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Efficacy of Bay Leaf (Syzygium polyanthum) Decoction in Improving Glycaemic Control in Type 2 Diabetes Mellitus Patients: A Randomized Controlled Trial

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ABSTRACT

Background: Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by hyperglycaemia, leading to complications such as cardiovascular disease and kidney failure. The increasing prevalence of T2DM necessitates effective management strategies, including complementary therapies like bay leaf (Syzygium polyanthum), which has demonstrated potential for glycaemic control. **Purpose:** This study aimed to evaluate the effectiveness of bay leaf decoction in improving glycaemic control among T2DM patients in Malangan Village. **Methods:** A randomized controlled trial (RCT) involved 60 adults aged 30-65 years with fasting blood sugar (FBS) levels between 126-200 mg/dL, selected through purposive sampling. Participants were randomly assigned to an intervention group receiving a bay leaf decoction (10 grams in 250 mL water, twice daily for 12 weeks) or a control group received a placebo decoction made of water with the addition of one teaspoon of honey. Primary outcomes included changes in FBS, while secondary outcomes assessed postprandial blood sugar (PBS) and HbA1c. Compliance and adverse events were monitored, and data were analysed using paired and independent t-tests ($p < 0.05$). **Results:** The intervention group showed significant reductions in FBS, PBS, and HbA1c compared to baseline ($p < 0.001$) and the control group (FBS: $p = 0.045$; PBS: $p = 0.012$), while HbA1c reduction in the control group was not significant ($p = 0.071$). Older age, lower exercise frequency, family history of diabetes, hypertension, and obesity were associated with poorer glycemic control ($p < 0.05$), whereas female gender, higher education, higher income, and employment status correlated with better outcomes ($p < 0.05$). Notably, obesity had the strongest negative impact (FBS: $\beta = 7.2$, $p = 0.018$; HbA1c: $\beta = 0.22$, $p = 0.019$). No severe adverse events were reported. **Conclusion:** Bay leaf decoction significantly improves glycaemic control through mechanisms such as enhanced insulin sensitivity, α-glucosidase inhibition, and antioxidant properties. This natural, cost-effective approach is promising as a complementary therapy for T2DM. Future research should explore long-term effects, optimal dosage, and integration with lifestyle interventions to maximize benefits.

KEYWORDS

Bay leaf, Diabetes mellitus, Fasting blood sugar, HbA1c, Postprandial blood sugar

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1. BACKGROUND

Diabetes mellitus (DM) is a chronic metabolic disorder characterized by hyperglycemia, resulting from defects in insulin secretion, insulin action, or both (Ohiagu et al., 2021). The global prevalence of diabetes is rising at an alarming rate, with significant implications for public health. In Indonesia, the prevalence of DM has seen a steady increase over the years. According to the Indonesian Basic Health Research (Riskesdas) data in 2018, the prevalence of diabetes in Indonesia reached 10.9%, indicating a growing public health challenge (Badan Penelitian dan Pengembangan Kesehatan, 2018). The incidence is particularly high in urban areas due to lifestyle changes, but rural regions are not exempt from this trend. Yogyakarta, a province known for its cultural heritage, has reported a DM prevalence of around 2.6%, highlighting the need for effective management strategies in various communities (Nugroho et al., 2020).

The complications of uncontrolled diabetes, such as cardiovascular disease, neuropathy, and nephropathy, can significantly reduce patients' quality of life and lead to increased morbidity and mortality (Dilworth et al., 2021; Ohiagu et al., 2021). Malangan Village, a rural area with limited access to modern healthcare facilities, has been identified as having a high rate of diabetes. Residents in this community often rely on traditional and herbal remedies due to the unavailability or high cost of conventional medications. This scenario underscores the importance of identifying accessible, effective, and culturally accepted treatment options for managing diabetes in such settings (Nugroho et al., 2020).

Bay leaf (Syzygium polyanthum) has long been used in traditional medicine and shown to have various health benefits, including strong antioxidant activity. Ethanol extracts of bay leaf show the ability to scavenge free radicals, inhibit lipid peroxidation, and have anti-inflammatory and analgesic activities (Widyawati et al., 2019). Phenolic compounds in bay leaf play an important role in its antioxidant effects, which can help reduce oxidative stress in the body. Components such as 1,8-cineole are also associated with other benefits, including wound healing, protection of the gastrointestinal tract, and support of the nervous system (Teheni et al., 2024). In the context of metabolism, bay leaf contains flavonoids, saponins, and tannins that could potentially support the management of blood glucose levels, making it a promising candidate as a natural antidiabetic agent (Syahfitri et al., 2023).

Bay leaf infusion or extract can help lower blood sugar levels in alloxan-induced diabetic animal models (syahfitri et al., 2023). This effect is attributed to the presence of flavonoids, saponins, and tannins that act as antioxidants as well as inhibitors of the α-glucosidase enzyme, which slows the absorption of glucose after meals. Saponins in bay leaf may stimulate insulin secretion from pancreatic beta cells through a mechanism similar to oral antidiabetic drugs such as sulfonylureas. Human studies have shown a significant relationship between bay leaf consumption and reduced blood sugar levels. Bay leaf has great potential to be further developed as a supportive therapy in the management of diabetes (Widodo et al., 2023).

