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MEDICINAL EFFICACY AND PHARMACOLOGICAL PROFILE OF VIJAYSAR (*PTEROCARPUS MARSUPIUM* ROXB.), JARUL (*LAGERSTROEMIA SPECIOSA* LINN.), AND METHIKA (*TRIGONELLA FOENUM-GRAECUM* LINN.): A REVIEW ARTICLE

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ABSTRACT

Type 2 diabetes mellitus (T2DM) is the most common metabolic disorder characterized by chronic hyperglycaemia due to insulin resistance, impaired insulin secretion and progressive pancreatic β-cell dysfunction. Pharmacological treatments are effective, but the increasing prevalence of T2DM and the limitations of long-term therapy have led to an increased interest in complementary strategies such as medicinal plants. Some of the traditional plants with antidiabetic properties are Vijaysar (*Pterocarpus marsupium* Roxb.), Jarul or Banaba (*Lagerstroemia speciosa* (L.) Pers.) and Methika or Fenugreek (*Trigonella foenum-graecum* L.). The biological activities of these have been ascribed to a wide variety of phytochemicals including epicatechin, pterostilbene, marsupin, corosolic acid, ellagitannins, galactomannan, 4-hydroxyisoleucine and steroidal saponins. Experimental studies indicate the possibility of these plants affecting glucose uptake, insulin secretion, insulin signaling, carbohydrate digestion, hepatic gluconeogenesis, oxidative stress and lipid metabolism. Also, human studies showed improvements in glycemic parameters, but the quality and quantity of evidence differs substantially between plants. Fenugreek has relatively better clinical data like randomized controlled trials and meta-analysis while Vijaysar and

Jarul have lesser evidence. Here we review phytochemical composition, proposed mechanisms, experimental evidence, clinical studies, safety considerations and needs of future research of these three medicinal plants in T2DM. The successful integration of these botanicals into evidence-based management of diabetes will require standardization of plant preparations, rigorous randomized controlled trials and systematic evaluation of herb-drug interactions. Type 2 diabetes mellitus Vijaysar Pterocarpus marsupium Jarul Lagerstroemia speciosa Banaba Methika Fenugreek Trigonella foenum-graecum phytochemicals insulin resistance medicinal plants.

KEYWORDS: Type 2 diabetes mellitus, Vijaysar, *Pterocarpus marsupium*, Jarul, *Lagerstroemia speciosa*, Banaba, Methika, Fenugreek, *Trigonella foenum-graecum*, phytochemicals, insulin resistance, medicinal plants.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a major metabolic disorder characterized by persistent hyperglycemia caused by insulin resistance, inadequate insulin secretion and progressive pancreatic β-cell dysfunction. It is a growing problem with increasing prevalence and a major public health problem. Chronic hyperglycaemia is associated with increased risks of microvascular complications (retinopathy, nephropathy and neuropathy) and cardiovascular disease.[1,2,3] The management of T2DM continues to be based on lifestyle modification and pharmacotherapy. Nevertheless, medicinal plants of traditional use have been of scientific interest since they are a source of different bioactive compounds, which can act on multiple pathways involved in glucose homeostasis and metabolic regulation.[4,5] Past use is a eason to investigate, but not by itself evidence of clinical efficacy or safety. The potential antidiabetic effects of medicinal plants have been investigated and Vijaysar (*Pterocarpus marsupium*), Jarul or Banaba (*Lagerstroemia speciosa*) and Methika or fenugreek (*Trigonella foenum-graecum*) are of special interest.[6,7,8,9,10,11] The plants differ in their primary phytochemical components and proposed mechanisms of action. The activity of pancreatic β-cells and insulin pathways in response to phenolic compounds present in Vijaysar has been studied. Jarul is known to have corosolic acid and other polyphenolic compounds related to glucose uptake. Fenugreek contains soluble dietary fiber and components that may affect carbohydrate absorption, insulin secretion, and lipid metabolism. There is a variable amount and quality of clinical evidence despite promising experimental findings. In this review, we critically assess the phytochemistry, proposed molecular mechanisms, preclinical and clinical

evidence, and safety of these three plants, emphasizing the limitations that must be addressed before recommending their use as an adjunct to conventional diabetes treatment.

Vijaysar (*Pterocarpus marsupium* Roxb.)

