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RECENT ADVANCES IN THE DEVELOPMENT OF POLYHERBAL FORMULATIONS FOR THE TREATMENT OF DIABETES MELLITUS

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ABSTRACT

Ayurveda, a traditional system of medicine, offers holistic approaches to managing various diseases, including the use of herbal medicines. Many researchers have focused on the use of different herbs for curing diseases, and they found it more effective when using a combination of multiple herbs. Polyherbal formulations are combinations of extracts from multiple plants and are explored to enhance therapeutic efficacy. Among the various illnesses, diabetes mellitus is a long-term metabolic condition that poses a serious threat to global health. The role of Ayurveda for curing diabetes includes lifestyle modifications, dietary recommendations, and herbal therapies. Polyherbal formulations are based on Ayurvedic principles that aim to address multiple targets for diabetes management. These formulations often comprise a blend of medicinal plant extracts containing diverse phytoconstituents. Polyherbal formulations are found to be more effective for treating diabetes mellitus due to the synergistic effect of herbal combinations and lower adverse effects than other medicinal systems. This article describes the role of the polyherbal formulations that were developed by various researchers in the last decade for the treatment of diabetes mellitus.

Keywords: Ayurveda, Herbal medicines, Polyherbal formulations, Diabetes mellitus, Streptozotocin and alloxan.

1 INTRODUCTION

In recent decades, exponential growth has been observed in the development of herbal medicine. Today, around 80% of people in the developing countries are depend on traditional medicine for their healthcare requirements, primarily medicines based on various species of plants. Ancient literature gives details of approximately 500 plants with their medicinal uses, while 800 plants have been utilized in indigenous medicine systems. Ayurveda, Siddha and Unani are some of the indigenous systems that employ different species of plants to treat various disease conditions [1]. The use of medicinal

plants as the main treatment part is a widespread practice across cultures. Although they typically don't have any negative effects or major side effects, herbs can be used as effectively as prescription medications. These natural remedies are a valuable gift from nature to humanity, and there is still much to discover and understand about their benefits [2]. In ancient cultures like India, Egypt, China, Rome, and Greece, plants were highly regarded as divine and supernatural healers. The use of plants as medicine has significantly influenced traditional medical systems like Ayurvedic, Unani and Chinese medicine. In addition to providing food, shelter, clothing, flavor, and fragrance, plants have become an essential source of medicine for fulfilling one of the basic needs of human beings [3]. In traditional herbal therapy, injuries or illnesses are treated with various plants or plant materials, either naturally or by processing of plant material. Medicinal plants with ethnomedicinal values are currently being studied for their therapeutic potential [4].

2 POLYHERBAL FORMULATIONS AND DIABETES MELLITUS

Polyherbal formulations are mixtures that contain two or more herbs. Ayurvedic drug formulation is based on two principles: use of a single drug or combining multiple drugs, later referred to as polyherbal formulation [1]. Polyherbal formulation, also known as polyherbal therapy or herb-herb combination, has been commonly employed worldwide for its medicinal as well as therapeutic applications [4]. In 1996, the World Health Organization (WHO) issued crucial guidelines for the assessment of herbal medicines. These guidelines were specifically created to basic standards for evaluating the quality, safety and efficacy of herbal medicines. The ultimate aim was to provide valuable support to national regulatory authorities, scientific organizations and manufacturers in their efforts to assess documentation, submissions and dossiers concerning herbal products. The principal objective of these guidelines was to ensure that herbal medicines meet rigorous standards and can be considered safer and effective for human usage. By setting these standards, the WHO sought to enhance public health by encouraging the suitable use of herbal remedies and products [5]. Ayurveda is an ancient Indian medicinal system focused on preventing suffering through diseases and promoting a long, healthy life. It uses natural elements to address the root cause of diseases by restoring balance and advocating a healthy lifestyle to prevent future imbalances. Ayurveda, originating in India thousands years ago, is referred to as the "Mother of All Healing." Etymologically, it combines the Sanskrit words "ayur" (life) and "veda" (science or knowledge), signifying "the science of life." It aims to achieve harmony and balance in all aspects of life, encompassing the mind, body, and spirit [6]. Ayurvedic physiology is based on the three humoral pathophysiological elements known as the Doshas, which are the fundamental basis for all psychosomatic functions or homeostasis. Vata, Pitta, and Kapha are the three doshas [7]. Polyherbal formulations can be prepared in various dosage forms to suit different routes of administration and patient preferences. Some common examples of dosage forms for polyherbal formulations include tablets [8], capsules [9, 10], powders [11], granules [12], syrups [10, 13], herbal oils [14], lotions [15], ointments and creams [16], gels [17], toothpastes [18], teabags [19] etc. Polyherbal formulations are now available for the treatment of various diseases, and this has been proven by various researchers. Based on the herbal constituents and their composition, polyherbal formulations show various pharmacological effects like wound healing [20], antidiabetic [21, 22], anticancer [23], anti-inflammatory, antioxidant [24], antimicrobial [25, 26] and much more.