Bay leaf (Syzygium polyanthum) is traditionally used in Indonesian culture for its medicinal properties, particularly its potential to manage blood sugar levels (Widyawati et al., 2019). Recent studies have suggested that bay leaf contains bioactive compounds such as polyphenols, flavonoids, and essential oils, which may have hypoglycemic effects (Singletary, 2021). Unlike other commonly used herbs in diabetes management, such as cinnamon or bitter melon (Yedjou et al., 2023), bay leaf is more readily available in Malangan Village. It is already part of the local diet, making it a practical and culturally appropriate option.

The novelty of this study lies in its focus on bay leaf as an accessible and affordable herbal remedy for diabetes management, specifically tailored to the needs of the Malangan Village population. While various herbs have been studied for their antidiabetic properties, the efficacy of bay leaf in a real-world setting in a community with limited access to modern medicine has not been thoroughly explored. This research aims to fill this gap by evaluating the effectiveness of bay leaf decoction in reducing blood sugar levels among patients with diabetes mellitus in Malangan Village. This study not only contributes to the body of knowledge on herbal medicine for diabetes management but also has the potential to inform policy decisions regarding integrating traditional remedies into primary healthcare, especially in rural areas with limited resources. By providing evidence on the efficacy of bay leaf in managing blood sugar levels, this research could help improve the quality of life for individuals living with diabetes in similar communities.

2. METHODS

This study was a randomized controlled trial (RCT) conducted to evaluate the effectiveness of bay leaf (Syzygium polyanthum) decoction in reducing blood sugar levels among type 2 diabetes mellitus (T2DM) patients. The study involved 60 adults aged 30-65 years diagnosed with T2DM, residing in Malangan Village. Participants were recruited using purposive sampling based on predefined inclusion and exclusion criteria. Inclusion criteria required participants to have fasting blood sugar (FBS) levels between 126-200 mg/dL and not be receiving insulin therapy. Exclusion criteria included pregnant or breastfeeding women, individuals with severe diabetes complications, and those with known allergies to bay leaf.

Following recruitment, participants were randomly assigned to either the intervention or control group using computer-generated random numbers to minimize selection bias. Allocation concealment was ensured by an independent researcher who sealed assignments in opaque, sequentially numbered envelopes, which were opened only after participant enrollment. This method ensured effective allocation concealment, reducing the risk of selection bias and maintaining study integrity.

The primary variable was the change in FBS levels. Secondary variables included postprandial blood sugar (PBS) and HbA1c levels. Validated glucometers and laboratory assays were used to measure FBS, PBS, and HbA1c levels. Compliance was assessed through direct questioning and collection of unused decoctions.

The intervention group received a decoction made from 10 grams of dried bay leaves boiled in 250 mL of water, consumed twice daily for 12 weeks. The control group received a placebo decoction made of water with the addition of one teaspoon of honey. Baseline and post-intervention blood samples were collected simultaneously at 8:00 AM from all participants to ensure consistency in fasting conditions. Follow-up measurements for FBS, PBS, and HbA1c levels were conducted at the end of the 12-week intervention period. Adverse events were monitored and documented during biweekly follow-up visits.

Data were analyzed using paired and independent t-tests to compare baseline and post-intervention values. Statistical significance was set at $p < 0.05$. Allocation was concealed using a computer-generated

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randomization list managed by an independent researcher.

The study adheres to the ethical principles outlined in the Declaration of Helsinki. Ethical approval will be obtained from the Institutional Review Board (IRB) of the associated academic institution. Informed consent will be obtained from all participants before their inclusion in the study, ensuring they are fully aware of the study's purpose, procedures, potential risks, and benefits. Participants are assured of their right to withdraw from the study at any time without any penalty or loss of benefits. The confidentiality of participant data is maintained by using anonymized data codes and secure data storage systems.

3. RESULTS

Table 1. Characteristics of Respondents

Characteristic	Intervention group		Control group	
	Frequency (f)	Percentage (%)	Frequency (f)	Percentage (%)
Age (years)				
36-45	10	33.3	12	40
46-55	12	40	10	33.3
56-65	8	26.7	8	26.7
Gender				
Male	16	53.3	15	50
Female	14	46.7	15	50
Exercise Frequency				
≥ 3 times/week	18	60	17	56.7
< 3 times/week	12	40	13	43.3
Occupation				
Farmer	9	30	10	33.3
Entrepreneur	8	26.7	6	20
Employee	7	23.3	9	30
Civil servant	6	20	5	16.7
Income				
Low	12	40	13	43.3
Medium	12	40	11	36.7
High	6	20	6	20
Education				
Primary	9	30	12	40
Secondary	12	40	11	36.7
Tertiary	9	30	7	23.3
Family History of Diabetes				
Yes	15	50	14	46.7
No	15	50	16	53.3
Other Condition				
Hypertention	9	30	8	26.7
None	21	70	22	73.3
Nutritional Status				
Normal	15	50	14	46.7
Overweight	9	30	10	33.3
Obese	6	20	6	20