Botanical and traditional importance

Vijaysar or Bijasar or Indian kino is a member of the family Fabaceae. It has been used in traditional Indian medicine for a long time. “The main plant material traditionally studied for its medicinal properties is the heartwood but bark, leaves and gum have also been used in traditional medicine. The preparations are water, powders and extracts soaked in heartwood.[6,12,13] Vijaysar has a long history of traditional use, leading to pharmacological investigation especially on its possible effects on glucose regulation. However, the differences in the plant material, in the extraction procedures, and in the preparation methods can influence the chemical composition and the biological activity.

Phytochemical constituents

Bioactive constituents of P. marsupium include epicatechin, pterostilbene, marsupin, pterosupin, liquiritigenin and other phenolic compounds.[13,14,15,16] Epicatechin has been of particular interest because of its reported effects on pancreatic β-cell function and glucose metabolism. A related stilbene compound, pterostilbene, that is structurally similar to resveratrol, has also been studied for its potential metabolic and antioxidant properties. The biological effects of Vijaysar may be attributed to the synergistic action of different phytochemicals. However, the role of individual compounds and possible synergistic effects need to be explored.

Proposed antidiabetic mechanisms

Experimental data suggest that Vijaysar may modulate glucose metabolism through several complementary mechanisms. Function and protection of pancreatic beta cells. The effects of epicatechin and related phenolic compounds on pancreatic β-cell function, insulin biosynthesis and secretion have been studied. Furthermore, they could have antioxidant properties that reduce oxidative damage related to β-cell dysfunction.[14,15] lucose utilization by peripheral tissues. Experimental studies have reported glucose-lowering effects of extracts and isolated constituents of Vijaysar. These effects may include an increase in glucose utilization and changes in insulin-related metabolic activity.[14,16] Insulin signal modification. The components of Vijaysar have been studied for their possible impact on pathways such as AMP-activated protein kinase (AMPK) and protein kinase B (AKT involved in glucose

transport and metabolic regulation. However, the clinical significance of these proposed mechanisms is not clear.[15,16] Antioxidant activity. Inhibition of carbohydrate digesting enzymes. The experimental results suggest that extracts of Vijaysar may inhibit enzymes involved in digestion of carbohydrates. Phenolic constituents may also contribute to antioxidant activity that may reduce oxidative stress associated with chronic hyperglycemia.[13,14,15,16] These mechanisms provide a biological rationale for future studies, but should not be considered established therapeutic effects in humans.

Jarul (*Lagerstroemia speciosa*): Banaba

Botanical background

Lagerstroemia speciosa (L.) Pers. *Family:* Lythraceae. Common names: Jarul or Banaba In traditional medicine, the leaves have been used for diabetes management in Southeast Asia.[7] Leaves are rich in different classes of bioactive compounds like triterpenoids, ellagitannins, flavonoids, and other phenolic compounds. Corosolic acid is one of the most widely studied constituents of these.[7,20]

Corosolic Acid

Corosolic acid is a pentacyclic triterpenoid and is one of the major bioactive components that contribute to the glucose-lowering properties of Banaba. Experimental studies suggest the potential for increased glucose uptake and action on insulin-sensitive metabolic pathways.[20,21] Other phenolic constituents, besides corosolic acid, can be responsible for the overall biological activity of the plant. Therefore, whole-plant extracts should not be automatically assumed to be pharmacologically equivalent to purified corosolic acid.[21-23]

Mechanisms of action of Jarul

Several mechanisms have been proposed for the antidiabetic activity of *L. speciosa*.

Corosolic acid has been shown to improve glucose disposal from the circulation, possibly due to enhanced cellular glucose uptake.[20,21]

Modulation of insulin signalling

Experimental studies indicate that corosolic acid may affect insulin-related signaling pathways that are involved in glucose transport.[21]

Inhibition of carbohydrate-digesting enzymes

Banaba extracts have shown inhibitory activities on carbohydrate digestion-related enzymes such as α-glucosidase. This may lead to a lower postprandial glucose excursion.[22]

Suppression of hepatic glucose production

Experimental studies suggest that constituents of Banaba may affect hepatic gluconeogenesis, but the clinical relevance of this mechanism is unclear.[21,23]

Antioxidant and anti-inflammatory effects

Phenolic compounds and ellagitannins may have antioxidant activity, which may be relevant because oxidative stress is involved in insulin resistance and diabetic complications.[7,23]

Clinical evidence for Jarul

Clinical evidence for Banaba remains considerably smaller than that for fenugreek.

