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Medicinal Plants Approach for Diabetes Mellitus-A Computational Model

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Abstract: The multidimensional metabolic syndrome that includes diabetes mellitus poses a serious threat to world health. There is an increasing interest in researching herbal remedies for their possible therapeutic advantages, even as traditional allopathic treatments continue to be widely used. This work throws light on the multiple ways of metabolism and biochemical interactions of medicinal plants in the control of glucose level, highlighting their crucial role in the process. The work clarifies several herbal extracts' efficacy and safety profiles, such as Aloe vera, Garlic, Gurmar, Bitter Melon, Neem, Tulsi, and through a thorough literature review and empirical evidence. These plants, which are abundant in bioactive substances like tannins, flavonoids, and alkaloids, show promise in treating insulin resistance, improving pancreatic function, and controlling blood sugar level. A further assessment of the rising risk associated with diabetes mellitus is discussed, and a differential equation model for diabetes mellitus is developed to minimize the complications. When using medicinal plants to treat diabetes, several factors are considered, including blood sugar level, sugar intake activity, and plasma insulin concentrations. The stability criterion for the mathematical model is examined through the system of differential equations. A representation highlighting the medicinal plants that can aid individuals with diabetes mellitus is provided. The blood sugar level, insulin generalization variable and plasma insulin concentration have all been measured at different points in time. Aloe vera, Gurmar, Garlic, Tulsi, Bitter Melon and Neem are among the medicinal plants selected for their demonstrated anti-hyperglycemic properties due to their easy availability in India. Mathematical solutions were calculated for every plant and proved to be steady.

Introduction

Diabetes mellitus, which is often known as type 1 and type 2 diabetes, is a metabolic syndrome (Sarkar et al., 2023; Roy et al., 2023; Tyagi et al., 2024). In type 1 diabetes, β-cells are destroyed, resulting in the pancreas generating less insulin. In type 2 diabetes, a sufficient number of β-cells are produced but not utilized by the body to allow insulin to bring glucose into the cells (Pramanik, 2018; Biswas et al., 2023; Jaiswal and Gupta, 2023; Sur et al., 2023). To treat diabetes, many allopathic and ayurvedic treatments are available (Dhakar and Tare, 2023). A vital part of controlling diabetes mellitus is the use of medicinal plants (Acharya et al., 2023; Pawar et al., 2023; Vikhe et al., 2024). Insulin resistance or decreased pancreatic production are the two main causes of diabetes mellitus. Maintaining plasma glucose levels is important for the prevention of serious health problems. If the level of glucose goes beyond 120 mg/dl, it can result in long-term hyperglycemia which can increase the risk of developing kidney diseases (Roy and Robert, 2007). Diabetes can be treated with medicinal plants because of the presence of numerous active phytochemicals that are relevant for therapy, such as alkaloids, tannins, flavonoids and other components.

To control blood sugar, inhibitors of DPP4 (Dipeptidyl-peptidase 4) help maintain the activity of glucagon-like

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Table 1. Summarized studies depicting different medicinal plants for diabetes mellitus.

Technical name (Usual Name)	Section of the Plant used	Paternal name	Provenance	References
Aloe barbadensis Miller (Aloe vera)	Leaf extract	Asphodelaceae Liliaceae	North-West India	(Alinejad et al., 2015)
Allium sativum (Garlic)	Garlic extract that contains allicin	Amaryllis	Central India	(Ashraf et al., 2011)
Gymnema sylvestra (Gurmar)	Leaf extract	Apocynaeceae	Central and western India	(Paliwal et al., 2009)
Momordica charantia (Bitter-melon)	Aqueous extract	Cucurbitales	South East India	(Banerjee et al., 2019)
Azadirachta indica (Neem)	Ethanolic extract	Cucurbits	All parts of India	(Satyanarayana et. al., 2015)
Ocimum sanctum (Tulsi)	Leaf extract	Lamiaceae	North central India	(Hussain et al., 2001)

