancer

Cancer is a global disease that affects both urbanized and developing nations, with approximately 20 million individuals suffering from it as per 2022 data and this number is expected to rise to 35 million by 2050 [169]. Treatments based on plants have shown promising effects in the treatment of cancer [170], and phytoconstituents and their derivatives are promising treatment options for cancer patients, including as a means to attenuate the adverse side effects of anticancer drugs [171]. Examples of phytoconstituents with anticancer activity used for their therapeutic potential include vincristine and vinblastine obtained from *Catharanthus roseus*. These compounds are employed in the treatment of Hodgkin's and non-Hodgkin's lymphoma, choriocarcinoma, neuroblastoma, Wilkins's tumor, reticulum cell sarcoma, leukemia in children, as well as neck and testicular cancer [18,157]. Other phytoconstituents with anticancer activity include allicin, aloesin, curcumin, capsaicin, diosgenin, β-sitosterol, brugine, vindoline and vindolicine [71,191,192,198,204]. The anticancer effects of capsaicin and curcumin have been demonstrated through various mechanistic pathways, which include inhibiting activator protein-1 (AP-1), PI3K/AKT/mTOR/AKT/FOXO, IGF-1R/p-Akt, Wnt-TCF, impeding HIF-1α/VEGF/Rho-GTPases via signal transducer and activator of transcription 3 (STAT3) signaling, declining PI3K/AKT/mTOR/AKT/FOXO pathway. Furthermore, Inhibiting IGF-1R/pAkt signaling transduction represses HER2-integrin, c-erbB-2, and MMP-2/9 by inhibiting protein kinase C (PKC) and mitogen-activated protein kinase (MAPK) signaling. It also inhibits nuclear factor kappa B (NF-κB) activation, arrests the cancer cell cycle at the G2 phase, and reduces oxidative stress (Table 2) (Figure 3) [172–174].

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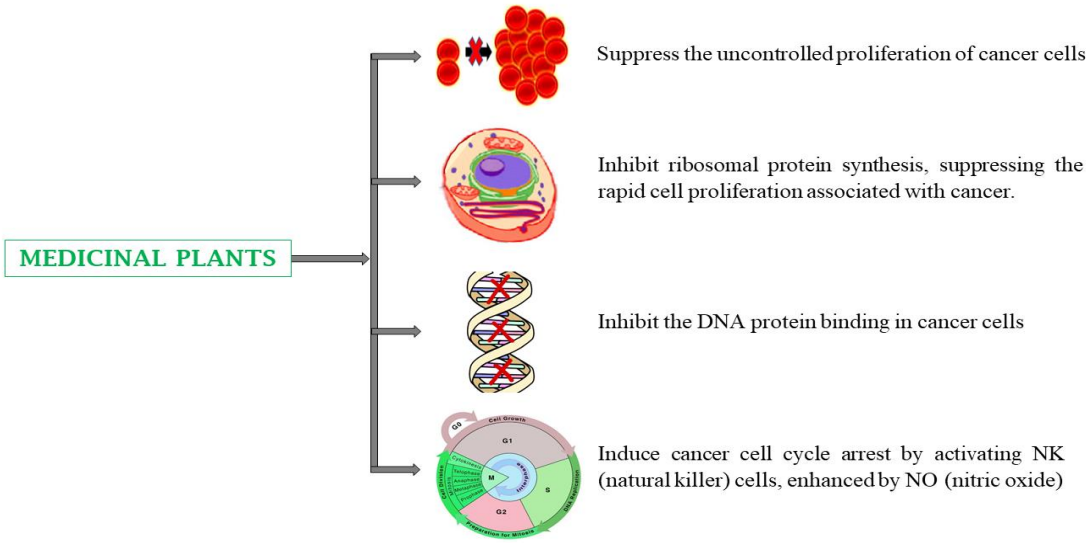

Figure 3. Schematic diagram illustrating the organ/tissue targeted by anticancer medicinal plants: Medicinal plants suppress the uncontrolled proliferation of cells during division, the synthesis of proteins in ribosomes, DNA protein bindings of cancer cells, and arrest cancer cell cycle by inhibiting cell division.

5.3. Infectious Diseases

The global threat of antimicrobial resistance (AMR) has led to an increased interest in discovering alternative treatment options to conventional antibiotics [175–177]. Several phytoconstituents have antimicrobial properties, and have shown promising potential against multi-drug resistant Gram-negative and Gram-positive bacteria [178]. Examples of phytoconstituents with antimicrobial activity include allicin, spirostanol azadirone, nimbin, gedunin, euxanthone, harunmadagascarin D, piperine, reserpine, berberine, chelerythrine, allitridin, quercetin, dictamnine, ellagic acid, gallic acid and aloe-emodin [71,191,192,196,207,219]. Compounds such as piperine, reserpine and berberine show their antimicrobial activity through the inhibition of efflux pumps, DNA intercalation or DNA gyrase inhibition. Dictamnine has been reported to inhibit topoisomerase IA, II and IV, inhibit bacterial cell division, cell wall formation, protein synthesis, replication, transcription and biofilm formation, slicing of intermediate complex of DNA topoisomerase I and, depolarize the bacterial cell membrane. Chelerythrine and allitridin are able to trigger bacterial cell lysis and suppress cell membrane Na+/K+-ATPase activity. Quercetin has been reported to interact with crucial enzymes such as β-lactamases while allicin can inhibit sulfhydryl dependent bacterial enzymes (Table 2) (Figure 4) [158,179,180].