In a dose-response study of patients with type 2 diabetes, standardized L. Speciosa extract with corosolic acid was associated with decreased blood glucose during short term treatment.[20] Another controlled crossover study studied purified corosolic acid and found a reduction in post-challenge blood glucose concentrations.[24] These results suggest the possibility that corosolic acid is involved in the glucose-lowering effect of banaba. But the studies were quite small and short.[7,23,25] L. has also been reported to possess antihyperglycaemic effect in pre-clinical research. speciosa preparations in animal models, further supporting the biological plausibility of the glucose-lowering activity of the plant.[26] Therefore, the current evidence supports the biological plausibility and preliminary clinical efficacy, but larger randomized controlled trials are needed.

Methika (*Trigonella foenum-graecum* L.)

Botanical background

Methika, also known as fenugreek, belongs to the family Fabaceae and is extensively used as a cooking spice and traditional medicine herb. The main object of study was the effect of the seeds on metabolism.[8-10] Fenugreek seeds are rich in dietary fiber and possess a variety of potentially bioactive constituents such as galactomannan, 4-hydroxyisoleucine, steroidal saponins, alkaloids, flavonoids and polyphenols. The combination of high fiber content and metabolically active phytochemicals makes fenugreek especially interesting in T2DM.[8-10]

Antidiabetic mechanisms of Methika

Delayed carbohydrate absorption

Galactomannan and other soluble fiber components can increase intestinal viscosity and delay the absorption of carbohydrates. This may reduce the magnitude of postprandial glucose excursions.[9,10]

Insulinotropic activity

4-Hydroxyisoleucine, a characteristic amino acid derivative in fenugreek, has been studied for its ability to stimulate insulin secretion in a glucose-dependent manner.[9]

Improvement in insulin sensitivity

Fenugreek has been reported to enhance insulin sensitivity and glucose metabolism in experimental studies, but clinical studies have yielded inconsistent results.[10]

Effects on lipid metabolism

Fenugreek has also been studied for possible effects on cholesterol and triglycerides. Dyslipidemia is a frequent comorbidity of T2DM, so these effects might be particularly important.[8,10]

Clinical evidence for Methika

Fenugreek has a comparatively extensive clinical literature

A controlled trial was conducted early on to investigate fenugreek seed powder in patients with non-insulin-dependent diabetes mellitus and noted improvements in glycemic parameters. More recently, clinical research has investigated standardized preparations of fenugreek. A randomized double blind placebo-controlled trial evaluating a patented fenugreek seed extract provided evidence for safety and efficacy in type 2 diabetics.[28]

A systematic review and meta-analysis of randomized controlled trials found fenugreek supplementation was associated with significant reductions in fasting blood glucose, postprandial glucose, and HbA1c.[29] Another systematic review and meta-analysis also showed significant improvements in glycemic parameters but considerable heterogeneity was found among studies.[30] There is clinical evidence that fenugreek may have a modest beneficial effect on glycemic control, especially when used as an adjunct to conventional treatment. But differences in dose, preparation, duration, and patient characteristics make interpretation difficult.[31,32,33,34]

Comparative evaluation of the three medicinal plants

Vijaysar, Jarul and Methika vary in their chief constituents, proposed mechanisms and degrees of clinical evidence. In Vijaysar, phenolic compounds associated with β-cell function and insulin-related signaling have been studied. Jarul is characterized by corosolic acid and polyphenols that can potentially impact cellular glucose uptake. Methika is a combination of soluble fiber and compounds investigated for their insulinotropic and lipid-modulating properties.

Table 1: Comparative evaluation of Vijaysar, jarul, and methika.