peptide-1(GLP-1) and glucose-dependent insulinotropic polypeptide, which stimulate insulin secretion and inhibit glucagon secretion. DPP4 has been inhibited in extracts from *Camellia sinensis*, *Pometia pinnata*, *Syzygium* sp., *Artocarpus heterophyllus*, *Lagerstroemia speciosa* and *Persea americana* (Paul et al., 2024). To improve glycemic control, several phytochemicals work to increase the sensitivity of non-pancreatic cells to insulin (Singh and Singh, 2008). Diabetes mellitus problems can be prevented by a natural remedy that restores and repairs pancreatic beta cells (Shaefer et al., 2015). GLP-1 is released by the L cells located in the ileum and colon of the GI tract. After this, GLP-1 attaches to the G-protein coupled receptors on the beta cell to reduce glucagon production and trigger insulin release when glucose is present.

In this article, we extensively evaluated the therapeutic properties of extracts from Aloe vera and various other medicinal plants, including Gurmar, Garlic, Tulsi, and several others. The primary objective was to evaluate and contrast the health benefits derived from these plants, known for their traditional and medicinal significance. Our research methodology involved the development of a sophisticated mathematical model based on differential equations and graphical representations. This model was designed to quantify and analyze the efficacy of these plant extracts on various health parameters. By utilizing this method, we could methodically evaluate each plant's possible advantages, offering a more scientific and evidence-based view of their medicinal worth. Detailed descriptions and analyses of the medicinal properties of *Aloe vera*, Gurmar, Garlic, Tulsi, and other plants are provided below, offering insights into their roles in promoting health and wellness.

Aloe Vera (*Aloe barbadensis* Miller): Aloe vera is recognized for its anti-diabetic properties, which can be particularly beneficial for managing blood glucose level. The plant has components that can assist in controlling blood glucose level, making it a beneficial addition for people with type 1 and type 2 diabetes (Alinejad et al., 2015).

Clinical uses

Wound healing, Anti-inflammatory, Commonly reported toxicity symptoms, Hepatitis, Fatigue, Nausea etc.

Figure 1. Aloe Vera (*Aloe barbadensis* Miller)

Garlic (*Allium sativum*): Garlic (*Allium sativum*) has played a special role in traditional healing practices since the dawn of times to treat infectious diseases, fighting parasites, bacteria, fungi, viruses, and respiratory tract infections, skin, and food. Garlic-induced disorders yield various healthful substances like flavonoid compounds, amino acids, saponins, sugars, mucus compounds, vitamins, mineral salts, and microelements. Its effects on the cardiovascular system are well-known for their preventive and therapeutic benefits. Garlic reduces blood pressure and functions by decreasing the level of triacylglycerols, total cholesterol and LDL (low-density lipoprotein) in the body. Functioning as a blood thinner, preventing clot formation and breaking down blood clots while reducing blood pressure (Oyelere et al., 2022; Ashraf et al., 2011). India is known as the world's largest producer of medicinal plants.

Clinical uses

Antioxidant activity, Antihypertensive, Immunomodulatory activity, Anti-inflammatory, Antidiabetic effect, Antimicrobial activity (antiviral, antibacterial, antifungal and antiparasitic).

Figure 2. Garlic (*Allium sativum*).

Gurmar (*Gymnema silvestre*): Gurmar is antidiabetic plant. It is a slow-growing woody medicinal plant found in central India. Leaves are used in Ayurvedic medicines. Dihydroxy gymnemic compound found within the plant is separated from the plant.

Clinical uses

Cytotoxic and anti-diabetic activity, Anthraquinones anti-inflammatory, Reduce cholesterol anti-cancer activity. It help blood inflammation, aids weight loss, lower "bad "cholesterol and triglyceride.

Figure 3. Gurmar (*Gymnema silvestre*).