Diabetes mellitus is a common endocrine disorder affecting a large population worldwide. It has various causes, including physical inactivity, obesity, family history, race, and age. The diabetic condition can lead to life-threatening complications like neuropathy, nephropathy, retinopathy, and cardiovascular disorders. While synthetic antihyperglycemic agents are commonly used for treatment, their serious side effects have led people to turn to herbal remedies, which are gaining popularity [27]. Diabetes mellitus involves a group of heterogeneous disorders that cause a rise in concentration of blood glucose. Diabetes mellitus has been sub-classified as type 1 diabetes, type 2 diabetes, neonatal diabetes, maturity-onset diabetes of the young (MODY), gestational diabetes and steroid-induced diabetes. The present classification for diabetes mellitus is type 1 or type 2 diabetes. The correct diagnosis of diabetes is done by biochemical diagnosis during fasting and by oral glucose tolerance tests, as well as by hemoglobin A1c (HbA1c) estimation [28, 29].

2.1 Causes of Diabetes Mellitus

The abnormalities or disruptions in the gluco-receptor of the ß cells which make them respond to an increased level of glucose or to a relative lack of ß cells. Either way, the decreased insulin production can lead to ß-cell failure, and the direct impact of hyperglycemia on neuronal metabolism and theory of principle in microvascular disease that leads to brain hypoxia. Insulin receptors are ‘downregulated' and there are fewer receptors in peripheral tissues. They are normal, but hypersensitive and hyperinsulinemic and have dyslipidaemia, hyperuriaemia, and abdominal obesity. This gives rise to resistance to relative insulin, mostly in the muscles, fat and liver. Hyperinsulinemia has been associated to angiopathy. Relative insulin shortage is due to fat, excess hyperglycemia hormone (glucagon) etc. and the ß cells lag behind. The two concepts have proven that disorders of nitric oxide metabolism result in nerve injury and changes in perineural blood flow. Other rare forms of diabetes mellitus include MODY, some endocrine disorders, pancreatectomy and gestational diabetes mellitus (GDM) (type 3). Diabetes mellitus can be caused by the disturbance of some receptors. The glucagon-like peptide-1 (GLP-1) receptor, beta3 (ß3) ardent receptor, peroxisome proliferator activated (γ) receptor (PPARγ), and some enzymes

like as α glycosidase and dipeptidyl peptidase IV enzyme are examples of specialized receptors. The major areas of current research into diabetic neuropathy include protein kinase C, oxidative stress, advanced glycation end products and the polyol pathway [30-33].