Characteristic	Vijaysar	Jarul	Methika
Scientific name	*P. marsupium*	*L. speciosa*	*T. foenum-graecum*
Principal part studied	Heartwood	Leaves	Seeds
Major constituents	Epicatechin, pterostilbene, marsupin	Corosolic acid, ellagitannins	Galactomannan, 4-hydroxyisoleucine, saponins
Major proposed action	β-cell protection and insulin signalling	Glucose uptake and insulin sensitization	Delayed carbohydrate absorption and insulinotropic effects
Preclinical evidence	Extensive	Extensive	Extensive
Human evidence	Limited/moderate	Limited	Relatively substantial
RCT evidence	Limited	Limited	More extensive
Meta-analysis evidence	Limited	Limited	Available
Major research gap	Large standardized RCTs	Larger long-term RCTs	Standardization and heterogeneity

Comparison of molecular mechanisms

Proposed mechanisms of regulation of glucose homeostasis by Vijaysar, Jarul and Methika The figure should separate mechanisms experimentally investigated and effects supported by the evidence of human clinical studies as shown in **[Fig.1]**.

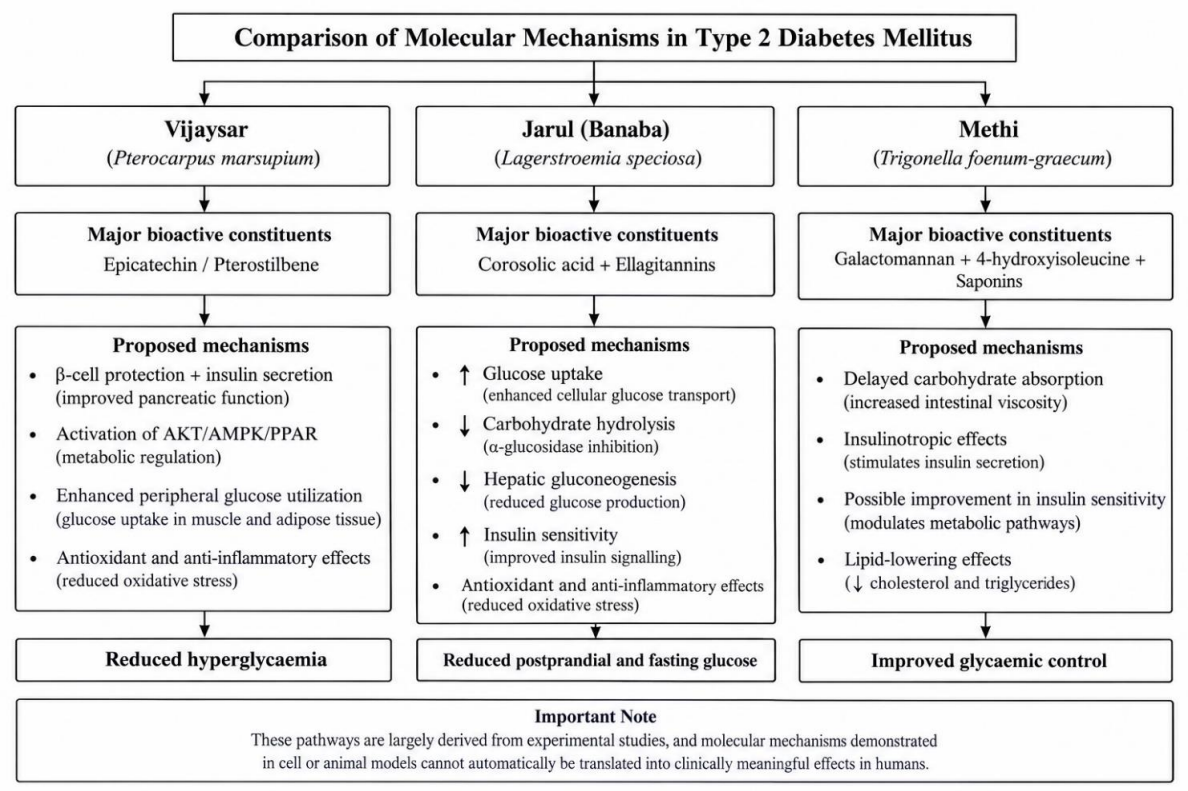


Fig.1 shows the Comparison of molecular mechanisms.

The mechanistic findings offer a basis for further research, but should be interpreted with caution. Effects seen in cell cultures or animal models do not necessarily translate into clinically meaningful benefits in humans. Bioavailability, metabolism, dose, extract composition, and patient characteristics may influence treatment outcomes.