The characteristics of respondents in the intervention and control groups are relatively similar. In terms of age distribution, most respondents in both groups fall between 36 and 55 years of age. Specifically, 40% of the intervention group and 33.3% of the control group are aged 46-55 years, while 33.3% of the intervention group and 40% of the control group are in the 36-45 age range. A smaller portion of participants, 26.7% in both groups, are aged 56-65 years. Gender distribution is also balanced, with 53.3% of the intervention group being male and 50% of the control group. Female respondents make up 46.7% of the intervention group and 50% of the control group. In terms of exercise frequency, a higher proportion of participants engage in physical activity at least 3 times per week 60% in the intervention group and 56.7% in the control group.

Occupation-wise, farmers make up 30% of the intervention group and 33.3% of the control group. The other major occupations include entrepreneurs (26.7% in the intervention group and 20% in the control group), employees (23.3% in the intervention group and 30% in the control group), and civil servants (20% in the intervention group and 16.7% in the control group). Income levels show similar distributions, with 40% of the intervention group falling in the low and medium categories, compared to 43.3% in the control group. Only 20% of both groups have high income levels. In terms of education, 30% of the intervention group has a primary education, while this figure is higher in the control group at 40%. Secondary education is more common in the intervention group (40%) compared to 36.7% in the control group. Tertiary education is slightly more common in the intervention group (30%) compared to the control group (23.3%).

Half of the participants in both groups have a family history of diabetes. The presence of hypertension is similar between groups, with 30% of the intervention group and 26.7% of the control group having this condition. Regarding nutritional status, 50% of the intervention group and 46.7% of the control group have a normal weight. Overweight individuals constitute 30% of the intervention group and 33.3% of the control group, while obese individuals make up 20% in both groups.

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Table 2. Results of t-test, Paired t-test, and Post Hoc Analysis

Parameter	Mean + SD		t-value	p-value	Paired t-value	Paired p-value	Post hoc p-value
	Pre	Post					
Fasting Blood Sugar (FBS) (mg/dL)							
Intervention	156.2 + 20.5	135.3 + 15.8	2.52	0.014	5.27	<0.001	0.045
Control	158.4 + 21.2	145.8 + 17.6	1.94	0.058	3.12	0.003	
Postprandial Blood Sugar (PBS) (mg/dL)							
Intervention	210.3 + 25.1	186.7 + 18.4	3.10	0.002	4.53	<0.001	0.012
Control	212.8 + 26.7	194.5 + 19.2	2.36	0.022	2.89	0.005	
HbA1c (%)							
Intervention	7.2 + 0.6	6.5 + 0.5	2.84	0.006	4.82	<0.001	0.071
Control	7.3 + 0.7	6.9 + 0.6	1.56	0.125	2.15	0.037	

The statistical analysis of the study highlights significant changes in Fasting Blood Sugar (FBS), Postprandial Blood Sugar (PBS), and HbA1c levels in both the intervention and control groups. The intervention group, FBS levels dropped from 156.2 ± 20.5 mg/dL pre-intervention to 135.3 ± 15.8 mg/dL post-intervention. The t-test comparing pre- and post-intervention FBS values within the group showed a significant reduction ($t = 5.27$, $p < 0.001$), indicating the effectiveness of the intervention. In contrast, the control group showed a smaller reduction in FBS from 158.4 ± 21.2 mg/dL to 145.8 ± 17.6 mg/dL, with a less significant paired t-test result ($t = 3.12$, $p = 0.003$). When comparing post-intervention FBS between the two groups, the t-test showed a significant difference ($t = 2.52$, $p = 0.014$), further supported by the post hoc test ($p = 0.045$), confirming the intervention group's superior reduction in FBS compared to the control group. This reduction suggests that Bay Leaf extract played a pivotal role in stabilizing blood glucose levels.

The Postprandial Blood Sugar (PBS), the intervention group saw a significant decrease from 210.3 ± 25.1 mg/dL to 186.7 ± 18.4 mg/dL ($t = 4.53$, $p < 0.001$), while the control group experienced a smaller reduction from 212.8 ± 26.7 mg/dL to 194.5 ± 19.2 mg/dL ($t = 2.89$, $p = 0.005$). Comparing post-intervention PBS between the two groups, the difference was statistically significant ($t = 3.10$, $p = 0.002$), with the post hoc test confirming this result ($p = 0.012$), highlighting the greater impact of the intervention on postprandial blood glucose, underscoring the intervention's stronger effect on reducing postprandial glucose spikes, which is critical for managing diabetes. Regarding HbA1c, the intervention group showed a significant reduction from 7.2 ± 0.6% to 6.5 ± 0.5% ($t = 4.82$, $p < 0.001$), while the control group had a less significant decrease from 7.3 ± 0.7% to 6.9 ± 0.6% (t = 2.15, p=0.037). The groups comparison post-intervention demonstrated a significant difference (t = 2.84, p = 0.006), although the post hoc test showed a marginal significance (p = 0.071), the consistent trend across FBS, PBS, and HbA1c indicates the intervention's effectiveness.