2.2 Role of Polyherbal formulations in Management of Diabetes mellitus

Diabetes mellitus, a worldwide pandemic, can be effectively managed with polyherbal formulations. These treatments have fewer side effects, are cost-effective and are readily available [34]. Some of the polyherbal formulations that show an antidiabetic effect are highlighted below:

Aher et al. (2026) developed polyherbal formulation using Hydroalcoholic extracts of *Azadirachta indica, Momordica charantia, Gymnema sylvestre* and *Trigonella foenum-graecum*. The prepared formulation evaluated and useful for the control and treatment of type 2 diabetes mellitus [35]. Jilakara et al. (2025) developed a polyherbal nanosuspension formulation for the treatment of diabetes mellitus [36]. Kaur and Sharma (2023) have prepared antidiabetic capsules. They formulated a polyherbal dosage form consisting of the well-known plant anti-diabetic constituents such as leaves of *Azadirachta indica*, berries and fruit coat of *Withania coagulans,* heartwood of *Pterocarpus marsupium* and rhizomes of *Picrorhiza kurroa*. They blended different methanolic extracts of these components in equal proportions to form the polyherbal extract and tested it for in-vitro antioxidant and antidiabetic activities. The antidiabetic action revealed dose-dependent behavior as compared with the industry standards. In general, their study suggested that they were stable and effective in treating hyperglycemia in the study of polyherbal capsules [37]. The study of Paul and Majumdar (2023) deals with the study of 'Madhurakshak Activ', a formulation of polyherbal, which contains *Momordica charantia, Syzygium cumini, Mangifera indica* and *Gymnema sylvestre*, all of which are an antidiabetic drug. They used in vitro and in silico techniques to estimate the glucose absorption, diffusion, amylolysis kinetics and its transport across yeast cells with the aqueous and hydro-alcoholic extracts of Madhurakshak Activ. They conclude that there is a dose dependent glucose adsorption, glucose uptake to yeast cells is linear with the amount of glucose and glucose diffusion is proportional to time [38]. Kitphati et al. (2023) have prepared a polyherbal formulation and also evaluated the glucose uptake stimulatory activities and hepatic safety. Main ingredients in this formulation are extracts of leaves of *Andrographis paniculate, Orthosiphon aristatus, Phyllanthus niruri, Syzygium polyanthum* leaves, bark of *Cinnamomum verum* and rhizome of *Curcuma zanthorrhiza* and *Curcuma longa*. Indirect glucose oxidase method is used for the assessment of glucose uptake stimulatory activity. Their findings showed that both extracts enhanced glucose uptake by 23.88±5.21% (water) and 55.58±1.24% (ethanol) when compared with the control [39]. Akhtar et al. (2023) investigated the therapeutic potential of a polyherbal emulsion in diabetic rats induced by aloxan, which revealed its antioxidant properties, α-amylase inhibitory activity, hypoglycemic, hypolipidemic and histoprotective effects on pancreas and kidney. *Citrullus colocynthis, Nigella sativa* and *Silybum marianum* extracts and oils are the source of the polyherbal formulation. The formulation was found to significantly decrease blood glucose levels, triglycerides, total cholesterol, LDL-c and VLDL-c. The formulation also increased insulin and HDL-c levels in an in vivo experiment in alloxan induced diabetic rats. Furthermore, histopathological normalization was found in tissues of pancreas and kidney of treated rats [40]. Most of the marketed allopathic medicines show adverse effects on some patients. Alhamhoom et al. (2023) investigated the anti-diabetic effects of a polyherbal formulation (PHF) and an allopolyherbal formulation (APHF) to enhance therapeutic efficacy and minimize side effects by reducing individual herb dosages. Prepared PHF contains leaf extracts of *Cassia auriculata*, *Centella asiatica* and rhizome extracts of *Zingiber officinale*, while APHF is prepared by combining PHF and metformin. Streptozotocin-induced diabetic albino rats were administered PHF, APHF and metformin for 21 days. Histopathological analysis of the liver and pancreas was also performed. Significant anti-diabetic and anti-hyperlipidemic effects were demonstrated by both PHF and APHF, with APHF demonstrating the most promising effect when compared to PHF alone [41]. One of the best methods of preparing stable formulations for treating diabetes is by the use of polyherbal granules. Iqbal et al. (2023) formulated new polyherbal granules as dried seed extracts of *Hordeum vulgare: Elettaria cardamomum: Cicer arietinum* (2.5:1:1) according to the traditional uses of these seeds in glycemic management in diabetes. The PHGs was evaluated for in vitro antidiabetic activity by α-amylase and α-glucosidase enzyme inhibition assay. The PHGs exhibited a significant antioxidant and antidiabetic activity in vitro, with an IC50, which is associated to their ability to neutralize the free radical and inhibit the specific enzyme involved in diabetes [42]. Mahapatra and Verma (2022) formulated and tested a novel antidiabetic polyherbal formulation using different ratios of *Annona squamosa* (leaves) and *Withania somnifera* (roots), *Tinospora cordifolia* (stems) and *Azadirachta indica* (leaves). In the experimental rats, the substantial reduction in blood glucose levels was detected related to diabetic control group when different prepared formulations and Glibenclamide as reference drug were administered to them [43]. Polyherbal formulation of antidiabetic tablet with streptozotocin induced diabetic rats has been developed and evaluated by Majhi et al. (2022). The extracts from *Aloe vera, Capparis decidua, Camellia sinensis, Phyllanthus amarus, Musa sapientum, Punica granatum* Flower, *Punica granatum* Seed and *Tinospora cordifolia* were found to have antihyperlipidemic and antioxidant activity. The hypoglycemic and antihyperglycemic activities were evaluated in diabetic and normoglycemic rats and at certain doses the polyherbal extract was found to be more effective. They have observed that developed polyherbal extract (dose: 400 mg/kg followed by 200 mg/kg) could be a source for new antidiabetic drugs and improvements were observed