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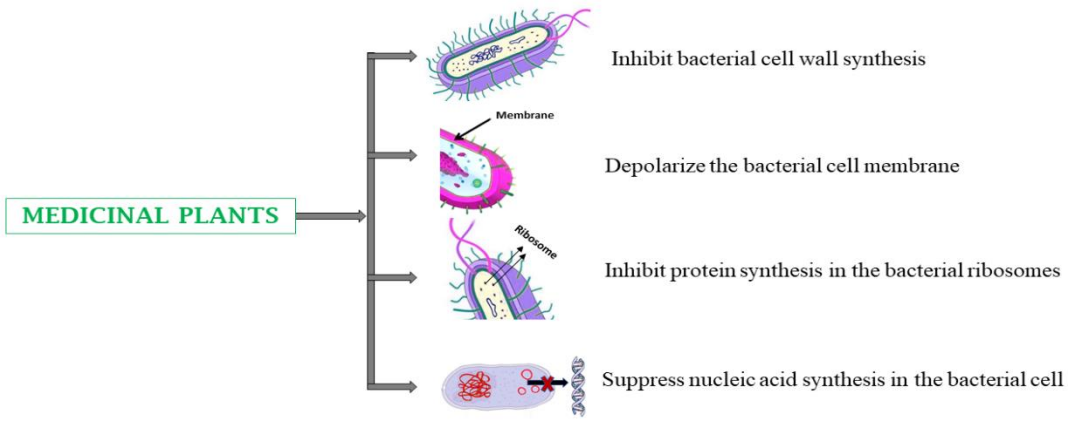

Figure 4. Schematic diagram illustrating the organ/tissue targeted by antimicrobial medicinal plants: Medicinal plants inhibit cell wall synthesis, depolarize bacterial cell membranes, inhibit protein synthesis in bacterial ribosomes, and suppress nucleic acid synthesis in the bacterial cell.

5.4. Inflammatory Diseases

Chronic inflammation severely damages healthy tissues and has been associated with a variety of pathological conditions including cancer, neurological diseases and auto-immune disorders. Medicinal plants and their phytoconstituents can provide a valuable approach to prevent inflammatory processes [181]. Examples of phytoconstituents with anti-inflammatory potential include parthenolide, colchicine, capsaicin, kaempferol, resveratrol, naringenin. diosgenin, β sitosterol, quercetin, nimbidin, gallic acid, epicatechin, epigallocatechin, genistein, curcumin, catechin and plantamajoside. These exert their anti-inflammatory effect via multiple signaling pathways involved in inflammation [51,71,170,196,212]. Quercetin and catechin promote the activity of superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GPx), glutathione reductase (GR), glutathione S-transferase (GST), γ-glutamylcysteine synthetase (γ-GCS) NADPH: quinone oxidoreductase-1 (NQO1) and the expression of heat shock proteins 70 (HSP70). Epigallocatechin suppresses lipoxygenase and cyclooxygenase. Curcumin inhibits inducible NOS (iNOS) and myeloperoxidase (MPO) activity. Quercetin suppresses M-CSF-activated macrophages, decreases IL-2 secretion, IL-2R expression, lysosomal enzyme release from activated neutrophils, PLA2 activity. Quercetin and curcumin inhibit IL-1β, IL-6, TNF-α, PGE2 production and NF-κB activation. Genistein suppresses tyrosine-protein kinase by inducing antiproliferative effects on T cells (Table 2) (Figure 5) [182,183].

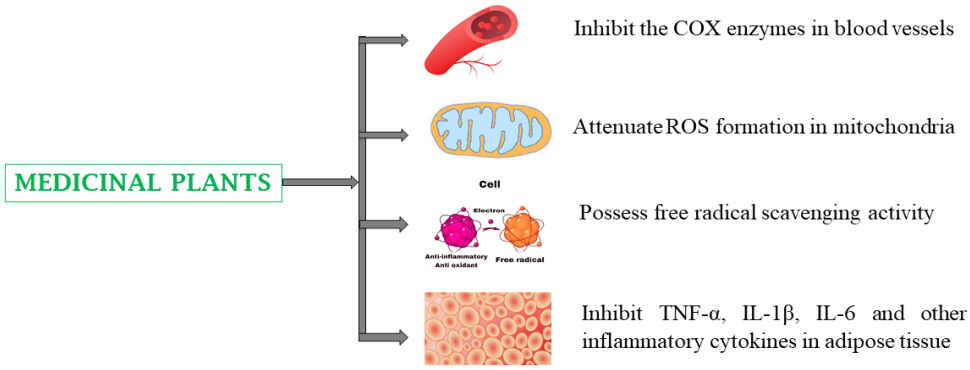

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Figure 5. Schematic diagram illustrating the organ/tissue targeted by anti-inflammatory medicinal plants: Medicinal plants inhibit the COX enzyme in blood vessels, attenuate ROS formation in mitochondria, possess free radical scavenging activity in inflamed cells, inhibit TNF-α, IL-1β and other inflammatory cytokines in adipose tissue.