Table 3. Multivariate Analysis of Characteristics Against Fasting Blood Sugar, Postprandial Blood Sugar, and HbA1c

Characteristic		Parameter	β	p-value	95 % CI
Age	46-55	FBS	5.2	0.045	0.11-10.29
		PBS	6.5	0.033	0.56-12.44
		HbA1c	0.21	0.041	0.01-0.41
	56-65	FBS	7.8	0.031	0.69-14.91
		PBS	8.3	0.020	1.30-15.30
		HbA1c	0.26	0.022	0.04-0.48
Gender	Female	FBS	-2.4	0.065	-4.96-0.16
		PBS	-4.1	0.048	-8.15-0.05
		HbA1c	-0.12	0.078	-0.26-0.02
Exercise Frequency	< 3 times/week	FBS	4.6	0.021	0.68-8.52
		PBS	5.8	0.019	0.93-10.67
		HbA1c	0.15	0.017	0.03-0.27
Occupation	Entrepreneur	FBS	-3.1	0.047	-6.15- -0.05
		PBS	-4.8	0.041	-9.36- -0.24
		HbA1c	-0.08	0.062	-0.17-0.01
	Employee	FBS	-2.7	0.051	-5.42-0.02
		PBS	-5.3	0.035	-10.21- -0.39
		HbA1c	-0.09	0.048	-0.18- -0.00
	Civil servant	FBS	-2.0	0.059	-4.09-0.09
		PBS	-3.7	0.029	-7.01- -0.39
		HbA1c	-0.07	0.072	-0.15-0.01
Income	Medium	FBS	-3.7	0.038	-7.18- -0.22
		PBS	-4.5	0.021	-8.30- -0.70
		HbA1c	-0.09	0.033	-0.17- -0.01
	High	FBS	-2.9	0.052	-5.84-0.04
		PBS	-3.9	0.044	-7.68- -0.12
		HbA1c	-0.08	0.049	-0.16-0.00
Education	Secondary	FBS	-2.5	0.054	-5.05-0.05
		PBS	-3.8	0.043	-7.46-0.14
		HbA1c	-0.07	0.067	-0.14-0.00
	Tertiary	FBS	-3.2	0.042	-6.29- -0.11
		PBS	-4.4	0.034	-8.49- -0.31
		HbA1c	-0.09	0.048	-0.18- -0.00
Family History of Diabetes		FBS	6.8	0.020	1.07-12.53
		PBS	9.0	0.006	2.61-15.39
		HbA1c	0.19	0.014	0.04-0.34
Hypertension		FBS	4.9	0.033	0.41-9.39
		PBS	6.2	0.029	0.65-11.75
		HbA1c	0.13	0.036	0.01-0.25
Nutritional Status	Overweight	FBS	5.1	0.025	0.64-9.56
		PBS	6.3	0.022	0.94-11.66
		HbA1c	0.17	0.025	0.02-0.32
	Obese	FBS	7.2	0.018	1.25-13.5
		PBS	8.1	0.014	1.66-14.54
		HbA1c	0.22	0.019	0.04-0.40

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Table 3 presents the results of a multivariate analysis identifying the relationships between various demographic and clinical characteristics and fasting blood sugar (FBS), postprandial blood sugar (PBS), and HbA1c levels. The analysis reveals that individuals aged 46-55 exhibit a significant increase in FBS (β = 5.2, p = 0.045), PBS (β = 6.5, p = 0.033), and HbA1c (β = 0.21, p = 0.041). Furthermore, the 56-65 age group shows even greater increases in all parameters: FBS (β = 7.8, p = 0.031), PBS (β = 8.3, p = 0.020), and HbA1c (β = 0.26, p = 0.022). Regarding gender, the data indicate that females tend to have lower FBS values (β = -2.4, p = 0.065), although this result does not achieve strong statistical significance. However, females display lower PBS (β = -4.1, p = 0.048), suggesting a potential positive influence from hormonal or lifestyle factors distinct to women compared to men.

Additionally, infrequent exercise (less than three times per week) correlates positively with increased FBS (β = 4.6, p = 0.021), PBS (β = 5.8, p = 0.019), and HbA1c (β = 0.15, p = 0.017), indicating that physical inactivity may be a significant risk factor for poor glycemic control. Employment status also plays a role in regulating blood sugar levels. Entrepreneurs exhibit lower FBS (β = -3.1, p = 0.047) and PBS (β = -4.8, p = 0.041) compared to other occupational groups, suggesting that potentially more flexible working conditions may contribute to better health management. Higher educational attainment (tertiary) is associated with decreased blood sugar levels, as evidenced by lower FBS (β = -3.2, p = 0.042) and PBS (β = -4.4, p = 0.034).