in diabetic complications [44]. When treating diabetes mellitus, precautions should be taken to prevent side effects of the formulation administered. Gardezi et al., (2022) prepared and evaluated the antioxidant, antidiabetic, hepatoprotective and nephroprotective potential of a combination of methanolic extracts of *Nigella sativa, Cicer arietinum, Silybum marianum* and *Citrullus colocynthis* seeds, and *Zingiber officinale* rhizome in alloxanized diabetic rats. The polyherbal extract has an appreciable hypoglycemic activity, which lowers blood glucose level and enhances insulin level. Liver protective effects of the extract are also observed by decreasing the concentration of liver marker enzymes. The study proposes that the polyherbal extract might be used as a herbal medicine for reducing the severity of diabetes and its use could be extended to nutraceuticals where it could be used as a substitute for antidiabetic drugs from chemical origin [45]. The hydroalcoholic polyherbal extract of *Ichnocarpus frutescens, Ficus dalhousie, Crateva magna, Alpinia galangal* and *Swertia chirata* has been investigated for its in vitro α-amylase inhibitory effect by Quazi et al. (2022). The extract exhibited good activity in inhibiting alpha-amylase with the percentage of inhibition as 72.96 ± 0.70% at 16 mg/mL, which is comparable with the standard drug acarbose (78.40 ± 0.36%). The various chemical classes present in the extract such as alkaloids, glycosides, polyphenols, tannins and terpenoids indicates that the extract has potential antidiabetic activity by inhibiting alpha-amylase [19]. Shanmugam et al, (2022) developed a new antidiabetic polyherbal formulation. The study is aimed at understanding the concept of synergism in herbal therapies which is based on a polyherbal aqueous extract of *Gymnema sylvestre, Mangifera indica, Momordica charantia* and *Syzygium cumini* for their antidiabetic activity. The anti-diabetic activity was assessed in streptozotocin induced diabetic rats and recorded the histopathological changes of the pancreas after acute toxicity evaluation of the both extracts. *Gymnema sylvestre* aqueous extract showed good blood sugar control whereas the polyherbal extracts had highly significant antidiabetic activity which was more pronounced than that of Glibenclamide [46]. Kambale et al. (2022) discussed the application of Nanotechnology in the formulation of polyherbal medicine for diabetes. Lifestyle, exercise and medication are needed for a lifetime to manage the high blood glucose caused by a lack of insulin production or use, but they are still not curable. Conventional treatment is still very expensive therefore, many people are resorting to herbal treatment, but their effectiveness is limited because of poor bioavailability. Nanoparticulate formulations of plant origin (plant nanomedicines) are investigated to improve the efficacy of plant extracts or plant compounds used in the treatment of diabetes. These formulations have demonstrated promising results in improving the bioavailability and the amount of the necessary dose required for the treatment [47]. The antidiabetic and antihyperlipidemic properties of a polyherbal formulation comprising of seven plants were studied in STZ-nicotinamide induced diabetic rats by Kishor et al. (2021). The effect of two doses orally (200 mg/kg and 400 mg/kg) was compared with glibenclamide (5 mg/kg). The blood glucose level, lipid profile, lipoproteins and hepatic marker enzymes were found to be highly reduced in diabetic