Gymnemic acids are anti-inflammatory, anti-sweetener, and antidiabetic. A cluster of molecules with antidiabetic properties has been recognized as a closely linked group. These compounds decrease the craving for sweets by inhibiting the activation of taste buds' receptors by sugar molecules in food. Likewise, gymnemic acid molecules attach to receptors in the absorptive outer layers of the intestine, preventing the absorption of sugar molecules and decreasing blood glucose level (Augusti, 1996; Paliwal et al., 2009). Several potential ways exist by which G's leaves, particularly its Gymnemic acids, function. Sylvestre lowers blood glucose level by boosting insulin secretion and promoting islet cell regeneration. Additionally, it enhances glucose utilization by increasing certain enzyme activities linked to insulin-dependent pathways.

Bitter melon (*Momordica charantia*): Momordica charantia has antiviral, antibacterial, anticancer properties. Due to its hyperglycemic properties, it is very much useful. Bitter gourd has blood glucose-lowering properties.

Clinical uses

Bitter gourd lowers dietary carbohydrate digestion, prevents diabetic complications, And has the ability to shield the body from other non-communicable illnesses.

Figure 4. Bitter melon (*Momordica charantia*).

Diabetes has been efficiently treated globally with plant-based therapy at a reasonable cost. In fact, this might be the only kind of therapeutic option accessible to diabetic patients in many parts of the world, particularly in developing nations. Various authors have written several reviews of anti-diabetic herbal plants. Many plants that are utilized as herbal medications for controlling the blood glucose level in diabetic patients are mentioned in Ayurveda because they are inexpensive and have fewer adverse effects. They are valuable as alternative medicine. It has been claimed that the active ingredients found in medicinal plants can release insulin, regenerate pancreatic β cells, and combat insulin resistance. One factor contributing to the genesis of diabetes complications is hyperglycemia. Herbs that lower blood glucose level stimulate insulin secretion, improve muscle or adipose tissue's glucose absorption, and prevent the liver and intestines from producing glucose (Anwar et al., 2003; Banerjee et al., 2019). This study has shown that the leaves contain abundant amounts of calcium, magnesium, potassium, phosphorus, and iron. Furthermore, the leaves and edible fruit also offer a rich source of B vitamins (Liu et al., 2009).

Neem (*Azadirachta indica*): The medicinal plant from India, Neem (Azadirachta indica), has over 140 isolated compounds and at least 35 active principles. These components act as tumor suppressors by disrupting carcinogenesis (Satyanarayana et al., 2015). After being treated for 6 weeks with this medicine, a substantial decline in the blood glucose level was observed.

Clinical uses

Prevents Kidney stones, Treats infections, Improve digestion, Increase Metabolism, Prevents obesity, Regulates blood sugar level.

Figure 5. Neem (Azadirachta indica).

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Holy basil (*Ocimum sanctum*): Holy basil is a healing herb. It is a spiritual plant used in Hindu worship and is a sign of purity.

Clinical uses

Antimicrobial, Relieves stress, Lowers blood pressure, blood sugar and cholesterol, Alkaline the body, Increases inflammation, etc.

Figure 6. Holy basil (*Ocimum sanctum*).

Tulsi leaves have anti-diabetic effects that are beneficial to reducing blood glucose level. Consuming *Ocimum sanctum* increases the activity of pancreatic beta cell function and insulin secretion. Tulsi, an aromatic shrub native to tropical regions of the eastern continent, belongs to the Liliaceae family of basil plants (tribe Ocimene). Its origins are believed to trace back to North central India. Highly respected in Ayurveda as "The Incomparable One" and "Mother Medicine of Nature," Tulsi is also called "The Queen of Herbs" and is valued for its special medicinal and spiritual qualities, hence being named "elixir of life." Taking Tulsi on a regular basis is thought to assist with handling daily stress, warding off sickness, and improving overall health, wellness, and longevity. Additionally, Tulsi enhances complexion luster and vocal sweetness and promotes beauty, intelligence, endurance and a composed emotional state (Mahajan et al., 2013; Hussain et al., 2001). In addition to its positive effects on health, Tulsi is recommended for addressing a range of issues, including anxiety, ringworm, skin conditions, insect bites, snake bites and scorpion bites. Tulsi is regarded as a strong adaptogen because of its special combination of pharmacological properties that enhance resilience and general well-being.

