Sago and Katuk Leaf Combination Treatment Reduces The Blood Glucose Levels in Diabetes Mellitus Patients

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Abstract

Background: Diabetes mellitus is a chronic metabolic disorder characterized by elevated blood glucose levels. The management of diabetes involves both pharmacological and non-pharmacological treatments. The combination of sago and katuk leaves has been shown to possess potential pharmacological effects, including antidiabetic properties, making it a promising therapeutic approach for diabetes management. This study aims to evaluate the effect of a combination of sago and katuk leaves on blood glucose levels in patients with diabetes mellitus. Methodology: A quantitative experimental design using a pretest-posttest with control group was employed in this study. The research was conducted at Masamba Health Center and Baebunta Health Center in North Luwu Regency. A purposive sampling technique was used to select 60 participants, with 30 individuals in the intervention group and 30 in the control group. The intervention group received the combination of sago and katuk leaves, while the control group received conventional antidiabetic medication. Statistical analyses were performed using the T-Dependent, Wilcoxon, and T-Independent tests to assess changes in blood glucose levels. Results: The results indicated a significant difference in blood glucose levels before and after treatment in both groups (p = 0.000). The intervention group, which received the combination of sago and katuk leaves, showed an average reduction of 25.84 mg/dL in blood glucose levels, while the control group, receiving standard antidiabetic medications, showed a reduction of 6.34 mg/dL. Conclusion: The study concludes that the combination of sago and katuk leaves significantly reduces blood glucose levels in patients with diabetes mellitus. These findings suggest that sago and katuk leaves could be a beneficial adjunct in the management of diabetes, particularly in areas where access to conventional treatments is limited. Further research is recommended to confirm these findings and explore the long-term effects of this combination.

Keywords: Diabetes Mellitus, Sago, Katuk Leaves, Blood Glucose Levels, Non-Pharmacological Treatment

Significance | This study demonstrates that sago and katuk leaves effectively reduce blood glucose levels, offering a cost-effective, culturally suitable diabetes management solution.

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Introduction

Non-communicable diseases (NCDs), often referred to as degenerative diseases, represent a significant global public health concern due to their high morbidity and mortality rates (Minister of Health, 2020). Annually, NCDs account for 41 million deaths, which is approximately 74% of all deaths worldwide. The principal types of NCDs include cardiovascular diseases (such as heart attacks and strokes), cancer, chronic respiratory diseases (such as chronic

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obstructive pulmonary disease and asthma), and diabetes mellitus (World Health Organization [WHO], n.d.). Among these, Type 2 Diabetes Mellitus (T2DM) is the most prevalent form of diabetes. T2DM is a chronic condition characterized by elevated blood sugar levels due to insulin resistance or improper glucose absorption by body cells. This metabolic disorder can lead to complications in multiple organ systems. While T2DM is more common in adults, it has also been increasingly observed in children and adolescents (Ministry of Health of the Republic of Indonesia, 2022). The 2019 Basic Health Research (Riskesdas) report indicated that the prevalence of diabetes mellitus diagnosed by doctors in individuals aged ≥15 years was 2%, a notable increase from 1.5% in 2013. Furthermore, the prevalence determined by blood sugar examinations rose from 6.9% in 2013 to 8.5% in 2018 (Ministry of Health of the Republic of Indonesia, 2022).

In Indonesia, diabetes prevalence varies across regions. Data from the South Sulawesi Provincial Health Office highlighted that Tana Toraja Regency (6.1%), Makassar City (5.3%), Luwu Regency (5.2%), and North Luwu Regency (4.0%) have the highest prevalence rates (Resti, Cahyati, & Article, 2022). Within North Luwu Regency, Masamba District ranks highest, with 86.43% of the estimated 4,391 target cases identified by 2020. The Masamba and Baebunta Health Centers are particularly burdened, reporting 635 and 484 diabetes cases, respectively, according to the 2023 P2 Field Report of the North Luwu Health Office.