A family history of diabetes emerges as a significant factor, with FBS (β = 6.8, p = 0.020) and PBS (β = 9.0, p = 0.006) indicating increased risk for individuals with such a background, aligning with the understanding that genetic factors contribute to diabetes predisposition. The presence of hypertension is also positively correlated with FBS (β = 4.9, p = 0.033) and PBS (β = 6.2, p = 0.029), highlighting that individuals with hypertension may have poorer blood sugar control, thereby underscoring the importance of monitoring and managing both conditions concurrently. Individuals with overweight and obesity status show significant increases across all blood sugar parameters, with FBS increases (β = 5.1 and β = 7.2), PBS increases (β = 6.3 and β = 8.1), and HbA1c increases (β = 0.17 and β = 0.22). This indicates that excess body weight is a major risk factor for diabetes mellitus.

4. DISCUSSION

Table 3 findings underscore the association between advancing age and increased diabetes risk, consistent with literature indicating that aging contributes to insulin resistance and alterations in glucose metabolism. The complexity of managing T2DM in older adults is due to factors such as increased susceptibility to hypoglycemia, dependence on caregivers, and the impact of frailty, which can significantly impair functional ability and quality of life (Gomber et al., 2022). A deeper understanding of the pathophysiological mechanisms at play is needed, particularly in relation to conditions that further complicate diabetes management. Although the findings showed that most respondents in this study belonged to a younger age group (36 to 55 years), the implications of T2DM in an aging society remain important. As the population ages, healthcare providers must adapt existing guidelines and therapeutic options to meet the specific needs of older adults with T2DM, this includes recognizing the importance of individualized care plans that consider the unique challenges posed by age-related comorbidities, frailty, and metabolic changes. Understanding these dynamics is critical to optimizing care and improving health outcomes for older adults with T2DM, ensuring that they receive appropriate support and interventions tailored to their specific health profile. This article calls for ongoing research and policy adjustments to effectively address the implications of T2DM in an aging society, emphasizing the importance of proactive and comprehensive care strategies (Bellary et al., 2021).

The research highlights that sex hormones are significant in regulating various metabolic processes, including glucose homeostasis and insulin dynamics, which contribute to the differences observed in diabetes progression and outcomes between men and women. The study's findings reinforce the importance of considering gender-specific responses to newer glucose-lowering agents. For instance, the pronounced cardiovascular benefits of GLP-1 receptor agonists in women illustrate that therapeutic strategies should be adapted to account for these differences. Additionally, the identification of pharmacokinetic and pharmacodynamic variations, such as the impact of body composition on drug action, suggests that dosage and drug choice may need to be tailored based on gender. Moreover, the balanced gender distribution in the study's participants allows for a comprehensive analysis of the effects of these interventions across both sexes, further validating the significance of gender medicine in clinical practice. This approach not only enhances the efficacy of diabetes management but also minimizes adverse effects, ultimately improving health outcomes for all patients (Ciarambino et al., 2022).

Physical inactivity is recognized as a major contributor to the rising prevalence of type 2 diabetes mellitus (T2DM) alongside factors such as energy-dense diets and an aging population. Regular physical activity, particularly at moderate to vigorous intensities, has been demonstrated to counteract many risk factors associated with T2DM. Exercise improves insulin sensitivity, reduces HbA1c levels (a marker of long-term blood glucose control), and enhances peak oxygen consumption (VO2peak), all of which are critical in preventing and managing diabetes.(Shawahna et al., 2021) Exercise positively impacts glycemic parameters, lipid profiles, blood pressure, and high-sensitivity C-reactive protein (hs-CRP), a marker of inflammation. In individuals with T2DM, regular exercise improves blood glucose control, lowers cardiovascular risk factors, and aids in weight management by reducing body fat and increasing lean muscle mass. This multifaceted approach to managing diabetes not only improves metabolic health but also reduces the risk of complications such as cardiovascular diseases, dyslipidemia, nephropathy, neuropathy, and retinopathy (Shawahna et al., 2021; Wondmkun, 2020).

Regular exercise reduces fasting blood glucose (FBS), postprandial blood sugar (PBS), and HbA1c, as well as body fat, cholesterol levels, blood pressure, and cardiovascular risks. Moreover, exercise enhances insulin sensitivity, muscle strength, aerobic capacity, and mental health, all of which are vital in managing T2DM. The integration of exercise in diabetes management still faces challenges. There is a notable lack of clear guidelines and specific instructions for both patients and healthcare providers regarding the optimal type, intensity, and frequency of exercise for managing T2DM. Addressing these gaps in healthcare delivery and providing personalized recommendations based on individual patient needs could further enhance the effectiveness of exercise as a preventive and therapeutic measure for diabetes. The evidence strongly suggests that promoting consistent physical activity is crucial for improving glycemic control and reducing the need for antidiabetic medications, which could lead to better long-term health outcomes for individuals with T2DM (Amanat et al., 2020; Shawahna et al., 2021).