Molecular mechanisms comparison

Vijaysar contains epicatechin, pterostilbene and phenolic compounds related to these two compounds and these have been studied for their possible effects on pancreatic β-cell function, oxidative stress, glucose utilization and insulin-related signaling. Pathways involving AMPK and AKT have been suggested, but the clinical relevance of these pathways remains to be established.[13,14,15,16] Jarul is high in corosolic acid and other polyphenolic compounds that may increase cellular glucose uptake and affect postprandial glucose regulation. The inhibition of carbohydrate-digesting enzymes and possible effects on hepatic glucose production have also been studied.[17-24] Methika is rich in galactomannan and other soluble fibers that may slow down the absorption of carbohydrates. Its 4-hydroxyisoleucine content has attracted interest because of potential insulinotropic effects, and saponins and other constituents may affect lipid metabolism.[9, 10, 34, 35-39]

Vijaysar has traditional use, experimental research, and historical clinical evidence to back it. Jarul has encouraging mechanistic and early clinical data. Of the three, Methika has the most clinical evidence.[7,11,13,17,18]

The three plants can overlap, but different mechanisms affecting glucose homeostasis. Metabolic research in T2DM increasingly considers interactions among metabolic, skeletal, and hepatic health.[40,41] All three plants have biologically plausible antidiabetic effects, but the quality and quantity of human evidence vary greatly. The study results should be interpreted in view of the differences in clinical, biochemical and genetic profiles of the T2DM populations.[42] Metabolic research increasingly recognizes the interaction between diabetes, skeletal health, and hepatic metabolism. Bone formation and resorption have been assessed in patients with type 2 diabetes mellitus using bone turnover markers such as procollagen type 1 N-terminal propeptide (P1NP) and beta-isomerized C-terminal telopeptide of type I collagen (β-CTX).[43,44,45]

Antioxidant and modulating oxidative stress activities

Oxidative stress is a major contributor to the pathophysiology of type 2 diabetes mellitus (T2DM) and is caused by an imbalance between the production of reactive oxygen species and the endogenous antioxidant defense mechanisms. Persistent hyperglycaemia may increase oxidative damage to cellular lipids, proteins, and nucleic acids and contribute to pancreatic β-cell dysfunction and vascular complications. Vijaysar (*Pterocarpus marsupium*), Jarul or Banaba (*Lagerstroemia speciosa*) and Methika or fenugreek (*Trigonella foenum-graecum*) are rich sources of phenolic compounds, flavonoids and other phytochemicals studied for antioxidant activity.[45-47] The phenolic constituents of Vijaysar, namely epicatechin and related compounds, have been studied for their free-radical-scavenging activity and possible protection from oxidative injury in experimental models. Banaba leaves have been reported to contain polyphenols, ellagitannins and other constituents associated with antioxidant activity. Flavonoids, polyphenols and other bioactive compounds, which may be involved in antioxidant defense and metabolic regulation, are present in fenugreek seeds.[45-47] The results provide a biological rationale for studying the three plants in diabetes associated oxidative stress. Laboratory demonstrations of antioxidant activity, however, do not necessarily translate into clinically meaningful protection against diabetic complications. Further human studies are needed to evaluate whether standardized preparations improve oxidative-stress biomarkers or clinical outcomes.

Cardioprotective and cardiovascular risk-modifier properties

Cardiovascular disease risk is increased in people with T2DM, partly due to insulin resistance, dyslipidemia, oxidative stress, endothelial dysfunction and chronic low-grade inflammation. Thus, medicinal plants acting on glucose regulation, lipid metabolism or oxidative pathways have been of interest as possible adjuncts in cardiometabolic research.[45-48] Vijaysar has been studied mainly in terms of glucose lowering and metabolic effects, while Banaba has been studied for corosolic acid-associated effects on glucose uptake and metabolic regulation. The soluble fiber, saponins and other constituents of fenugreek may influence cardiovascular risk factors through possible effects on circulating lipids and postprandial glycaemia.[45-48] These mechanisms suggest that the cardiovascular benefit of the proposed interventions might be indirect, via an improvement in metabolic risk factors. However, there is still a lack of direct evidence for prevention of myocardial infarction, stroke, heart failure or cardiovascular death. Hence, their possible cardioprotective effects should be separated from the proven cardiovascular outcome benefits for certain conventional therapies.