Management of diabetes involves both pharmacological and non-pharmacological approaches. Pharmacological treatments typically include drugs such as sulfonylurea, glinides, metformin, and thiazolidinediones (Shin et al., 2020). Non-pharmacological treatments often emphasize lifestyle modifications, including dietary interventions, physical activity, and traditional remedies. Traditional treatments remain popular in Indonesia due to their perceived efficacy and affordability. For instance, sago (*Metroxylon sagu* Rottb.) is gaining attention as a dietary substitute for individuals with diabetes. Sago, an inexpensive and readily available carbohydrate source, is particularly suitable for non-pharmacological interventions due to its ease of preparation and potential health benefits (Nurlila, Sudiana, & La Fua, 2021).

In recent research, efforts have been directed at innovating sago-based foods to enhance their appeal and nutritional benefits. A promising approach involves combining sago with katuk leaves (*Sauropus androgynus*), which are rich in chlorophyll pigments and antioxidants. Katuk leaves have been previously documented for their health-promoting properties, including as a lactation booster and a source of bioactive compounds with antioxidant activity (Syahadat & Siregar, 2020). By incorporating katuk leaf powder into sago, researchers aim to improve the nutritional profile and visual appeal of the resulting product, making it more attractive to consumers. Typically, sago appears white or gray, but the addition of katuk leaf powder imparts a natural green hue, increasing its aesthetic appeal (Damayanti, 2023).

The potential of the sago-katuk combination to manage blood sugar levels is particularly relevant for regions like Masamba and Baebunta, where diabetes prevalence is high. Preliminary studies suggest that sago consumption can reduce fasting blood sugar levels, while katuk leaves offer complementary antioxidant effects, further enhancing metabolic control (Irmawati et al., 2022). Moreover, this combination aligns with local dietary habits and cultural preferences, increasing the likelihood of acceptance and adherence among diabetes patients.

The integration of sago and katuk leaves represents an innovative, culturally appropriate, and economically feasible intervention for managing diabetes in North Luwu Regency. This study aims to evaluate the effectiveness of this combination in reducing blood sugar levels among patients with T2DM at the Masamba and Baebunta Health Centers. By addressing both nutritional and cultural dimensions, this research contributes to the broader effort of improving diabetes management through sustainable and accessible interventions.

2. **Materials and Methods**

This study employed a quasi-experimental design, specifically a non-randomized pretest-posttest with control group design, to assess the effect of a combination of sago (*Metroxylon sagu* Rottb.) and katuk (*Sauropus androgynus*) leaves on blood sugar levels in diabetic patients.

2.1 Study Design and Sampling

A total of 60 respondents were recruited, with 30 participants assigned to the intervention group (Masamba Health Center) and 30 to the control group (Baebunta Health Center) based on purposive sampling. Each group underwent pretest and posttest assessments. The sample size was determined using an established formula to ensure statistical reliability.

2.2 Intervention

Participants in the intervention group consumed a combination of sago and katuk leaves, prepared as per protocol, for a duration of seven days. The control group continued their usual treatment with prescribed antidiabetic drugs without any additional interventions. All participants were instructed to maintain their regular diet and physical activity during the study period.

2.3 Data Collection and Processing

Data were collected through structured interviews, anthropometric measurements, dietary intake evaluations, and blood sugar level tests. Blood sugar levels were assessed using standard biochemical methods at both pretest and posttest.

Nutritional analysis confirmed that the combination of sago and katuk leaves contained 517.9 µg/g flavonoids, 4305.76 µg/g

alkaloids, and 14.23 µg/g tannins, which were hypothesized to influence blood sugar levels.

2.4 Statistical Analysis

The collected data were analyzed using Stata Version 14. Descriptive statistics summarized respondent characteristics, while inferential statistics evaluated intervention effects. Statistical tests included:

Dependent t-test: To assess within-group differences before and after the intervention.