rats treated with PHF. The histopathological examination showed an improvement of the pancreatic tissues [48]. Gopalakrishnan et al. (2020) studied the effect of a polyherbal remedy on insulin resistance and oxidative stress in rats with high fat diet induced type 2 diabetes mellitus. According to their investigation, diabetic rats had higher glucose concentrations and higher concentrations of triglycerides, cholesterol, low-density lipoprotein cholesterol and lower the concentrations of insulin and high-density lipoprotein cholesterol. PHF when given orally was observed to reduce glucose, triglycerides, cholesterol and LDL-cholesterol levels whereas increasing HDL-cholesterol as well as insulin levels [49]. Dhakar and Dwivedi (2020) formulated a polyherbal recipe with ethanolic extract of leaves of some medicinal plants and evaluated the antidiabetic activity of the formulation in animals. *Azadirachta indica, Allium sativum* and *Annona squamosa* are common Indian herbs used in the treatment of several diseases such as diabetes mellitus. The rats with alloxan and streptozotocin-induced diabetes were orally given the formulation prepared from the ethanolic extract of the plants leaves. The polyherbal formulation at the dosage of 200 mg/kg showed significant antidiabetic activity which was equivalent to the drug use as standard. Biochemical and histopathologic studies support this effect and indicate that the polyherbal formulation may be effective in treating diabetes [50]. Jain and Soni (2019) formulated and assessed the antidiabetic potential of a polyherbal pill that contained methanol extracts of *Carissa carandus, Ocimum sanctum, Moringa oleifera* and *Manilkara zapota*. The formulation exhibits positive effects which significantly reduced blood glucose levels, lipid profile and body weight in diabetic animals than in controls [51]. Solairaj and Jebaseelan (2019) designed and tested a polyherbal formulation to prevent diabetes by streptozotocin-induced diabetes in rats. The polyherbal formulation of the leaves of *Madhuca indica, Aegle Marmelos* and the rhizome of *Costus speciosus* was fed to normal and diabetic rats. Dose levels of 200 mg/kg and 400 mg/kg of the polyherbal formulation exhibited the lowest blood glucose levels on days 1, 5 and 10. As compared to all its doses, the polyherbal formulation 24 hours after oral administration was found to cause significantly lower blood glucose level [52]. The polyherbal formulation consisted of the combination of the five plants *Phyllanthus amarus, Tinospora cordifolia, Emblica officinalis, Eugenia jambolana, Gymnema sylvestre,* and *Cassia auriculate* which were developed by Telapolu et al. (2018). The glucose-lowering ability of the hydroalcoholic extract of the formulation was investigated. To understand the effect of the formulation hydroalcoholic extract on the expression of the mRNA of the glucose transporter, RT-PCR was used [53]. Moukette et al. (2017) studied antidiabetic activities of an aqueous extract of three plants, *Spilanthes africana, Portulaca oleracea* and *Sida rhombifolia* on streptozotocin induced diabetic rats. The diabetic rats were treated with different doses of the extract mixture for 21 days, while a positive control was used as glibenclamide. They found that the glycaemia, triglyceride, total cholesterol and LDL-cholesterol levels decreased significantly with the use of the extract mixture [54]. Tomy, et al., (2016) pointed out the antidiabetic activity of polyherbal formulations. They assessed the