Individuals with medium and high-income levels demonstrate a positive impact on reductions in FBS, PBS, and HbA1c, with statistically significant p-values. This suggests that higher income individuals may have better access to nutritious food and appropriate medical care. The connection between working hours and HbA1c levels, a key marker of long-term glycemic control, provides critical insight into how lifestyle factors impact diabetes management. Longer working hours were correlated with higher HbA1c levels. This trend, although not statistically significant, suggests that prolonged working hours could impair glycemic control. Specifically, the odds of poor diabetic control (HbA1c >9.0%) were notably higher for individuals working over 52 hours per week. This was especially pronounced among elderly female workers, where long working hours were significantly associated with poor glycemic control, as indicated by an odds ratio of 3.30 (95% CI 1.19–9.18). These findings highlight the susceptibility of elderly female workers to the negative health effects of extended working hours, which may be due to factors such as increased stress, inadequate time for self-care, and disruptions in meal or medication routines (Lee et al., 2020).

In contrast, employment status also appears to play an influential role in regulating blood sugar levels. Entrepreneurs, who often enjoy more flexible working conditions compared to other occupational groups, showed significantly lower fasting blood sugar and postprandial blood sugar levels. This finding suggests that the autonomy and flexibility afforded by entrepreneurial work may facilitate better management of diabetes. Flexible schedules allow for more regular meals, exercise, and consistent medication adherence, all of which are crucial for maintaining stable blood sugar levels. Additionally, entrepreneurs might experience less work-related stress than those in more rigid or demanding jobs, further contributing to their improved glycemic control. The contrast between long working hours and flexible employment conditions underscores the importance of work-life balance in diabetes management. Prolonged and stressful working environments can disrupt key factors such as diet, physical activity, and adherence to diabetes medications, leading to worse glycemic outcomes (Butt et al., 2022). Elderly female workers may face additional challenges due to age-related factors and the demands of their work, making them more vulnerable to poor diabetes management. On the other hand, those with more control over their work schedules, like entrepreneurs, benefit from the ability to prioritize their health. This flexibility appears to foster a more favorable environment for maintaining optimal blood glucose levels, ultimately reducing the risk of diabetes-related complications. These findings emphasize the need for targeted interventions and workplace policies aimed at improving the work-life balance for individuals with diabetes, particularly those working long hours or in high-stress occupations (Kacem et al., 2021; Lee et al., 2020).

Greater educational levels may facilitate a better understanding of healthy eating patterns and active lifestyles. Education level has been identified as a significant determinant in the risk and management of type 2 diabetes mellitu s (T2DM). Research shows that individuals with lower educational attainment have a higher risk of developing T2DM. A 10.4-year follow-up study observed 598 new diabetes cases, with the adjusted hazard ratios indicating a 1.58 times higher risk of T2DM in individuals with low education compared to those with high education (HR 1.58, 95% CI 1.28–1.96). The association between low education and T2DM was also reflected in elevated glycated hemoglobin (HbA1c) levels, suggesting that individuals with lower education experience worse glycemic control. This association may stem from psychosocial factors, occupational stress, and unhealthy behaviors, which are more prevalent in lower educational groups and contribute to the increased diabetes risk (Na-Ek et al., 2022).

Higher education not only correlates with a lower risk of developing T2DM but also with better glycemic management. Evidence shows that individuals with tertiary education demonstrate significantly lower fasting blood sugar and postprandial blood sugar levels. This can be attributed to the fact that individuals with higher educational levels are more likely to understand and adopt healthier eating habits and engage in physical activity, both crucial for preventing and managing diabetes. They may also have better access to healthcare resources and possess the necessary knowledge to navigate treatment options, leading to improved disease outcomes. In contrast, those with lower education levels may have limited access to such resources and knowledge, making it harder to maintain a healthy lifestyle or follow medical advice. Moreover, low education often correlates with socio-economic disadvantages, which can result in stress, unhealthy behaviors such as poor dietary choices and physical inactivity, and reduced healthcare access, all of which contribute to the development and worsening of diabetes (Dilmurodovna, 2024). The findings underscore the importance of educational interventions and public health strategies that target individuals with lower educational attainment to promote diabetes prevention and effective management. By improving health literacy and access to preventive care among these populations, the incidence of T2DM can potentially be reduced, along with its associated complications (Na-Ek et al., 2022).

Genetic predisposition plays a crucial role in the onset and progression of type 2 diabetes mellitus (T2DM). Studies show that individuals with a family history of diabetes face a significantly higher risk of developing the disease. One study highlighted that individuals with a family history of diabetes have elevated fasting blood sugar (FBS) and postprandial blood sugar (PBS) levels, with β values of 6.8 ($p = 0.020$) and 9.0 ($p = 0.006$), respectively. This aligns with the broader understanding that genetic factors contribute significantly to T2DM, influencing insulin resistance, pancreatic β-cell function, and glucose metabolism. The inheritance of certain genetic mutations or polymorphisms from family members predisposes individuals to the metabolic imbalances that characterize diabetes. Women with a history of GDM have a nearly tenfold increased risk of developing T2DM compared to those who had normoglycemic pregnancies. This elevated risk suggests that GDM may serve as a precursor to T2DM, driven by both genetic susceptibility and metabolic disturbances during pregnancy (Vounzoulaki et al., n.d.).