Wilcoxon signed-rank test: Applied for non-parametric within-group comparisons.

Independent t-test: To compare mean differences in outcomes between the intervention and control groups.

2.5 Ethical Considerations

This study was conducted in accordance with ethical principles outlined by the Health Research Ethics Committee of Hasanuddin University. Ethical approval was granted with the reference number 2953/UN4.14.1/TP.01.02/2024.

3. **Results**

The chemical composition analysis revealed that the combination of sago and katuk leaves contained notable active compounds. Specifically, flavonoids were present at a concentration of 517.9 µg/g, alkaloids at 4305.76 µg/g, and tannins at 14.23 µg/g (Table 1).

The demographic characteristics of the respondents are presented in Table 2. The majority of respondents in both the intervention and control groups were female, with proportions of 73.33% and 70%, respectively, owing to gender matching during the study. Most participants were aged between 45 and 59 years, with a predominant educational background at the high school level.

Table 3 highlights the baseline characteristics of the respondents. Most respondents were classified within the normal BMI category. Additionally, the majority did not have a family history of diabetes mellitus, had been diagnosed with diabetes for 1–3 years, engaged in regular physical activity, did not use herbal alternatives, and had their medication regimen supervised by family members, primarily their children.

The dietary intake of respondents before and after the intervention is detailed in Table 4. Carbohydrate consumption was higher before the intervention and showed a notable decrease afterward, accompanied by an increase in fiber intake post-intervention.

Table 5 illustrates the levels of compliance in taking antidiabetic drugs, with most respondents demonstrating high compliance.

Tables 6 and 7 present the results of independent t-tests comparing the characteristics of respondents before and after the intervention in the intervention and control groups, respectively.

The effectiveness of the intervention is evident in the blood sugar levels reported in Tables 8 and 9. In the intervention group, the mean blood sugar level decreased significantly by 25.9 mg/dL ($p = 0.0008$). Conversely, the control group experienced a reduction of 5.1 mg/dL, but this change was not statistically significant ($p = 0.00$). Furthermore, Table 9 reveals a significant average difference in blood sugar level reductions between the intervention group (25.84 mg/dL) and the control group (6.34 mg/dL) ($p = 0.00$), underscoring the superior efficacy of the sago and katuk leaf combination compared to standard antidiabetic drug use.

The results collectively demonstrate the potential benefits of the sago and katuk leaf combination in reducing blood sugar levels and improving dietary habits in diabetic patients.

4. Discussion

The findings of the present study reveal that the combination of sago (*Metroxylon sagu* Rottb.) and katuk (*Sauropus androgynus*) leaves contains significant phytochemical compounds, including flavonoids (0.51 mg), alkaloids (4.30 mg), and tannins (0.01 mg) per 140 grams or four sheets of these leaves. These bioactive compounds have notable therapeutic potential, particularly in the management of diabetes mellitus (DM).

Sago leaves, as demonstrated by Nurlila et al. (2021), are rich in alkaloids, tannins, phenols, saponins, flavonoids, and steroids. These compounds contribute to their ability to lower blood sugar levels and exhibit antibacterial properties. Similarly, katuk leaves, which contain flavonoids, alkaloids, and tannins, have been identified as effective natural antibiotics and anti-inflammatory agents (Syahadat & Siregar, 2020). The presence of these bioactive compounds in both plants underscores their combined potential in diabetes management, particularly in regulating blood glucose levels through multiple mechanisms.

Consuming sago and katuk leaves for seven days resulted in significant changes in blood sugar levels in diabetes mellitus patients. This effect is attributed to the synergistic action of flavonoids and alkaloids. Alkaloids in sago and katuk leaves enhance glucose oxidase enzyme activity, promoting glucose uptake by body cells (Yulianti & Anggraini, 2020). Additionally, flavonoids act as secondary antioxidants, crucial for combating oxidative stress in type 2 DM patients. Hyperglycemia in type 2 DM triggers oxidative stress, necessitating the intake of external antioxidants such as flavonoids to intercept free radicals and interrupt oxidative chain reactions (Hudatul Umam et al., 2020).