Hepatoprotective activity and regulation of hepatic metabolism

The liver is critical in glucose homeostasis, lipid metabolism, and oxidative stress modulation. Insulin resistance and its associated metabolic derangements in T2DM may contribute to hepatic steatosis and liver injury. The hepatoprotective potential of medicinal plants has been investigated in experimental models of oxidative and chemically induced hepatic damage.

Experimental and pharmacological reviews have suggested the potential hepatoprotective effects of Vijaysar, including the enhancement of some biochemical markers of liver injury and antioxidant responses in animal models. These findings are preliminary and should not be interpreted as evidence for efficacy in human liver disease.[45] Hepatoprotective effect of Fenugreek has been investigated, and the possible mechanisms include its antioxidant effect and modulation of lipid metabolism.[46-47]

Corosolic acid and polyphenolic constituents of Banaba have been studied for metabolic effects relevant to glucose regulation. However, there is no evidence of hepatoprotection in humans. Additional studies are needed to assess liver enzymes, hepatic fat accumulation, inflammatory markers, histological changes, and safety with standardized preparations. The evidence available justifies further research on these plants in hepatic metabolic disorders,

but it does not define them as treatments for MASLD, steatohepatitis or other chronic liver diseases.

Antidyslipidaemic and hypolipidaemic properties

Dyslipidemia characterized by abnormalities like elevated triglycerides, increased atherogenic lipoproteins and decreased high-density lipoprotein cholesterol (HDL-C), is often associated with insulin resistance and T2DM. Effects of plant-derived fiber, polyphenols and saponins on intestinal lipid absorption, cholesterol metabolism and circulating concentrations of lipids have been studied. Among the three plants reviewed here, fenugreek has the most directly relevant human evidence. Its soluble fiber, high in galactomannan, may slow the absorption of nutrients, and steroidal saponins and other constituents have been studied for their effects on cholesterol and lipid metabolism. A meta-analysis of clinical trials reported reductions in total cholesterol and possible improvements in other lipid parameters, but results for triglycerides, low-density lipoprotein cholesterol (LDL-C), and HDL-C have varied among analyzes.[48-49] Vijaysar showed potential anti-hyperlipidaemic activity in experimental studies and its polyphenolic constituents may be responsible for metabolic effects. Nevertheless, the clinical evidence for a consistent lipid-lowering effect is still limited.[45] Banaba has mostly been studied for its glucose-regulating effects and its independent effects on lipid profiles and cardiovascular outcomes need further evaluation.[46] These findings support the potential adjunctive role of fenugreek in research on dyslipidemia associated with T2DM. However, the generalizability of the results is limited by the variation in plant preparations, dose, duration of treatment, populations studied and quality of trials. None of these plants should replace evidence-based lipid-lowering treatment when clinically indicated.

Integrated relevance of cardiometabolic

The interconnected metabolic pathways extend the possible effects of these three medicinal plants. The phytochemicals they contain have been examined for their antioxidant activity, ability to regulate glucose and lipid metabolism, and protect against experimental hepatic injury. These actions could be relevant to the multifactorial pathophysiology of T2DM where dysglycaemia, dyslipidemia, oxidative stress and hepatic metabolic dysfunction often co-exist.[45-49] Of the three plants, fenugreek has a relatively stronger human evidence base for glycemic control and changes in serum lipid parameters. Vijaysar has a large pre-clinical pharmacological literature. Banaba has been studied for antioxidant activity and glucose-

regulating effects. However, the evidence is not so strong for all outcomes, and experimental antioxidant, cardioprotective or hepatoprotective effects cannot be considered as proof of prevention or treatment of cardiovascular or liver disease in humans, as illustrated in **Fig. 2.**