This article aims to model the effects of components of medicinal plants, namely aloe vera, garlic, Gurmar, bitter melon, Neem, and Tulsi, on blood glucose level, plasma glucose concentrations, sugar-consuming activity and plasma insulin concentrations. Since, these six medicinal herbs are widely available in India, research has been done on how they affect blood glucose level. Mathematical models assess the impact of medicinal plants on blood glucose level in individuals with prediabetes and diabetes.

Methodology (Mathematical Modelling)

Mathematical models have been designed to explain diabetic activity. Several models are constructed on sugar and sugar concentration, which these models can describe. Under definite circumstances, these models are cogent. We assume a mathematical model made up of blood glucose level (BSL) $G(t)$ insulin generalization variable $X(t)$ and plasma insulin concentration $I(t)$. After a certain criterion, a mathematical model has been constructed (Huard and Kirkham, 2022; Chudtong and Gaetano, 2021; Xie, 2023; Lopez et al., 2020; Choudhury et. al., 2018; Sugiyanto and Khalda. 2020). The model is characterized as

$$\frac{dG}{dt} = -(m_1 + a_1)G + m_2 I + m_1 G_b \quad (1)$$

$$\frac{dX}{dt} = -m_2 X + m_3 I - m_3 I_b + m_6 I_b \quad (2)$$

$$\frac{dI}{dt} = -m_3 I + m_4 G + m_4 m_5 - m_6 I + m_6 I_b \quad (3)$$

Variables and parameters are mathematical models used to represent values or characteristics that are subject to change or influence. Symbols typically represent variables and can take on different values in a model, while the limiting factors have fixed values that are determined with the help of the model or through external input. Both variables and parameters are essential components of mathematical models used in various fields.

Below is a description of all of the values of variables and parameters utilized in mathematical models:

$G(t)$ **:** blood glucose level in plasma at a specific time $t\,(mg/dl)$

$X(t)$ **:** A variable used to represent the insulin generalization variable in the remote compartment of the body $\min^{-1}$

$I(t)$: The insulin concentration at the time $t(\mu U/ml)$

G_b **:** The baseline glucose level in the blood before injection (mg/dl)

I_b **:** The insulin concentration in blood before injection $(\mu U/ml)$

m_1 **:** The rate at which the tissues take up glucose when insulin is not present $(\min^{-1})$.

m_2 **:** The rate at which the ability of tissues to uptake glucose decreases over time $(\min^{-1})$.

m_3 **:** The insulin-independent increase in tissue's capacity for glucose uptake as a function of insulin concentration I_b $(\min^{-2}\,(\mu U/ml))$.

m_4 **:** The rate at which beta cells in the pancreas release insulin due to a glucose infusion and elevated

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glucose level beyond a specific threshold.

h [(μU/ml) min^{-2} (mg/dl)$^{-1}$]

m_5 : The lowest blood glucose level needed to trigger the release of insulin from the beta cells in the pancreas

m_6 : The rate at which insulin is cleared from the bloodstream over time

a_1 : The rate at which the blood glucose level changes when medicinal plant active ingredients are consumed.

The amount of three factors above stated $N(t) = G(t) + X(t) + I(t)$.

The amount of plasma glucose at any given time "t" is influenced by how plasma glucose level are changing and the current level of plasma glucose. Specifically, the number of plasma glucose molecules affected over time is multiplied by the number of existing plasma glucose molecules. Furthermore, a rise in plasma glucose level can potentially impact the total amount of plasma glucose, so the number of existing plasma glucose molecules is multiplied by the amount of sugar in the plasma. When multiplied with fixed free insulin value, the initial glucose value before injection shall provide the number of plasma glucose at time "t". several things can have an impact on any region of the part of the body during the generalized insulin from any part of the body, including (1) the rate of blood glucose level reduction multiplied by the activity of sugar ingestion and (2) an increase in plasma insulin concentration, which can increase the quantity of free insulin in the bloodstream. Moreover, decreased insulin concentration across all tissues can also impact insulin activity, potentially resulting in a rise in free insulin in fasting glucose. These variables can greatly influence how glucose metabolism is regulated and how metabolic diseases like diabetes develop.