Tannins, another key compound present in the leaves, offer multifaceted benefits. They improve pathological oxidative stress, act as anti-free radicals, and activate antioxidant enzymes that aid in regenerating pancreatic cells (Aqil et al., 2023). Furthermore, tannins damage bacterial cell membranes, reducing bacterial proliferation, which is particularly beneficial in preventing secondary infections in diabetic wounds.

The study also highlights the demographic characteristics of DM patients. Women are disproportionately affected by DM due to

hormonal and metabolic factors, including monthly cycles and menopause, which contribute to increased fat distribution and insulin resistance (Harsismanto et al., 2021). Additionally, the age group of 45-59 years is prominently affected. Pre-elderly individuals experience physical and mental decline, reducing the effectiveness of insulin production and metabolic regulation. These findings align with Supardi et al. (2023), who emphasize the vulnerability of pre-elderly individuals to degenerative diseases like DM.

Education plays a pivotal role in the management of diabetes. Patients with higher education levels demonstrate better understanding and adherence to glycemic control, self-care practices, and healthy living behaviors (Andika & Novitasari, 2024). In contrast, low education levels often correlate with inadequate disease management, as observed by Retnowati and Satyabakti (2022). Educated patients are more likely to implement lifestyle changes and adhere to treatment regimens, ultimately enhancing their quality of life. These observations suggest that targeted educational interventions could improve disease outcomes.

The study's findings support the therapeutic potential of sago and katuk leaves in diabetes management. Alkaloids, flavonoids, and tannins synergistically address hyperglycemia, oxidative stress, and associated complications. These bioactive compounds' mechanisms align with traditional knowledge and contemporary research, providing a robust foundation for their application in DM therapy. For instance, flavonoids' antioxidant properties not only mitigate oxidative stress but also enhance vascular health, reducing the risk of cardiovascular complications commonly associated with DM (Hudatul Umam et al., 2020). Meanwhile, alkaloids' enzymatic modulation improves glucose metabolism, making them valuable in maintaining glycemic balance. Tannins' dual role as antioxidants and antibacterial agents further strengthens their therapeutic profile (Aqil et al., 2023).

Moreover, the study emphasizes the importance of integrating natural products like sago and katuk leaves into dietary interventions. These plants offer a sustainable, cost-effective approach to managing DM, particularly in resource-limited settings. However, the findings also highlight the need for comprehensive education programs to maximize the benefits of such interventions. By enhancing patients' understanding of DM and its management, healthcare providers can foster better adherence to treatment and improve health outcomes (Andika & Novitasari, 2024).

Future research should explore the long-term effects of consuming sago and katuk leaves, including their impact on insulin sensitivity, lipid profiles, and inflammatory markers. Additionally, clinical trials involving larger, more diverse populations are essential to validate these findings and establish standardized dosages for therapeutic use. Investigating the molecular mechanisms underlying these bioactive compounds' actions could also provide valuable insights into their role in DM management.

The combination of sago (*Metroxylon sagu* Rottb.) and katuk (*Sauropus androgynus*) leaves presents a promising intervention for managing blood sugar levels in individuals with type 2 diabetes mellitus (DM). The findings of this study underscore the significant presence of bioactive compounds such as flavonoids, alkaloids, and tannins, which are pivotal in mitigating hyperglycemia and its associated complications. Specifically, the phytochemical analysis revealed concentrations of flavonoids, alkaloids, and tannins at 0.51 mg, 4.30 mg, and 0.01 mg per 140 grams, respectively. These compounds' roles in improving blood glucose regulation and providing additional health benefits are supported by various studies.