5.5. Cardiovascular Diseases

Vascular dysfunction is a major contributor to the development of cardiovascular diseases (CVDs) and several scientific studies have emphasized the value of phytoconstituents in the prevention and treatment of cardiovascular disorders [184]. Phytoconstituents with protecting effects against CVDs include quercetin, curcumin, arjungenin, arjunic acid, arjunolic acid, ellagic acid, ginsenoside Rg1, ginsenoside Rg3 and luteolin [190,204,215,217,218]. Bioactive compound such as ginsenoside Rg1 is useful in preventing CVDs through various mechanisms including improving lipid profile by activating PPARα (peroxisome proliferator-activated receptor-alpha) levels, regulating the activation of the PI3K/Akt pathway, preventing acetylcholinesterase (ACE) activity and vascular smooth muscle cell (VSMCs) proliferation, decreasing adrenal catecholamine levels. Ginsenoside Rg3 has been reported to increase nitric oxide (NO) and cyclic guanosine monophosphate (cGMP) levels, contributing to vasorelaxation and improved endothelial function. It activates Ca^{2+}-gated potassium channels, which are crucial in modulating cellular excitability. Ginsenoside Rg3 also stimulates cholinergic pathways, activates M2 muscarinic receptors, and enhances the NO pathway, leading to vasodilation. Additionally, it reduces calcium overload and inhibits the Na^{+}/Ca^{2+} exchanger, which is beneficial in myocardial ischemia. While specific studies on Rg3's effect on the phosphorylation of Akt/FoxO3a are limited, ginsenosides have been reported to influence the Akt signaling pathway, which is involved in cell survival and metabolism. Furthermore, Rg3 increases the phosphorylation of Nrf2, a key transcription factor, which upregulates antioxidant enzymes such as heme oxygenase-1 (HO-1), superoxide dismutase (SOD), catalase (CAT), glutathione peroxidase (GSH-Px), and glutathione (GSH) content. These mechanisms collectively enhance the cellular antioxidant capacity and contribute to its therapeutic potential in cardiovascular and metabolic disorders. (Table 2) (Figure 6) [180,184].

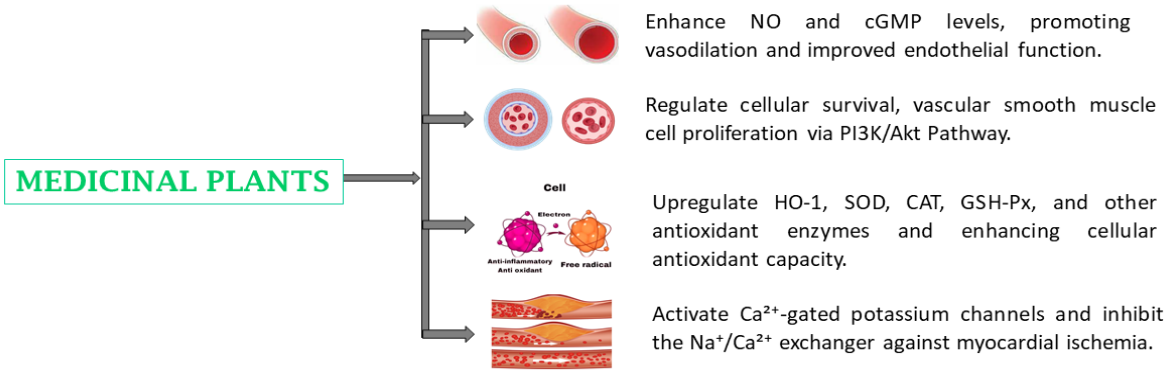

Figure 6. Schematic diagram illustrating the mechanisms of action of cardiovascular protective medicinal plants: Medicinal plants enhance NO and cGMP levels, promoting vasodilation and improving endothelial function. They regulate cellular survival and vascular smooth muscle cell proliferation via the PI3K/Akt pathway. Additionally, they upregulate key antioxidant enzymes, including HO-1, SOD, CAT, and GSH-Px, thereby enhancing cellular antioxidant capacity. These plants also activate Ca^{2+}-gated potassium channels and inhibit the Na^{+}/Ca^{2+} exchanger to protect against myocardial ischemia.

5.6. Gastrointestinal Disorders

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GI disorders are becoming more prevalent worldwide due to rapid globalization and lifestyle, primarily dietary habit, changes. Some GI disorders can be ameliorated with phytoconstituents [185]. Examples of phytoconstituents protecting against GI disorders include curcumin, amaroswerin, chebulagic acid, gallic acid, ternatin, tannins, quercitrin and chebulic acid [204,216,219]. Ternatin displays gastroprotective activity by suppressing intestinal transit, secretion and motility, hindrance of the cellular enzyme and neurotransmitter systems, interacting with calcium channels. Tannins have been reported to activate net water absorption, decrease electrolyte secretion, modify the activity of Na+K+ATPase, stimulate chloride channels, alter chloride secretion. Quercitrin can regulate arachidonic acid metabolism by suppressing COX and lipoxygenase activity, reduce Ca^{2+} availability during excitation-contraction coupling-related phases, excessive contractility of the ileum and jejunum, inhibit 5-HT3 receptors, antagonize the effect of 5-HT4 agonists, stimulate the PPARγ pathway, elevate acetylcholine levels by enhancing gastric motility and assisting gastric emptying, increasing the stomach and proximal small bowel motility and reduce pain by blocking muscarinic receptors (Table 2) (Figure 7) [186,187].