Any reduction of insulin concentration i_b shall also affect plasma count in the body at the time t. β Cells post-injection of sugar have a sugar concentration h multiplied by the amount of plasma sugar in the body. Sugar plasma is affected by β cells created in the pancreas post-injection of sugar concentration (Sugiyanto and Khalda. 2020). It is further multiplied by the quantity of sugar when β cell releases insulin. The quantity of sugar plasma insulin in the body is increased by the reduced rate of insulin. The quantity of insulin is increased by the quantity of pancreatic plasma β cells that have initially decayed before to injection.

Mathematical Analysis

Theorem 1: The system of equation (1), (2) and (3) obtained the equilibrium points E_{q0}

$$G_0 = \frac{m_2 m_4 g_b + m_2 m_4 m_5 + m_2 m_6 i_b}{(m_1 + a_1)(m_3 + m_6) - m_2 m_4} + g_b$$

$$X_0 = \frac{(m_1 + a_1) m_3 (m_4 g_b + m_4 m_5 + m_6 i_b) + (m_6 i_b - m_3 i_b)((m_1 + a_1)(m_3 + m_6 - m_2 m_4)}{m_2((m_1 + a_1)(m_3 + m_6) - m_2 m_4)}$$

$$I_0 = \frac{(m_1 + a_1) m_4 g_b + (m_1 + a_1) m_4 m_5 + (m_1 + a_1) m_6 i_b}{(m_1 + a_1)(m_3 + m_6) - m_2 m_4}$$

Theorem 2: The equilibrium point exists if $G_0, X_0, and\ I_0$ is real and non-negative.

Proof. Existence of the equilibrium point above exist if $G_0, X_0, and\ I_0$ is real and non-negative.

1. G_0 is real and non-negative, which $(m_1 + a_1)(m_3 + m_6) - m_2 m_4 > 0.$
2. X_0 is real and non-negative, which $(m_1 + a_1)(m_3 + m_6) - m_2 m_4 > 0.$
3. I_0 is real and non-negative, which $(m_1 + a_1)(m_3 + m_6) - m_2 m_4 > 0.$

The stability of the diabetes mellitus model will be discussed in relation to the obtained equilibrium point.

Theorem 3. The equilibrium point, E_{q0}, system of equation (A)-(C) will be asymptotically stable locally if $(m_1 + a_1 + m_3 + m_6)^2 = 4[(m_1 + a_1)(m_3 + m_6) - m_2 m_4].$

Proof. The eigenvalues of the Jacobian matrix are as follows.

$\lambda_1 = -m_2 < 0,$

$$\lambda_2 = \frac{-(m_1 + a_1 + m_3 + m_6) + \sqrt{(m_1 + a_1 + m_3 + m_6)^2 - 4[(m_1 + a_1)(m_3 + m_6) - m_2 m_4]}}{2}$$

$$\lambda_3 = \frac{-(m_1 + a_1 + m_3 + m_6) - \sqrt{(m_1 + a_1 + m_3 + m_6)^2 - 4[(m_1 + a_1)(m_3 + m_6) - m_2 m_4]}}{2}$$

If

$(m_1 + a_1 + m_3 + m_6)^2 = 4[(m_1 + a_1)(m_3 + m_6) - m_2 m_4]$

, then $\lambda_1 < 0,\ \lambda_2 < 0, \lambda_3 < 0.$ This means that the equilibrium point is asymptotically stable locally.

Results and Discussion

The parameter values in a graphical representation of medicinal plants that can benefit people with diabetes mellitus are considered. Utilizing graphs to examine and display data, comprehend numerical values, and simplify understanding of qualitative structures for a diabetic patient undergoing medicinal plant treatment consistently over a period of 30 days.