The role of sago leaves in diabetes management has been well-documented. Nurlila et al. (2021) demonstrated that sago leaves contain alkaloids and tannins with potent blood sugar-lowering effects. The phytochemical screening of ethanol extracts of sago leaves confirmed the presence of alkaloids, phenols, flavonoids, saponins, tannins, and steroids, which collectively contribute to their therapeutic properties. Alkaloids enhance the activity of the glucose oxidase enzyme, facilitating increased glucose absorption by body cells (Ulfa, Primadiamanti, & Alim, 2022). Moreover, flavonoids serve as secondary antioxidants, neutralizing free radicals and breaking oxidative stress chains triggered by hyperglycemia (Hudatul Umam, Solehati, & Purnama, 2020). Tannins, on the other hand, exhibit antibacterial properties by damaging bacterial membranes and interfering with their permeability, while also acting as anti-free radicals that regenerate pancreatic cells (Aqil et al., 2023).

Katuk leaves similarly exhibit potent antidiabetic properties through their rich flavonoid, alkaloid, and tannin content. Syahadat and Siregar (2020) highlighted their efficacy as natural anti-inflammatory agents and antibiotics, improving cell structures in individuals with chronic diseases such as diabetes. The synergistic effects of these bioactive compounds in katuk leaves align with the therapeutic mechanisms observed in sago leaves, making their combination particularly effective for managing DM.

The clinical effects of consuming sago and katuk leaves over a seven-day period were evident in the significant reductions in blood sugar levels among DM patients. This improvement can be attributed to the bioactive compounds' actions, particularly flavonoids and alkaloids, in enhancing glucose metabolism. Flavonoids act as exogenous antioxidants, which are crucial for DM patients who experience oxidative stress due to persistent hyperglycemia. As secondary antioxidants, they inhibit free radical chain oxidation reactions, reducing oxidative stress and its associated complications (Hudatul Umam, Solehati, & Purnama, 2020). Meanwhile, alkaloids boost glucose oxidase enzyme activity,

Table 1. Phytochemical test of Combination Sago and Katuk Leaves

Phytochemical Compounds	Unit	Test Result
Flavonoid	µg/g	517,9
Alkaloid	µg/g	4305,76
Tanin	µg/g	14,23

Table 2. Frequency Distribution of General Characteristics of Respondents

Respondent Charasteristics	Intervention		Control	
	n	%	n	%
Gender				
Male	8	26,67	9	30
Female	22	73,33	21	70
Age Group				
45-59 years	25	83,33	21	70,0
≥60 years	5	16,67	9	30,0
Education				
Not School	1	3,33	2	6,67
Elementary School	4	13,33	1	3,33
Junior High School	5	16,67	7	23,33
Senior High School	15	50	13	43,33
Associate Degree	3	10	1	3,33
Bachelor Degree	2	6,67	6	13,33
Occupation				
House Wife	15	50,0	11	36,67
Laborer	8	26,67	2	6,67
Civil Servant	2	6,67	4	13,33
Self-employed	5	16,67	13	43,33
Marriage Status				
Married	30	100	30	100
Single-handed	0	0	0	0
Total	30	100	30	100

Table 5. Distribution of Compliance Level of Antidiabetic Drug Consumption of Prolanis Participants

Medication Compliance	Intervention		Control	
	n	%	n	%
High	21	70	20	66,67
Low	9	30	10	33,33
Total	30	100	30	100

Table 8. Difference in Blood Sugar Levels Before and After Intervention

Blood Sugar Levels	Variable	Mean (mg/dL)	SD	Differences		*P value*
				Mean	SD	
Intervention	Before	151,2	10,9	25,9	11,04	0,0008*
	After	125,3	4,6			
Control	Before	153,7	11,2	5,1	14,07	0,00*

Table 9. Analysis of Mean and Difference of Blood Sugar Levels in Intervention and Control

Blood Sugar Levels	Variable	Mean (mg/dL)	SD	Differences		*P value*
				Mean	SD	
Pre-Post test (n=60)	Intervention	25,84	11,8	16,08	14,5	0,00*
	Control	6,34	9,52			