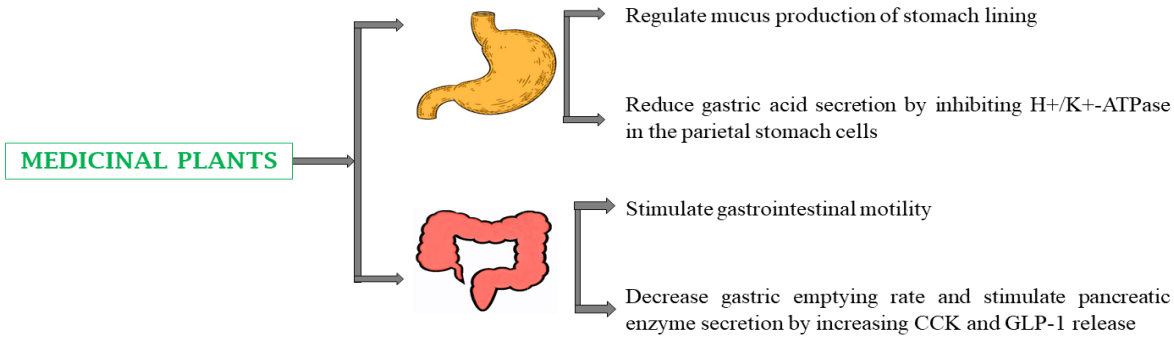

Figure 7. Schematic diagram illustrating the organ/tissue targeted by anti-ulcer medicinal plants: Medicinal plants inhibit H+/K+-ATPase in the parietal cells of the stomach, regulate mucus formation of the stomach lining, stimulate gastric motility in the small intestine and increase the release of CCK and GLP-1 by intestinal cells.

Phytoconstituents exhibit diverse therapeutic effects across various disease categories. These natural compounds exert multifaceted mechanisms of action, including the activation or inhibition of key signaling pathways, enzymes, and receptors. For example, in type 2 diabetes, phytoconstituents enhance glucose uptake and metabolic signaling while inhibiting enzymes linked to hyperglycemia. In cancer, they protect against oxidative stress and suppress pathways involved in tumor progression. In cardiovascular diseases, they modulate ion channels and signaling pathways to support cardiac health. Furthermore, phytoconstituents exhibit anti-inflammatory effects by reducing oxidative stress and cytokine activity, and combat infections by targeting microbial enzymes and proteins. Additionally, they alleviate gastrointestinal disorders by modulating enzymes and receptors linked to gut motility and inflammation. This broad-spectrum activity underscores their potential as natural therapeutic agents (Figure 8).

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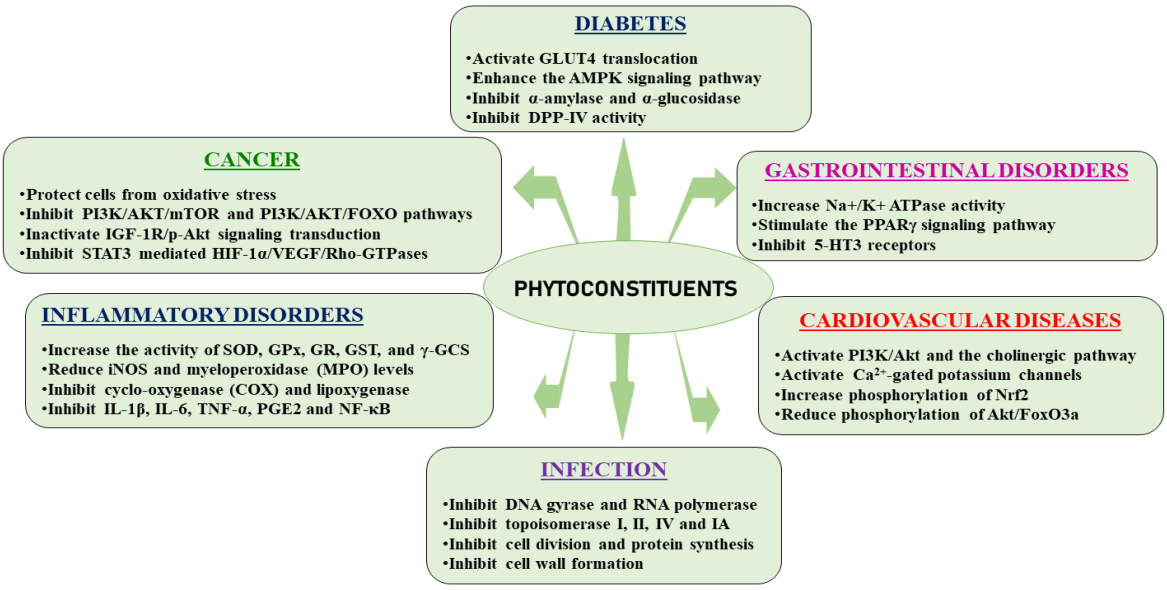