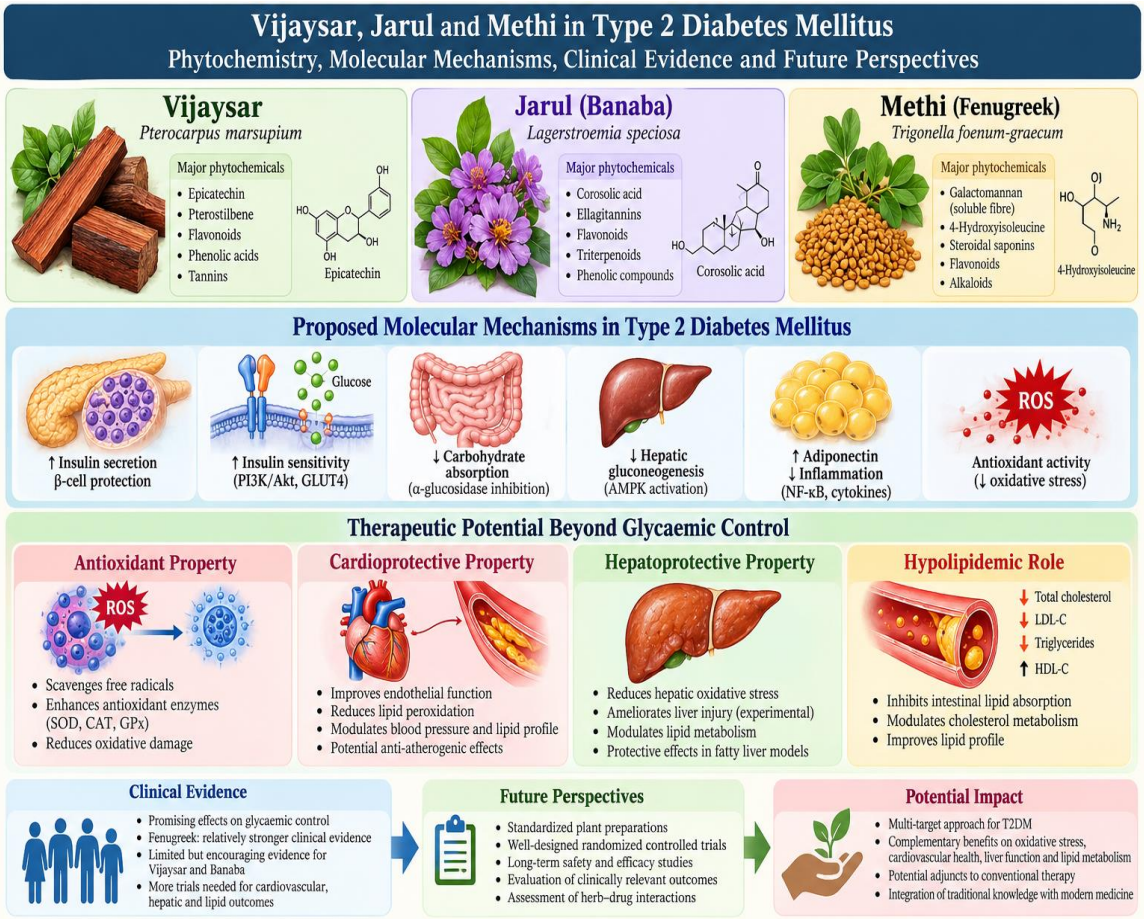


Fig 2: Shows the Antioxidant, Cardioprotective, Hepatoprotective, and Hypolipidemic Properties.

Safety considerations

Just because a medicinal plant is traditionally used doesn't mean it is safe. Herbal preparations can have side effects or interact with conventional medicines, and the risk profile of these preparations may vary depending on the composition, dosage, and duration of use. Fenugreek may cause GI upset, especially if taken in higher amounts. May affect carbohydrate metabolism. Increased risk of hypoglycaemia in concomitant use of insulin or other glucose-lowering medicines. Little is known about the tolerance of Vijaysar and Banaba preparations for short-term studies and there are no long-term safety data.[7, 8, 18, 23] Other issues include plant identification, manufacturing practices, contamination control, and changing levels of active constituents. Patients with T2DM should consult a qualified healthcare professional before using these products, especially if they are receiving a glucose-

lowering treatment. Based on preliminary experimental or clinical data, these plants should never replace the prescribed medication.

Limitations of the evidence available

Vijaysar (*Pterocarpus marsupium*), Jarul or Banaba *(Lagerstroemia speciosa*) and Methika or fenugreek (*Trigonella foenum-graecum*) have been reported to have promising pharmacological properties in type 2 diabetes mellitus (T2DM) and associated metabolic disorders with some limitations in interpretation.

Variability of botanical preparations: Pharmacological effects may vary depending on plant species, parts of the plant used, geographical origin, harvesting conditions, extraction methods and concentration of bioactive constituents. The results obtained with a standardized extract may not apply to the traditional preparations or to the commercial supplements.