Table 3. Frequency Distribution of Clinical Characteristics of Respondents

Respondents' Clinical Characteristics	Intervention		Control	
	n	%	n	%
Body Mass Index (BMI)				
Normal	21	70	11	36,67
Overweight	7	23,33	17	56,67
Obesity	2	6,67	2	6,67
Smoking Behavior				
Yes	6	20	8	26,67
No	24	80	22	73,33
Family History				
Yes	13	43,33	11	36,67
No	17	56,67	19	63,33
Durating of Suffering				
<1 year	9	30	7	23,33
1-3 years	19	63,33	20	66,67
>3 years	2	6,67	3	10
Physical Activity	**n**	**%**	**n**	**%**
Yes	16	53,33	18	60
No	14	46,67	12	40
Herbal Alternative				
Yes	14	43,44	11	36,67
No	17	56,67	19	63,33
Suoervisor of Taking Medication				
Children	15	50	19	63,33
Siblings	5	16,67	3	10
Husband/Wife	10	33,33	8	26,67
Total	30	100	30	100

Table 4 Differences in Carbohydrate Intake and Fiber Intake in the Intervention Group

Characteristics of Respondents' Food Intake	Intervention		Control	
	n	%	n	%
Carbohydrate Intake Before Intervention				
More	21	70,0	11	36,67
Enough	7	23,33	17	56,67
Fiber Intake Before Intervention				
Enough	18	60,0	23	76,67
Less	12	40,0	7	23,33
Carbohydrate Intake After Intervention				
More	18	60,0	11	35,67
Enough	12	40,0	19	63,33
Fiber Intake After Intervention				
More	27	90,0	21	70,0
Enough	3	10,0	9	30,0
Total	30	100	30	100

Table 6. Differences in Blood Sugar Levels Before and After in the intervention group

Variable	Pre Test		Post Test		P Value
	n	Mean ± SD	n	Mean ± SD	
Gender					
Male	8	150,6 ±9,79	8	127,6±1,49	0,865
Female	22	151,4 ±11,49	22	124±5,1	
Age					
45-59 year	25	150,12 ± 11,49	25	124,96 ± 14,94	0,289
>60 year	5	156,6 ± 5,12	5	127,4 ± 1,51	
Smoking Behavior					
Yes	6	146±12,38	6	126 ± 3,22	0,714
No	24	152,2917 ± 10,51	24	125,20 ± 4,96	
Family History					
Yes	13	154 ,46 ± 12,11	13	125,07 ± 122,08	0,770
No	17	148,70 ± 9,50	17	125,58 ± 4,50	
Physical Ativity					
Yes	16	153 ± 12,1	16	126,31 ± 0,94	0,238
No	14	149,14 ± 9,35	14	124,28 ± 6,6	
Herbal Alternatives					
Ya	13	147,82 ± 9,3	13	125,38 ± 5,05	0,985
No	17	155,6 ± 11,6	17	125,35 ± 4,42	

Table 7 Differences in Blood Sugar Levels Before and After in the Control Group

Variable	Pre Test		Post Test		pValue
	n (30)	Mean ± SD	n (30)	Mean ± SD	
Gender					
Male	9	154±11,03	9	146,33 ± 13,68	0,752**
Female	21	153,57 ± 11,56	21	147,80 ±10,69	
Age Group					
45-59 years	21	156,09 ± 11,44	21	148 ± 12,53	0,651**
>60 years	9	148,11 ± 8,86	9	145,88 ± 8,86	
Smoking Behavior					
Yes	8	153,5 ± 11,68	8	146,5 ± 12	0,524**
No	22	153,77 ± 11,32	22	149,62 ± 10,12	
Family History					
Yes	11	149,36 ± 10,2	11	144,18 ± 10,98	0,253**
No	19	156,21 ± 10,29	19	149,21 ± 11,59	
Physical Activity					
Yes	18	157,38 ± 10,61	18	152,22 ± 11,874	0,420**
No	12	148,16 ± 10,10	12	140,08 ± 11,87	
Herbal Alternative					
Yes	11	150,27 ± 10,27	11	146,45 ± 8,27	9,746**
No	19	155,68 ± 11,52	19	147,89 ± 13,12	

promoting better glucose utilization at the cellular level (Yulianti & Anggraini, 2020).