The convergence of genetic and familial factors in diabetes highlights the complexity of the disease. While family history and specific genetic markers increase susceptibility, the interplay between genetics, environmental influences, and lifestyle factors creates a multifaceted risk profile. Advances in genomic research offer hope for precision medicine approaches, but they also raise questions about equitable access to these innovations. Understanding these dynamics will be critical for developing more effective strategies to prevent and manage diabetes, particularly for those genetically predisposed to the disease. Future studies must explore strategies to enhance postpartum screening uptake and evaluate the long-term efficacy of preventive measures, especially across diverse populations (Cole & Florez, 2020).

Hypertension (HTN) and diabetes mellitus (DM) are often referred to as "silent killers" due to their insidious progression and lack of overt symptoms in the early stages. Both conditions are increasing in prevalence worldwide and frequently coexist, creating a synergistic impact on microvascular and macrovascular health, contributing to higher rates of cardiovascular disease (CVD), kidney failure, and all-cause mortality. The parallel development of HTN and DM is rooted in a variety of shared pathophysiological mechanisms, which reinforce each other's negative effects on the cardiovascular system and other organ systems (Yildiz et al., 2020).

One of the primary shared mechanisms between HTN and DM involves the disruption of endothelial function, insulin resistance, and chronic inflammation. In both conditions, insulin resistance and hyperglycemia contribute to vascular stiffness and impaired endothelial nitric oxide production, leading to increased vascular resistance and elevated blood pressure. Simultaneously, high blood pressure accelerates the damage to blood vessels caused by elevated glucose levels, further exacerbating the risk of both microvascular (e.g., nephropathy, retinopathy) and macrovascular (e.g., coronary artery disease, stroke) complications. Additionally, both conditions promote oxidative stress, inflammation, and abnormal lipid metabolism, which together contribute to atherogenesis and cardiovascular events (Darenskaya et al., 2021; Wong & Sattar, 2023). The relationship between HTN and DM is further highlighted by the observed correlation between hypertension and poor blood sugar control. Research shows that the presence of hypertension is positively associated with elevated fasting blood sugar (FBS) and postprandial blood sugar (PBS) levels, this indicates that individuals with hypertension tend to have poorer glycemic control, making it even more critical to monitor and manage both conditions concurrently. This co-management is particularly vital because the coexistence of HTN and DM significantly increases the risk of cardiovascular complications, necessitating aggressive intervention to control both blood pressure and blood glucose (Wong & Sattar, 2023).

The coexistence of hypertension and diabetes mellitus forms a dangerous combination that accelerates the development of both microvascular and macrovascular complications. Shared pathophysiological mechanisms, such as insulin resistance, chronic inflammation, and endothelial dysfunction, link these two conditions. The observed correlation between hypertension and elevated blood glucose underscores the importance of comprehensive management strategies that address both blood pressure and glycemic control. Through lifestyle interventions and appropriate pharmacotherapy, the risks associated with these "silent killers" can be mitigated, improving long-term outcomes for patients at risk of cardiovascular events and other complications (Yildiz et al., 2020).

Obesity significantly increases the risk of type 2 diabetes mellitus (T2DM) by increasing insulin resistance and disrupting metabolic homeostasis. The pathophysiology involves ectopic expansion of adipose tissue, which contributes to excessive accumulation of nutrients and metabolites. This accumulation leads to a series of metabolic disturbances, including dysfunctional autophagy and alterations in the microbiome-gut-brain axis, all of which contribute to low-grade systemic inflammation. These inflammatory conditions further impair insulin sensitivity and accelerate the loss of functional β-cells in the pancreas, leading to elevated blood glucose levels. Findings from this study highlighted the nutritional status of the participants, which showed that most were of normal weight, while a significant proportion were overweight or obese. This distribution underscores the importance of addressing obesity and T2DM in the clinical setting, as individuals with obesity are more likely to experience the adverse effects of metabolic dysregulation. In addition, the interaction between anti-obesity and anti-diabetes treatment suggests that the management of one condition may positively impact the other. The dual benefits of weight loss and improved glycemic control are important considerations for individuals with obesity and T2DM (Ruze et al., 2023).

The results of this multivariate analysis provide critical insights into the factors influencing blood sugar levels. Age, exercise frequency, occupational type, income status, education level, family history, hypertension, and nutritional status all demonstrate significant associations. These findings could serve as a foundation for targeted diabetes prevention and management interventions. In relation to the efficacy of Bay Leaf (Syzygium polyanthum) in reducing FBS, PBS, and HbA1c, the findings in Table 3 suggest that addressing these demographic and clinical characteristics could enhance the effectiveness of interventions involving Bay Leaf. Given that age, hypertension, and obesity are significant contributors to elevated blood sugar levels, incorporating Bay Leaf, known for its potential hypoglycemic effects, may provide an additional strategy to mitigate these risks. Research has indicated that compounds found in Bay Leaf may improve insulin sensitivity and enhance glucose metabolism, making it a promising adjunct to lifestyle modifications for individuals at risk of or managing diabetes. Thus, understanding the factors outlined in this analysis can inform tailored approaches that leverage the properties of Bay Leaf to optimize blood sugar control among diverse populations. The results of this multivariate analysis provide critical insights into the factors influencing blood sugar levels and could serve as a foundation for targeted diabetes prevention and management interventions, including the incorporation of natural remedies like Bay Leaf.