antidiabetic activity of "KathakakhadiradiKashyam" (KKS) as an indigenous polyherbal ayurvedic formulation obtained from the drug store of Ayurveda College, Coimbatore (AVP Ayurveda Pharmaceuticals) using diabetes induced rat model of streptozotocin. The results of the experiments exhibited that the KKS treated group had similar or better glucose lowering activity as compared with the group which was treated with standard drugs. They have found that KKS has potential as an antidiabetic agent [55]. Babu et al. (2016) evaluated the antidiabetic activity of polyherbal formulations such as extracts and decoctions of different parts of plant like leaves of *Annona squamosa, Psidium guajava, Tinospora cordifolia, Bougainvillea species, Aegle marmelos* and fruits of *Terminalia chebula*, Ficus carica and *Emblica officinalis*, flowers of *Hibiscus rosa-sinensis, Cassia auriculata*, rhizome of *Zingiber officinale* in experimentally induced hyperglycemic rats. They finally found that polyherbal formulations, especially in extracts, exhibited strong antidiabetic activity regarding controlling hyperglycemia [56]. The anti-diabetic activity of the polyherbal formulation was evaluated in type 2 diabetic rats induced by streptozotocin by Nagja et al. (2016). The formulation mixture contains hydroalcoholic extracts of *Andrographis paniculate, Eugenia jambolana, Gymnema sylvestre* and *Momordica charantia* and an extract of *Myristica fragrans* which had been previously treated with sodhana. They found that the blood glucose level decreased considerably at the given dosage [57]. Subhasree et al. (2015) prepared a polyherbal formulation for the treatment of diabetes. A polyherbal formulation of *Garcinia indica, Lagerstroemia parviflora, Salacia oblonga* and *Salacia roxbhurgii* was examined for its antidiabetic and antihyperlipidemic activity in streptozotocin induced diabetic rats. They reported that both blood glucose level and lipid level were significantly decreased in rats fed PHF and metformin. Besides, the actions of the enzymes involved in gluconeogenesis reduced and the histopathological examination indicated a positive effect on organs like pancreas, liver, and kidney [58]. In diabetic Wister rats induced by streptozotocin-nicotinamide, Petchi et al. (2014) have tested developed a polyherbal capsule formulation. A polyherbal formulation of *Tridax procumbens, Glycosmis pentaphylla* and *Mangifera indica* (2:2:1 ratio) is studied by them for its antidiabetic activity. The polyherbal formulation given to diabetic rats shows marked antidiabetic activity at 250 mg/kg and 500 mg/kg that were similar to glibenclamide, based on biochemical and histopathologic analysis [21]. Panda et al. (2013) tested the effect of polyherbal mixtures on the treatment of diabetes. The polyherbal formulation prepared by them consists of *Annona squamosa, Azadirachta indica, Aegle marmelos, Cajanus cajan, Cinnamomum tamala, Ferulaassa foetida, Gymnema sylvestre, Moringa oleifera, Tamarindus indica, Trigonella foenum-graecum,* and *Zingiber officinale*. The effect of formulated blends has been evaluated in diabetic rats induced by streptozotocin and has been corelated with glibenclamide. Glibenclamide was found to be as effective in bringing the enzyme levels down to normal. Suggesting their antihyperglycemic properties, the mixes were able to bring the glycemic level back to nearly normal level in the treated group [59]. Gauttam and Kalia (2013) emphasized on the polyherbal intervention to solve the complications related to metabolic diseases especially against diabetes. They optimized the phospholipid-encapsulated polyherbal anti-diabetic formulation which comprised *Withania somnifera, Trigonella foenum-graecum* and *Momordica charantia* extracts. The optimized formulation (HA) is then encapsulated in a vesicle system (HAL) which is characterized with respect to various parameters. The antidiabetic activity of HA and HAL has been compared with a commercially available polyherbal formulation in streptozotocin induced diabetic rats in a study of 21 days. Phospholipid encapsulation was found to be effective in improving therapeutic outcomes with HAL (500 mg/kg) showing enhanced antidiabetic potential as compared to HA (1000 mg/kg) and comparable to metformin (500 mg/kg) [60]. A polyherbal formulation was developed by Yadav et al. (2013) and the hypoglycemic activity was studied by feeding the formulation to rats at varying doses once a day. The diabetic rats induced by streptozotocin showed significant differences in body weight, blood glucose, blood urea nitrogen and creatinine, alkaline phosphatase and serum amylase, serum cholesterol, serum transaminases. Liver and pancreas showed significant effects as revealed by histopathological examination [61].