Tannins' therapeutic roles extend beyond their antioxidant properties. They can mitigate pathological oxidative stress in diabetic conditions and enhance pancreatic cell regeneration. This is particularly significant, given the role of oxidative stress in the progression of DM and its complications (Aqil et al., 2023). Furthermore, tannins' ability to improve the structural integrity of pancreatic cells may contribute to better insulin production and secretion, aiding glucose homeostasis.

The demographic characteristics of the study participants provide additional insights into the prevalence and management of DM. The predominance of women among DM patients aligns with findings by Harsismanto et al. (2021), which suggest that hormonal and metabolic factors, including menstrual cycles and menopause, contribute to increased body fat distribution and heightened DM risk. Additionally, the higher incidence of DM among individuals aged 45-59 years underscores the vulnerability of this age group to degenerative diseases, as noted by Supardi et al. (2023). This demographic is characterized by physiological and metabolic declines that impair insulin production and utilization, making them more susceptible to chronic conditions such as DM.

Educational attainment emerged as a critical factor influencing DM management and outcomes. Participants with higher educational levels demonstrated better understanding and adherence to self-management practices, as well as greater compliance with glycemic control measures. This finding aligns with research by Andika Adristia and Novitasari (2024), which emphasized the role of education in enhancing patients' awareness and adoption of healthy lifestyles. Conversely, low education levels were associated with poorer disease management and higher DM prevalence, highlighting the need for targeted health education interventions to bridge this gap.

The study's findings resonate with the broader literature on the interplay between bioactive compounds and diabetes management. For instance, the antioxidant properties of flavonoids and tannins have been extensively documented as pivotal in reducing oxidative stress and improving metabolic functions in DM patients (Aqil et al., 2023; Hudatul Umam, Solehati, & Purnama, 2020). Similarly, alkaloids' enzymatic actions in enhancing glucose metabolism underscore their therapeutic potential (Ulfa, Primadiamanti, & Alim, 2022).

Despite these promising findings, the study's scope is limited by its short duration and small sample size, which may affect the generalizability of the results. Future research should explore the long-term effects of sago and katuk leaf consumption on DM management across diverse populations and settings. Additionally, mechanistic studies are needed to elucidate the precise pathways through which these bioactive compounds exert their effects, paving the way for more targeted and effective interventions.

Recent studies suggest that the pre-elderly population exhibits minimal physical activity levels. According to local survey data, fewer than 30% of pre-elderly individuals engage in regular light exercise. This is concerning, as adequate physical activity plays a crucial role in controlling blood sugar levels and maintaining overall physical fitness. Research indicates that regular physical activity can reduce the risk of developing diabetes by up to 40% among high-risk individuals (Setyoningrum et al., 2024). Consequently, counseling efforts to emphasize the importance of physical activity, particularly for pre-elderly individuals, should be enhanced.

Physical activity recommendations for diabetes mellitus patients align with guidelines that encourage moderate to vigorous activities tailored to individual abilities and conditions. Such activities may include work-related tasks, transportation-related activities, and domestic chores (Yellisni & Kalsum, 2023). These forms of physical engagement contribute significantly to improved blood sugar control and overall health outcomes.