Table 2: Parameter Estimations (Chudtong and Gaetano, 2021; Xie, 2023; Lopez et al., 2020; Choudhury et al., 2018; Sugiyanto and Khalda, 2020).

Parameter	Value
m_1	0.31700 min^{-1}
m_2	0.0123 min^{-1}
m_3	$0.0000492 \ (\text{min}^{-2} \ (\mu U/ml))$
m_4	0.0039 $(\mu\text{U/ml}) \text{ min}^{-2} \text{ (mg/dl)}^{-1}$
m_5	79.0353
m_6	0.2659
G_b	$70 \ (mg/dl)$
I_b	$6 \ (\mu U/ml)$
a_1	Aloe vera-0.30, Garlic- 0.26, Gurmar-0.1213, Bitter-melon-0.19, Neem-0.15, Tulsi-0.30

a. Aloe Vera (*Aloe barbadensis* Miller)

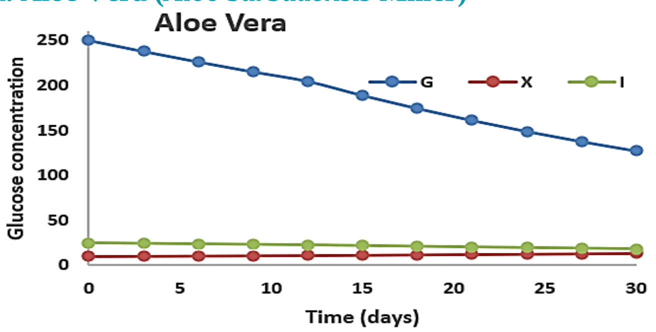

Figure 7. Graph showing blood sugar and insulin level over 30 days for a diabetic individual treated with Aloe Vera.

The figure 7 shows the level of various parameters with respect to time. Initially, the Glucose level was at 250mg/dl after taking Aloe vera extract Glucose level decreased continuously and it reached a normal level 127mg/dl. Blood glucose level $G(t)$ insulin generalization variable $X(t)$ and plasma insulin concentration *I(t)*, Aloe vera dietary supplements have been shown to have a good effect on type 2 diabetes and prediabetes patient's ability to regulate their diabetes.

b. Garlic (*Allium sativum*)

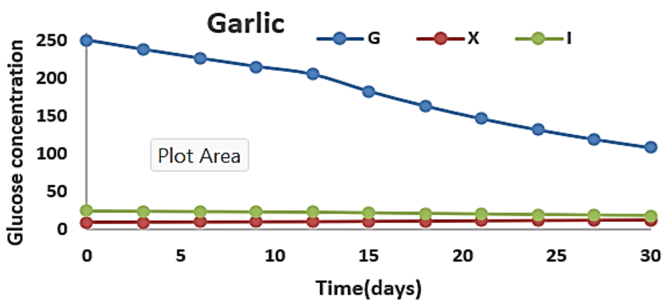

Figure 8. Graph of 4 hours of blood glucose and insulin fluctuations for a diabetic individual using Garlic.

The concentration of blood glucose level at various points following garlic consumption is shown in Figure 8 above, which also shows how blood glucose level return to normal. Several studies show that eating one clove of garlic or its equivalent per day will improve insulin sensitivity and help manage type 2 diabetes. Blood glucose level $G(t)$, insulin generalization variable $X(t)$ and plasma insulin concentration *I(t)*. After consuming clove of garlic, the glucose level steadily dropped to 108mg/dl, which is the normal level. Initially, the glucose level was 250mg/dl.

c. *Gymnema silvestre* (Gurmar):