Figure 8. Phytoconstituents with antidiabetic, anticancer, antimicrobial, anti-inflammatory and gastroprotective activity and their mechanisms of action: Phytoconstituents exhibit antidiabetic effects by increasing GLUT-4 translocation through AMPK activation, inhibiting DPP-IV, α-amylase and α-glucosidase activity; cardioprotective effects through activation of PI3K/Akt, cholinergic pathway, Ca^{2+}-gated potassium channels, inhibition of phosphorylation of Akt/FOXO3a; antibacterial effects by inhibiting DNA gyrase, RNA polymerase, topoisomerase I, II, IV and IA, cell division and protein synthesis; gastroprotective effects by altering Na+K+ATPase activity, stimulating PPARγ pathway, suppressing COX and lipoxygenase, inhibiting 5-HT3 receptors; anti-inflammatory and anticancer effects by increasing the action of SOD, catalase (CAT), GPx, GR, GST, γ-GCS, NQO, inhibiting IL-1β, IL-6, TNF-α, PGE2, and NF-κB activity and inhibiting the PI3K/AKT/mTOR and PI3K/AKT/FOXO pathways.

The phytoconstituents present in the medicinal plants most commonly used in ethnomedicine for DM, cancer, infection, CVDs, inflammatory and GI disorders, along with their pharmacological actions are listed in **Table 2**.

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Table 2. Phytoconstituents present in the medicinal plants most commonly used in ethnomedicine for DM, cancer, infection, CVDs, inflammatory and GI disorders, along with their pharmacological actions.

Medicinal plants	Parts	Form of extract	Phytoconstituents	Pharmacological action	Reference(s)
1. *Acacia arabica*	Flowers	Hot water extract, alcoholic and chloroform extract	Quercetin, gallic acid, catechin, kaempferol, isoquercitrin (quercetin 3-*O*-glucoside), tannins and polyphenols	Antidiabetic, antioxidant, restores pancreatic β-cell function, enhances insulin release, improves glucose tolerance and plasma insulin and inhibits excess metabolites (indole) production.	[5,52,54,188]
2. *Aframomum angustifolium*	Pods, seeds, roots and leaves	Ether and methanol, ethanol and aqueous extract	β-pinene, β-caryophyllene, α-pinene, cis-pinocarvyl acetate, α-terpineol, p-cymene, limonene.	Inhibits microbial efflux pumps, impairs membrane integrity, exhibits anti-inflammatory and cytoprotective properties, induces apoptosis, disrupts cellular activity, and inhibits β-secretase.	[189]
3. *Allium cepa*	Bulb, onion skin	Aqueous and ethyl alcohol extract	Quercetin, β-chlorogenin, apigenin, quercetin glucoside and allyl propyl disulfide	Inhibits α-glucosidase activity, lowers postprandial hyperglycemia, reduces blood glucose levels and exerts antioxidant, anti-proliferative activities and cardiovascular benefits, increases plasma insulin levels, lowers blood pressure and inhibits platelet aggregation.	[57,58,190]

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4. *Allium sativum*	Leaves, roots, and bulb	Aqueous and methanol extract	Allicin, diallyl disulphide (allian), quercetin, cysteine sulfoxide, alliin and curcubitanes triterpenoids	Lowers blood glucose levels, increases insulin secretion, activates GLUT-4 translocation, decreases cholesterol levels, and exerts antioxidant, anti-inflammatory, anticancer and antibacterial activities.	[5,58,167,191]
5. *Aloe barbadensis* Mill.	The green part of the leaf	Ethanol, gel extract	Glucomannan, acemannan, aloin, aloesin, aloe-emodin and emodin	Lowers glucose levels, increases insulin secretion, GSH (glutathione), cell migration, prevents cytokines, decreases lipid peroxidation and cell proliferation, prevents oxidative stress, impedes biofilm development, exerts anti-inflammatory effects,	[5,58,192]
6. *Annona muricata*	Leaves	Hydroalcoholic extract	Gallic acid, catechin, chlorogenic acid, caffeic acid,, ellagic acid, epicatechin, rutin, isoquercitrin, quercitrin, kaempferol and quercetin	Possesses anxiolytic, sedative and neuroactive properties	[193]
7. *Artocarpus heterophyllus*	Leaves, stem, roots and bark	Methanol, acetone, aqueous and ethanolextract	Cycloheterophyllin, artonins A and B, artocarpin, artocarpesin and norartocarpetin	Possesses antioxidant, anti-inflammatory, anticarcinogenic and antineoplastic effects.	[194]
8. *Asparagus adscendes*	Roots, leaves, and fruits	Aqueous extract	Palmitic acid, stearic acid, diosgenin, β-sitosterol, spirostanol glycoside, methyl palmitate, L-	Exerts antibacterial, anti-microbial, neuroprotective, anti-inflammatory, antidiabetic,	[71,158,195]