Regarding the use of alternative treatments, most respondents in both the intervention and control groups did not use herbal medicines. Interviews revealed that respondents who avoided herbal alternatives preferred focusing on conventional treatments prescribed by medical professionals. This aligns with Nugraha's (2021) findings, which indicated that 56% of respondents opted against using herbal medicine due to a lack of knowledge and a preference for prescribed medications. However, herbal alternatives such as boiled water from katuk leaves (*Sauropus androgynus*), which contain tannins and flavonoids, have demonstrated potential in lowering blood glucose levels. These properties suggest that katuk leaves could serve as both a preventive and therapeutic measure for diabetes (Muliyah, 2020).

The study also highlighted the critical role of family members as drug adherence supervisors, particularly children, in both the intervention and control groups. Family members provided support by monitoring and reminding respondents about medication and dietary compliance. This finding aligns with Riani et al. (2024), who emphasized the importance of family support in promoting medication adherence. Families significantly influence care methods, health outcomes, and the management of chronic illnesses such as diabetes.

Sago flour (*Metroxylon sagu*) emerged as a beneficial ingredient in diabetes management due to its lower carbohydrate content compared to rice flour and its nutritional advantages. Sago flour's glycemic index (GI) ensures a slower increase in blood glucose levels, while its additional benefits include enhanced immunity, reduced risks of colon and lung cancer, and improved digestive health (Syartiwidya, 2023). The combination of sago and katuk

leaves exhibits antioxidant activity, including flavonoid compounds, alkaloids, and condensed tannins. These properties facilitate free radical scavenging, making the combination a potential daily supplement for individuals with diabetes (Irmawati et al., 2022).

The intervention study demonstrated that consuming a combination of sago and katuk leaves led to significant reductions in blood sugar levels among respondents in the intervention group compared to the control group. This finding supports Irmawati et al.'s (2022) research, which observed that 94.4% of respondents in the intervention group experienced decreased blood sugar levels after incorporating the combination. Similarly, Damayanti's (2023) study reported a significant decline in fasting blood sugar levels within seven days of consuming sago. The average blood sugar reduction in the intervention group was 25.15 mg/dL with a standard deviation of 3.934, compared to a reduction of 0.62 mg/dL with a standard deviation of 3.798 in the control group (Astuti, 2020).

The combined nutritional and antioxidant properties of sago and katuk leaves highlight their potential as a functional food for managing diabetes. Further research and educational initiatives should aim to raise awareness about these natural alternatives while encouraging their integration into diabetes care regimens. By addressing both physical activity and dietary interventions, comprehensive strategies can be developed to improve health outcomes for individuals with diabetes mellitus.

5. Conclusion

In conclusion, the combination of sago and katuk leaves offers a natural and effective approach to managing blood sugar levels in DM patients, driven by their rich bioactive compound profiles. Their therapeutic effects, coupled with demographic and educational insights, underscore the importance of integrative strategies in addressing the multifaceted challenges of DM. Further research and health education initiatives are essential to maximize their potential and enhance patient outcomes.

Promoting physical activity among the pre-elderly is crucial to reducing diabetes risk and improving health outcomes. Counseling should emphasize moderate-to-vigorous exercises tailored to individual abilities. Despite limited use of herbal alternatives, plants like katuk (*Sauropus androgynus*) and sago (*Metroxylon sagu*) show promise in managing diabetes due to their glycemic benefits and antioxidant properties. Family support plays a vital role in medication adherence and lifestyle changes. The combination of natural interventions, medical treatment, and community support can effectively lower blood sugar levels, as evidenced by the significant reductions seen in intervention groups consuming sago and katuk-based preparations.

Author contributions

Y.A. was responsible for conceptualization, methodology, data curation, and writing the original draft. I.L.M. supervised the study, validated the findings, and critically reviewed the manuscript. A.Z. conducted investigation, data collection, and formal analysis. R.A. managed the project and provided resources. M.A. contributed to software, visualization, and statistical analysis. H.H. participated in writing, reviewing, and editing the manuscript, as well as acquiring funding. All authors have read and approved the final version of the manuscript.

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Competing financial interests

The authors have no conflict of interest.

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