Limitations of preclinical evidence: The majority of proposed mechanisms of antidiabetic, antioxidant, cardioprotective, and hepatoprotective effects are based on in vitro experiments and animal models. The results offer mechanistic insight but may not translate to a clinically meaningful benefit in humans.

Limited clinical evidence: Clinical studies for Vijaysar and Banaba are comparatively limited whereas Fenugreek has a comparatively broader clinical evidence base for glycemic control and lipid modulation. The available studies are limited by small sample sizes, short follow-up periods and methodological limitations that limit the assessment of efficacy and generalizability. Variation between studies in design and outcomes. Limitations include differences in dose, treatment duration, participant characteristics, concomitant medications and outcome measures, limiting cross-study comparisons. Difficulties in interpretation of results are also encountered due to differences in measurement of fasting blood glucose, glycated hemoglobin (HbA1c), lipid parameters and oxidative-stress biomarkers. There is no good evidence that it protects the heart or liver. Experimental data suggest antioxidant, lipid-modulating, and probably cardioprotective and hepatoprotective effects, but there is no sound clinical evidence of a reduction in cardiovascular events, progression of liver disease or diabetes-related complications. Lack of long-term safety data: Long-term safety, proper therapeutic dosages, pharmacokinetic profiles, and adverse effects of these plants are not well established. Further systematic studies are required on interactions with conventional antidiabetic, lipid-lowering, anticoagulant, and cardiovascular drugs.

Clinical relevance concerns: Changes in biochemical markers or molecular pathways do not necessarily translate into outcomes that are important to patients. There isn't enough evidence to know if these botanicals work better with conventional treatments or if they keep working over-time.

Limitations on comparative evidence: There is not much direct comparative head-to-head research on Vijaysar, Banaba and fenugreek. It cannot therefore be relied on to detect differences in relative efficacy, safety, dose-response relationships and suitability for particular patient populations.

Implications for future studies: Future research must consider the use of standardized and chemically characterized preparations, adequately powered randomized controlled trials, longer follow-up periods, full safety monitoring and systematic assessment of herb-drug interactions. Biochemical and molecular markers should be supplemented by assessments of clinically relevant outcomes. The evidence available suggests that more research is warranted for these medicinal plants; however, there is not enough evidence to suggest that they have shown clinical benefits as antioxidants, cardioprotective, hepatoprotective or hypolipidemic agents. Their value as adjuncts to conventional therapy should be determined by rigorous clinical investigation rather than by extrapolation from traditional use or experimental data.

CONCLUSION

Medicinal plants like Vijaysar (*Pterocarpus marsupium*), Jarul or Banaba *(Lagerstroemia speciosa*) and Methika or fenugreek (*Trigonella foenum-graecum*) contain diverse phytochemical constituents and exhibit promising pharmacological properties relevant to type 2 diabetes mellitus (T2DM) and co-morbid metabolic abnormalities. Their bioactive compounds – epicatechin, pterostilbene, corosolic acid, polyphenols, galactomannan, 4-hydroxyisoleucine and steroidal saponins – have been studied for possible effects on glucose homeostasis, insulin signaling, oxidative stress and lipid metabolism. In addition to their possible antidiabetic effects, these plants have raised interest due to their antioxidant, hypolipidemic, cardioprotective and hepatoprotective properties. There is a comparatively wider human evidence base for glycemic control and lipid modulation with fenugreek. Much of the evidence for Vijaysar and banaba is experimental/ preliminary. These pharmacological activities suggest potential additive benefits on cardiometabolic health. However, the available evidence does not show that these plants prevent cardiovascular events, treat chronic liver disease or reduce long-term diabetic complications in humans. Important

limitations are variation in botanical preparations, phytochemical composition, dosage, bioavailability, study design, and duration of follow-up. Therefore, future studies should focus on standard preparations, well-powered randomized controlled trials, long-term safety assessment and systematic assessment of interactions with traditional antidiabetic, lipid-lowering and cardiovascular drugs. These medicinal plants should be considered as potential adjuncts for further scientific study rather than substitutes for established treatment. Combination of traditional knowledge with robust pharmacological and clinical research may help to unravel their therapeutic roles in evidence-based management of T2DM and its associated metabolic complications.

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