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			leucine, chelerythrine, allitridin and brugine.	anticancer, estrogenic and hypolipidemic properties and destructs bacterial cells.	
9. *Azadirachta indica*	Leaves, flowers, seeds, fruits, roots, and bark	Alcoholic (ethanol), aqueous extract	Nimbidin, nimbin, meliacin, sesquiterpene, azadirone, gedunin, nimbolide, gallic acid, epicatechin, catechin and margolone	Exhibits anti-inflammatory, anti-arthritic, insecticidal, antitumor, antibacterial and immunomodulatory properties	[196]
10. *Capsicum frutescens*	Whole plant	Ethanol and aqueous extract	Capsaicin, β-carotene	Reduces blood glucose levels, improves glucose tolerance, increases insulin levels, and inhibits pro-inflammatory cytokines.	[4,197]
11. *Catharanthus roseus*	Leaves, stems, roots and whole plant	Methanol extract	Vinblastine, vindoline, vindolicine, vindolinine catharoseumine, cathachunine	Exhibits anticancer and antitumor activity, inhibits cell proliferation, inhibits human promyelocytic leukaemia, enhances glucose uptake.	[198]
12. *Centella asiatica*	Leaves, roots	Methanol, ethanol and aqueous extract	Asiatic acid, asiaticoside, madecassoside	Increases lecithin cholesterol acyltransferase (LCAT), plasma lipoprotein lipase (LPL), decreases HMG-CoA reductase activity, induces apoptosis in human melanoma SK-MEL-2 cells, and exhibits anxiolytic and neuroprotective properties.	[79,199,200]

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13. *Cinnamomum verum*	Seeds, fruits, leaves, roots and bark	Methanol, aqueous extract	Cinnamaldehyde, procyanidin B2	Exhibits anti-hyperglycemic and neuroprotection effects.	[201]
14. *Citrus aurantium*	Seeds, fruits, leaves, flowers, juice and peels	Methanol, aqueous, chloroform, and ethanol extract	Naringin, neohesperidine, p-synephrine, epigallocatechin-3-gallate	Possess anti-obesity properties, promotes weight loss, decreases blood glucose levels, enhances insulin secretion and improves glucose tolerance.	[4,202]
15. *Citrus limon*	Seeds, fruits, leaves, pulp and peels	Aqueous, methanol, ethyl acetate, ethanol, and acetone extract	Hesperidin, hesperetin, D-limonene	Exhibits radical scavenging, anxiolytic and anti-inflammatory effects, increases antioxidant cellular defences, lowers blood glucose levels, glucokinase activity, LDL cholesterol and prevents lipid accumulation.	[203]
16. *Curcuma longa*	Rhizomes	Methanol extract	Curcumin, turmerones, demethoxycurcumin, curcuminoids, dimethoxy curcumin, capsaicin	Reduces gastric mucosal damage and lipid peroxidation, inhibits TNF (tumor necrosis factor)-induced NF-κB activation, suppresses activation of activator protein 1 (AP-1), improves insulin resistance, reduces glucose levels, exerts anti-asthmatic, cardioprotective, anticoagulant and antioxidant properties	[172,204]

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17. *Eriobotrya japonica*	Leaves, fruits and seeds	Methanol and ethanol extract and ethyl acetate fraction	Ursolic acid, corosolic acid, euscaphic acid, quercetin-3-O-sophoroside, kampferol-3-O-rutinoside, cinchonain Ib, epicatechin	Exerts anti-inflammatory, hypoglycemic and antioxidant effects, lowers plasma glucose levels and enhances insulin secretion.	[205]
18. *Gymnema sylvestre*	Leaves	Methanol, ethanol, hexane, aqueous, petroleum ether, hydro-alcoholic extract	Gymnemagenin, gymnemic acid IV, ginsenosides, soyasaponins	Exerts anti-hyperglycemic and anticancer properties, decreases blood glucose levels and increases plasma insulin	[206]
19. *Harungana madagascariensis*	Leaves, roots, and bark	Methanol, aqueous, ethanol, hydro-ethanol extract	Harunmadagascarin D, kenganthranol C, euxanthone, astilbin, ferruginin A, betulinic acid, Harunmadagascarin A, dictamnine, piperine, reserpine	Exerts antibacterial, anti-plasmodial, free radical scavenging, suppresses topoisomerase-II anticancer activities and prevents efflux pump.	[158,207]
20. *Lantana camara*	Leaves, roots and flowers	Ethanol, methanol, aqueous extracts	Oleanonic acid, 22β-acetoxylantic acid, A stearoyl glucoside	Exhibits anticancer, cytotoxic and anti-mutagenic properties, reduces blood glucose levels.	[58,208]
21. *Momordica charantia*	Fruits, leaves, seeds, stem and roots	Methanol, ethanol, hydrophilic leaf and aqueous extract	α-momorcharin, β-momorcharin, 5β,19-epoxy-3β,25-dihydroxycucurbita-6,23(*E*)-diene, kuguacin A, momordicin, elasterol, lanosterol	Exerts antitumor, anticancer, anti-bacterial, hypoglycemic, anti-HIV-1 properties and promotes B cell proliferation.	[209]