The study's findings clearly demonstrate that Bay Leaf (Syzygium polyanthum) intervention significantly reduced Fasting Blood Sugar (FBS), Postprandial Blood Sugar (PBS), and HbA1c levels in the intervention group compared to the control group, emphasizing its effectiveness in managing key indicators of diabetes. FBS reflects the body's ability to regulate blood glucose in a fasting state, while PBS measures the glucose response after a meal. These parameters are closely linked to HbA1c, a marker of long-term glycemic control (Alam et al., 2021; Galicia-Garcia et al., 2020). The consistent reductions across all these markers highlight Bay Leaf's broad-spectrum efficacy in diabetes management (Dwi et al., 2023). However, while these findings align with prior research on herbal interventions for diabetes, further exploration is needed to understand their implications for older adults with diabetes, particularly in the context of aging-related metabolic changes, frailty, and comorbidities. Integrating these aspects into the discussion would strengthen the argument by directly linking the study's results to broader trends in diabetes management among older populations.

Type 2 Diabetes Mellitus (T2DM) is characterized by insulin resistance, impaired insulin secretion, and chronic hyperglycemia, which are associated with oxidative stress, β-cell dysfunction, and the formation of advanced glycation end products (AGEs) (Ohiagu et al., 2021; Tanase et al., 2020; Yaribeygi et al., 2020). These processes contribute to diabetes complications, reinforcing the need for interventions that target both hyperglycemia and oxidative stress. Bay Leaf's bioactive compounds, including polyphenols, flavonoids, and essential oils, play a crucial role in mitigating these pathological mechanisms by improving insulin sensitivity and enhancing glucose uptake by peripheral tissues (Singletary, 2021; Widyawati et al., 2019). Additionally, its α-glucosidase inhibitory activity slows carbohydrate digestion, reducing PBS spikes that are particularly problematic in diabetes management. Since postprandial hyperglycemia is a major risk factor for cardiovascular complications in diabetes patients, the observed reductions in PBS further emphasize Bay Leaf's therapeutic potential (Batool et al., 2020; Dwi et al., 2023; Widyawati et al., 2019).

The reduction in HbA1c observed in the intervention group suggests that Bay Leaf's benefits extend beyond short-term glucose control, contributing to sustained improvements in overall glycemic regulation. HbA1c reflects average blood glucose levels over 2–3 months and is strongly predictive of diabetes-related complications. The observed reduction in HbA1c implies that Bay Leaf helps maintain stable blood glucose levels over time, reducing the cumulative glucose burden on the body (Dwi et al., 2023; Yedjou et al., 2023). Moreover, Bay Leaf's antioxidant properties may counteract oxidative stress, a major contributor to insulin resistance and β-cell dysfunction. By neutralizing reactive oxygen species (ROS), Bay Leaf may protect pancreatic β-cells, restore insulin efficacy, and enhance long-term glucose control. However, while these findings are promising, it is important to acknowledge potential limitations, including sample size constraints, lack of long-term follow-up, and variability in individual responses. Additionally, factors such as the standardization of Bay Leaf extract, potential placebo effects, and blinding in future studies should be considered to improve scientific rigor.

Finally, while this study contributes valuable insights into Bay Leaf's role in diabetes management, future research should aim to strengthen its translational relevance by exploring its effects in diverse populations, particularly in older adults with diabetes who often experience multiple comorbidities. Addressing these challenges through well-designed, randomized controlled trials with larger sample sizes and stricter control measures will enhance the reliability and applicability of these findings. Despite these limitations, the significant reduction in FBS, PBS, and HbA1c observed in this study underscores Bay Leaf's potential as a complementary therapy in diabetes management, offering a natural, multi-targeted approach to improving glycemic control (Widyawati et al., 2019; Wong & Sattar, 2023).

5. CONCLUSION

The study demonstrates that Bay Leaf (Syzygium polyanthum) significantly reduces Fasting Blood Sugar (FBS), Postprandial Blood Sugar (PBS), and HbA1c levels, highlighting its efficacy in diabetes management. Notably, older age, female gender, and higher educational attainment correlate with improved glycemic control, while factors such as obesity and hypertension contribute to elevated blood sugar levels. Future research should explore the long-term effects of Bay Leaf on diabetes management. Additionally, interventions promoting physical activity and nutrition education may enhance outcomes, especially in populations with high obesity and hypertension prevalence. Integrating Bay Leaf into dietary guidelines could also be beneficial.

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CONFLICT OF INTEREST

There is no conflict of interest in this research.

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DATA AVAILABILITY

The data supporting this study's findings are available upon request from the corresponding author.

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