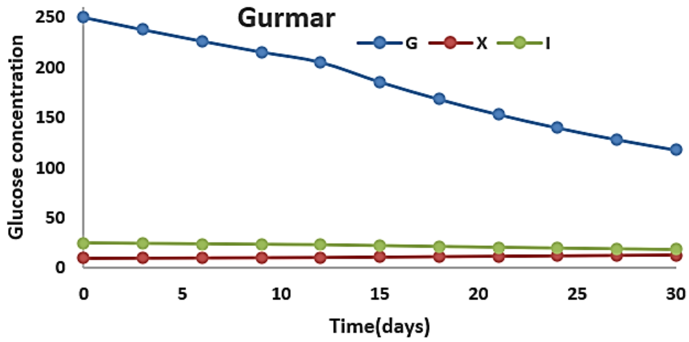

Figure 9. Graph showing blood sugar and insulin level over 30 days for a diabetic individual treated with Gurmar.

Figure 9 above shows how taking Gurmar as medicine significantly reduces blood glucose level, indicating how Gurmar is useful in regulating blood glucose level. A glucose level of 250mg/dl falls at 118mg/dl, Blood glucose level G(t), insulin generalization variable $X(t)$ and plasma insulin concentration *I(t)*. The use of the gurmar plant can be beneficial for both type 1 and type 2 diabetes and is also useful in treating complications of diabetes.

d. *Momordica charantia* (Bitter melon):

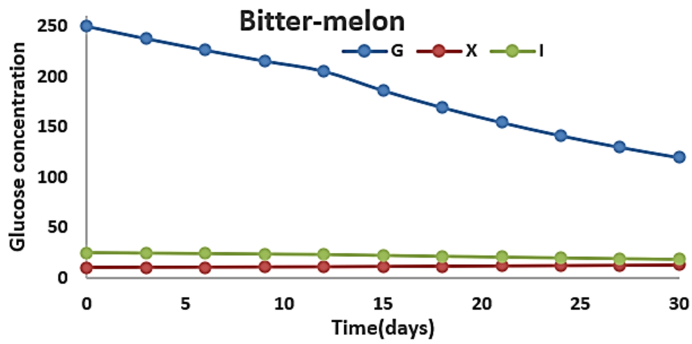

Figure 10. Graph showing blood sugar and insulin level over 30 days for a diabetic individual treated with Bitter-melon.

Figure 10 above shows how taking bitter melon juice as medicine significantly reduces blood glucose level, indicating how bitter melon is useful in regulating blood glucose level. A 250 mg/dl glucose level drops by 119 mg/dl. Blood glucose level G(t), insulin generalization variable $X(t)$ and plasma insulin concentration *I(t)*.

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Consuming bitter melon is effective against type 1 and type 2 diabetes and also helps in treating diabetic complications.

e. *Azadirachta indica* (Neem)

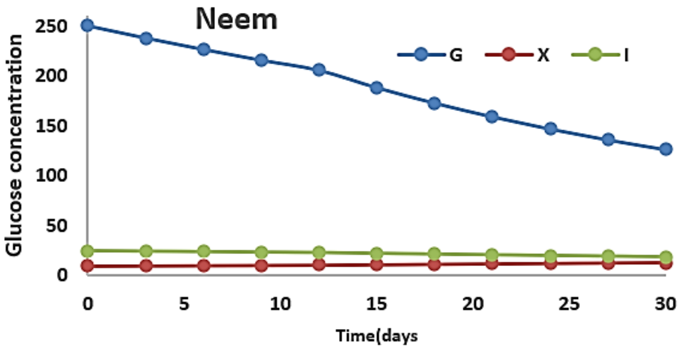

Figure 11. Graph showing blood sugar and insulin level over 30 days for a diabetic individual treated with Neem.