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22. *Musa paradisiaca*	Leaf, shoot, peel, pulp and fruit	Hexane, ethyl acetate, ethanol, aqueous, and methanol extract	β-sitosterol, stigmasterol, 24-methylene-cycloartanol, apigenin, myricetin, catechin, *p*-coumaric,α-pinene, α-thujene	Promotes NK (natural killer) cells and T cells proliferation, exhibits anti-promastigote, wound healing, antioxidant and antitumor effects	[210]
23. *Ocimum sanctum*	Leaves and stem	Ethanol and aqueous extract	Eugenol, β-sitosterol, rosmarinic acid, apigenin	Inhibits superoxide formation and lipid peroxidation, decreases oxidative stress and cell proliferation, induces apoptosis and possesses radioprotective properties	[211]
24. *Plantago ovata*	Seeds and husks	Aqueous extract	Aucubin, plantamajoside, kaempferol, catechin, epigallocatechin, genistein, curcumin	Exerts anti-inflammatory, antibacterial and antioxidant activities, lowers blood glucose levels, increases insulin secretion reduces insulin resistance, suppresses lipoxygenase and cyclooxygenase, prompts anti-proliferative effects on T-cells, impedes inducible (iNOS) and myeloperoxidase (MPO) level.	[5,182,212]
25. *Pterocarpus marsupium*	Leaves and bark	Ethanol, ethyl acetate, methanol, and aqueous extracts	Pterostilbene, stilbene, resveratrol, marsupin, epicatechin, liquiritigenin, pterosupin, azadiradione, gedunin	Exhibits anticancer, antidiabetic and insulin-like activities, increases glutathione content, lowers serum cholesterol, LDL cholesterol and reduces	[168,213]

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				triglyceride levels, inhibits α-amylase and α-glucosidase.	
26. *Punica granatum*	Fruits, leaves, seeds and peels	Methanol, extract	Ellagic acid, gallagic acid, punicic acid, luteolin, genistein, punicalagin, gallic acid, quercetin, catechin, urolithins	Posesses chemopreventive, anti-proliferative, antimetastatic, anticarcinogenic, anti-inflammatory, renoprotective and anti-oxidant effects, prevents cardiovascular diseases.	[214,215]
27. *Swertia chirayita*	Leaves, stems, roots and whole plant	Aqueous, ethanolic, alcoholic, chloroform and methanolic extracts	Amarogentin, swertiamarin, magniferin, swerchirin, amaroswerin, oleanolic acid, ternatin, tannins, quercitrin	Exhibits antidiabetic, anticancer, antileishmanial, anti-hepatitis, anti-arthritic, anti-atherosclerotic, chemopreventive, hypoglycemic, hepatoprotective, anti-inflammatory and gastroprotective properties, lowers blood glucose, suppresses intestinal transit, decreases electrolyte secretion, suppresses cyclooxygenase and lipoxygenase.	[187,216]
28. *Terminalia Arjuna*	Stem bark, root bark, fruits, heartwood, leaves and seeds	Ethanolic, benzene, ethyl acetate, hexane, aqueous, alcoholic,	Arjungenin, terminoside A, arjunic acid, arjunolic acid, ellagic acid, luteolin, ginsenoside Rg1, ginsenoside Rg3	Exerts free radical scavenging, cardioprotective and anticancer activities, inhibits nitric oxide production, increases NO production, improves lipid profile by activating PPAR-γ.	[184,217,218]

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		methanolic, and acetone extracts			
29. *Terminalia chebula*	Fruits, leaves, seed and bark	Methanol, ethanol, aqueous, acetone, alcoholic extracts	Ellagic acid, chebulic acid, gallic acid, chebulagic acid, berberine, quercetin	Exerts antibacterial, anti-proliferative, hepatoprotective and free radical scavenging and cytoprotective activities, prevents DNA intercalation and DNA gyrase and interacts with β-lactamase enzyme.	[158,219]
30. *Trigonella-foenum graecum*	Leaves, flowers, stem, and seeds	Hexanes, ethyl acetate, methanol, ethanolic, alcoholic, and aqueous, hydroalcoholic extracts	Diosgenin, trigonelline, eugenol, 4-hydroxyisoleucine	Exhibits anti-inflammatory, anticancer, hypoglycemic, neuroprotective and estrogenic properties, enhances GLUT-4 (glucose transporter 4), glucose uptake and increases insulin secretion.	[220]
31. *Zingiber officinale*	Rhizome	Ethanolic, aqueous, methanolic, ethyl acetate, and hexane extracts	6-shogaol, 6-gingerol, 10-gingerol, zingerone, 6-paradol	Exerts antioxidant and anti-proliferative properties, inhibits NF-kB (Nuclear factor kappa B) activation, NO (Nitric oxide) and PGE2 (prostaglandin E2) production, reduces IL-1β (Interleukin 1β) levels, inhibits cell growth, decreases blood glucose levels, enhances glucose utilization and glucose tolerance.	[221]

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32. *Emblica officinalis*	Fruits, leaves, seeds, barks, pulp and roots	Methanolic, ethanol, acetone, aqueous, hexane, chloroform, petroleum ether extracts	Gallic acid, chebulagic acid, pendunculagin, quercetin and ellagic acid	Exhibits antioxidant, free radical scavenging, anti-inflammatory and antitumor activities, has chemopreventive and hepatoprotective effects.	[222]
33. *Hibiscus rosa-sinensis*	Leaves, flowers, roots and stem	Methanolic, aqueous and ethanol extracts	Quercetin, cyanidin, niacin, saponins, flavonoids, β-sitosterol, stigmasterol, and triterpenes	Reduces blood glucose concentration, inhibits oxidative stress damage and lipid peroxidation activity, increases insulin secretion, exerts anti-inflammatory and antioxidant properties	[4,223]
34. *Withania somnifera*	Leaves and roots	Methanolic extract	Withanolide, withaferin-A, withanolide D, viscosalactone B, withanoside V	Induces apoptosis and early ROS (Reactive oxygen species) generation, exhibits anticancer, anti-inflammatory, analgesic, antileukemic, anti-angiogenic, antiproliferative, anti-glycating and free radical scavenging activities, inhibits TNF-α (Tumor necrosis factor-α),and IL-1β (Interleukin-β)	[224,225]
35. *Aconitum heterophyllum*	Roots, leaf, stem and seeds	Ethanolic extract	Aconitine, friedelin	Exerts antidiarrheal, antibacterial, antioxidant, free radical scavenging and hepatoprotective properties	[226,227]