Following table no.1 summarizes various studies on polyherbal formulations for diabetes treatment, detailing their formulations key plant ingredients and key findings related to antidiabetic activities.

Table 1: Summary of recent advancement in polyherbal formulations useful for treatment of diabetes [35-61].

Formulation Developed by-	Plants Used in Polyherbal Formulation	Key Findings
Aher et al. (2026)	Azadirachta indica, Momordica charantia, Gymnema sylvestre and Trigonella foenum-graecum	Polyherbal formulation evaluated and found effective against type 2 diabetes mellitus
Jilakara et al. (2025)	Gymnema sylvestre, Momordica charantia and Trigonella foenum-graecum	Developed a polyherbal nanosuspension formulation for the treatment of diabetes mellitus
Kaur and Sharma (2023)	Azadirachta indica, Picrorhiza kurroa, Pterocarpus marsupium and Withania coagulans	Stable polyherbal capsule formulation effective against hyperglycemia

Paul and Majumdar (2023)	Gymnema sylvestre, Mangifera indica, Momordica charantia and Syzygium cumini,	Dose-dependent glucose adsorption and diffusion
Kitphati et al. (2023)	Andrographis paniculata, Orthosiphon aristatus, Phyllanthus niruri, Syzygium polyanthum, Cinnamomum verum, Curcuma zanthorrhiza, Curcuma longa	Increased glucose uptake (up to 55.58% with ethanol extract)
Akhtar et al. (2023)	Nigella sativa, Citrullus colocynthis, Silybum marianum	Significant drop in blood glucose, cholesterol and triglycerides; histopathological normalization in pancreas and kidneys
Alhamhoom et al. (2023)	Cassia auriculata, Centella asiatica, Zingiber officinale	Anti-diabetic effect and anti-hyperlipidemic effects; improved histopathology of liver and pancreas
Iqbal et al. (2023)	Cicer arietinum, Elettaria cardamomum, Hordeum vulgare	Strong antioxidant and antidiabetic activities; good inhibitory effect against alpha-amylase and alpha-glucosidase enzymes
Mahapatra and Verma (2022)	Annona squamosa, Azadirachta indica, Tinospora cordifolia, Withania somnifera	Significant decrease in blood glucose levels comparable to Glibenclamide
Majhi et al. (2022)	Aloe vera, Camellia sinensis, Punica granatum, Capparis decidua, Tinospora cordifolia, Phyllanthus amarus, Musa sapientum,	Antihyperlipidemic and antioxidant activities; effective in normoglycemic and diabetic rats
Gardezi et al. (2022)	Cicer arietinum, Citrullus colocynthis, Nigella sativa, Silybum marianum, Zingiber officinale	Substantial hypoglycemic and hepatoprotective effects
Quazi et al. (2022)	Alpinia galangal, Crateva magna, Ficus dalhousie, Ichnocarpus frutescens, Swertia chirata	Significant alpha-amylase inhibition; potential antidiabetic activity through various chemical classes
Shanmugam et al. (2022)	Gymnema sylvestre, Momordica charantia, Syzygium cumini, Mangifera indica	Synergistic antidiabetic activity; significant effects in diabetic rats induced with streptozotocin
Kambale et al. (2022)	-	Highlighted use of nanotechnology in polyherbal formulations for diabetes treatment with enhanced bioavailability and efficacy of plant extracts
Kishor and Lalitha (2021)	Cassia auriculata, Cassia fistula, Cyperus rotundus, Salacia reticulate, Saussurea lappa, Syzygium cumini, Terminalia arjuna	Reduced blood glucose levels and show better lipid profile and hepatic marker enzymes
Gopalakrishnan et al. (2020)	Cassia auriculata, Cinnamomum Zeylanicum, Gymnema sylvestre, Syzygium cumini, Trigonella foenum- graecum,	Improved insulin resistance and oxidative stress in diabetic rats
Dhakar and Dwivedi (2020)	Azadirachta indica, Allium sativum, Annona squamosa	Significant antidiabetic activity comparable to standard drug
Jain and Soni (2019)	Carissa carandus, Ocimum sanctum, Moringa oleifera, Manilkara zapota	Positive effects on body weight, blood glucose levels and lipid profiles in diabetic animals
Solairaj and Jebaseelan (2019)	Aegle marmelos, Costus speciosus, Madhuca indica	Significant drop in blood glucose levels in diabetic rats