Neem may reduce level of sugar in the blood. Combining neem with diabetes drugs could lead to excessively low blood sugar level. Dried Neem leaves and seeds can be used as a natural remedy to treat type 2 diabetes. Figure 11 shows that a 250 mg/dL glucose level would be reduced by 100 mg/dL. Blood glucose level $G(t)$, insulin generalization variable $X(t)$ and plasma insulin concentration $I(t)$. Taking Neem leaves and seeds powder along with diabetes medications may cause blood glucose level to drop low.

f. *Ocimum sanctum* (Holy basil)

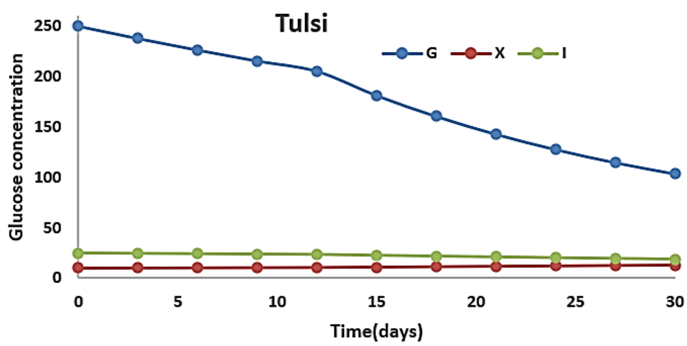

Figure-12: Graph showing blood sugar and insulin level over 30 days for a diabetic individual treated with Tulsi

Tulsi is a traditional Hindu herb that is effective in treating various types of ailments. It also reduces blood sugar level, as shown in figure 12. Blood sugar level $G(t)$, insulin generalization variable $X(t)$ and plasma insulin concentration $I(t)$. Tulsi can reduce fasting blood glucose level in type 2 diabetes patients. After using Tulsi, the glucose level from 250 mg/dl to 103 mg/dl.

Findings:

The blood glucose level, insulin generalization, and plasma insulin concentration have all been tested at various times. MATLAB software has been used to make the graphical representation of the mathematical model. The graph was created and then interpreted using a mathematical model based on parameter values. All of the six therapeutic plants exhibit the greatest variation in blood glucose level (Figures 7–12). After using the therapeutic herbs for 30 days, these improvements were made.

Table 3. Comparison of medicinal plants on Blood sugar level.

Time	G (Aloe vera)	G (Garlic)	G (Gurmar)	G (Bitter-melon)	G (Tulsi)	G (Neem)
0	250	250	250	250	250	250
3	238	238	238	238	238	238
6	226	226	226	226	226	226
9	215	215	216	216	215	216
12	205	205	205	205	205	206
15	189	183	186	186	181	188
18	174	164	169	169	160	173
21	161	147	153	154	143	159
24	149	132	140	141	127	147
27	138	120	128	130	114	136
30	127	109	118	120	103	126

Tulsi, Bitter melon, Gurmar, and Garlic had the least amount of variation in blood glucose level out of the seven therapeutic plants. After analysis, it reflects that the use of medicinal plants is very fruitful to maintain plants' Blood glucose levels in Table 3.

Conclusion

Research shows that medicinal plants have a lot of promise in helping manage diabetes. These plants can help control blood sugar levels, reduce stress in the body, and improve overall health. The studies found that certain compounds in these plants, like flavonoids and alkaloids, are likely responsible for their benefits. Including these plants in a diet might work well alongside traditional diabetes treatments and offer a natural way to control blood sugar. However, it's important to be careful with their use, as people might react differently, and they could interact with other medications. More research is needed to find the right amounts to use and ensure they are safe for long-term use. This research helps us see how traditional medicine can work with modern treatments for better diabetes care. While medicinal plants can be useful, they should be used based on solid evidence and tailored to each person's needs to make sure they are effective and safe.

Mathematically significant effects were seen on the change in insulin and blood glucose levels for both single

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medicinal plants and their combinations. Consequently, various medicinal plants have been utilised singly or in combination to treat diabetes and its aftereffects. In less developed areas, plant treatments remain the mainstay of medical care. The main aim of this article is diabetes mellitus and how plants might help treat it. Understanding the traditional use of many plants will be important for extending through scientific analysis. The current study, however, will improve the potential mechanisms of action of the many medicinal plants and validated data on diabetic patients that had previously been scientifically validated. Their claim to regularly utilize anti-diabetes will be strengthened by this innovation.

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Conflict of Interest

The authors declare no conflict of interest.

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