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6. Concluding Remarks

Medicinal plants have long been recognized as important traditional medicines [228]. They have gained widespread popularity as alternative treatment option for diabetes mellitus, cancer, infection, cardiovascular diseases, inflammatory and gastrointestinal disorders [229,230]. In developing countries, medicinal plants are easily accessible, affordable, and often part of the diet [18,231,232]. They are also a rich source of bioactive phytoconstituents that can be used as templates for drug discovery. It has been estimated that around 25% of all currently available drugs derive from phytoconstituents [18,233,234]. In the early stages of drug discovery, the use of *in-vitro* and *in-vivo* experiments helps identify compounds that are safe, effective and with minimal adverse side effects [235]. The majority of the scientific studies evaluating the biological properties of medicinal plants investigated in this review have been conducted in-vitro and in-vivo. Further studies are warranted to fully investigate the clinical therapeutic benefits of the medicinal plants considered, and unravel the mechanisms of action of their bioactive phytoconstituents at the molecular level. Continued efforts to better understand the therapeutic potential of medicinal plants are required to alleviate the global burden of diseases.

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Abbreviations

WHO – World Health Organization
DM – Diabetes Mellitus
CVD – Cardiovascular disease
GI disorder – Gastrointestinal disorder
NSAID – Non-steroidal anti-inflammatory drug
TCM – Traditional Chinese Medicine
PPARγ – Peroxisome proliferator-activated receptor
GHR – Ghrelin
GLP-1 – Glucagon like peptide-1
STZ – Streptozotocin
DPP-IV – Dipeptidyl peptidase IV
AP-1 – Activator protein-1
NF-κB – Nuclear factor kappa B
STAT3 – Signal transducer and activator of transcription 3

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PKC – Protein kinase C
MAPK – Mitogen-activated protein kinase
ACE – Acetylcholinesterase
VSMC – Vascular smooth muscle cell
NO – Nitric oxide
Akt/FoxO3a – Akt, protein kinase B; FoxO3a, forkhead box O
Nrf2 – Nuclear factor erythroid-2-related factor 2
HO-1 – Hemeoxygenase-1
SOD – Superoxide dismutase
GSH-Px – Glutathione peroxidase
CAT – Catalase
GR – Glutathione reductase
GST – Glutathione S-transferase
Γ-GCS – γ-glutamylcysteine synthetase
NQO1 – NADPH: quinone oxidoreductase-1
HSP70 – Heat shock proteins 70
iNOS – Inducible NOS
MPO – Myeloperoxidase
TC – Total cholesterol
LDL- Low density lipoprotein
TG – Triglyceride
MDA – Malondialdehyde
HDL – High density lipoprotein
VLDL – Very low density lipoprotein
SD rats - Sprague-Dawley rats
LPS – lipopolysaccharide
DCMM - Dichloromethane: methanol extract
TNBS - Trinitrobenzenesulfonic acid
ISO – Isoproterenol
CMC – Carboxy methyl cellulose
HDL-C – HDL-cholesterol
LDL-C – LDL-cholesterol
TNF-α – Tumor necrosis factor-α
IL-6 – Interleukin-6
NO – Nitric oxide
AST – Aspartate transferase
ALT- Alanine amino transferase
ALP – Alkaline phosphatase
GGT – Gamma glutamyl transpeptidase
FI – Food intake
FER – Food efficiency ratio
FBG – Fasting blood glucose
GLUT4 – Glucose transporter 4
DGAT-1 – Diacylglycerol o-acyltransferase 1
ApoB100 – Apolipoprotein
ApoA-1 – Apolipoprotein A-1
HbA1c – Hemoglobin A1c
NF-κB – Nuclear factor kappa B
iNOS – Inducible NO synthase
COX-2 – Cyclooxygenase-2
CAT – Catalase

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GSH – Glutathione
LDH – Lactate dehydrogenase
SGOT – Serum glutamic oxaloacetic transaminase
SGPT – Serum glutamate pyruvate transaminase
SALP – Serum alkaline phosphatase
LPO – Lipid peroxidation
GPx – Glutathione peroxidase
HOMA-IS – Homeostasis model assessment-insulin resistance
NEFA – Non-esterified fatty acids
TBARS – Thiobarbituric acid reactive substances
TAA – Total ascorbic acid
HMG-CoA – Hydroxy methylglutaryl-coenzyme A
ApoB – Apolipoprotein B
HMGR – HMG-CoA reductase
GSH – Glutathione
LCAT – Lecithin cholesterol acyltransferase
LPL – Lipoprotein lipase
TNF – Tumor necrosis factor
NK cells – Natural killer cells
GLUT4 – Glucose transporter 4
PGE2 – Prostaglandin E2
IL-1β – Interleukin 1β
ROS – Reactive oxygen species 1.

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