Telapolu et al. (2018)	Cassia auriculate, Emblica officinalis, Eugenia jambolana, Gymnema sylvestre, Phyllanthus amarus, Tinospora cordifolia	Glucose-lowering ability of hydroalcoholic extract; impact on glucose transporter mRNA expression
Moukette et al. (2017)	Portulaca oleracea, Spilanthes africana, Sida rhombifolia	Significant reduction in glycaemia, cholesterol, triglyceride, and LDL-cholesterol levels
Tomy et al. (2016)	Aegle marmelos, Annona Squamosal, Mentha spicata, Murraya koenigii, Trigonella foenum-graecum	Glucose-lowering activities comparable to standard drug
Babu et al. (2016)	Annona squamosa, Psidium guajava, Tinospora cordifolia, Bougainvillea species, Aegle marmelos, Terminalia chebula, Ficus carica, Emblica officinalis, Hibiscus rosa-sinensis, Cassia auriculata, Zingiber officinale	Significant antidiabetic activity in hyperglycemic rats
Nagja et al. (2016)	Momordica charantia, Eugenia jambolana, Gymnema sylvestre, Andrographis paniculata, Myristica fragrans	Significant decline in blood glucose levels
Subhasree et al. (2015)	Garcinia indica, Lagerstroemia parviflora, Salacia oblonga, Salacia roxbhurgii,	Reduction in blood glucose and lipid levels; positive effects on gluconeogenic enzyme activities and organ histopathology
Petchi et al. (2014)	Glycosmis pentaphylla, Tridax procumbens, Mangifera indica	Significant antidiabetic activity comparable to glibenclamide
Panda et al. (2013)	Aegle marmelos, Azadirachta indica, Annona squamosa, Cajanus cajan, Cinnamomum tamala, Ferula assafoetida, Gymnema sylvestre, Moringa oleifera, Tamarindus indica, Trigonella foenum-graecum, Zingiber officinale,	Effective antihyperglycemic properties
Gauttam and Kalia (2013)	Momordica charantia, Trigonella foenum-graecum, Withania somnifera	Enhanced antidiabetic potential through phospholipid encapsulation; comparable effectiveness to metformin
Yadav et al. (2013)	Azadirachta indica, Caesalpinia bonducella, Momordica charantia,, Syzygium cumini, Trigonella foenum-graecum	Significant changes in biochemical parameters indicative of improved diabetic condition

List of abbreviations

- WHO: World Health Organization
- MODY: Maturity-onset diabetes of the young
- LDL-c: Low-density lipoprotein-cholesterol
- VLDL-c: Very-low-density lipoprotein-cholesterol
- HDL-c: High-density lipoprotein cholesterol
- PHF: Polyherbal formulation
- APHF: Allopolyherbal formulation
- STZ: Streptozotocin
- OJ: Ojamin
- KKS: KathakakhadiradiKashyam
- HPTLC: High-Performance Thin-Layer Chromatography
- ICH: International Council for Harmonisation

3 CONCLUSION

Ayurveda's holistic approach to disease management, particularly in the context of diabetes mellitus, emphasizes the effectiveness of polyherbal formulations. The combination of diverse plant extracts in these formulations, aligned with Ayurvedic principles, offers a promising avenue for addressing the complexities of diabetes. The present article focuses on recent research and development of polyherbal formulations in the past decade, highlighting their potential as innovative formulations for the treatment of diabetes.

STATEMENTS ON COMPLIANCE WITH ETHICAL STANDARDS

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding this manuscript.

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