

Proximate and Phytochemical Composition of Bajakah (*Spatholobus littoralis* Hassk) Extract and its Effect on Fasting Blood Glucose in STZ-HFD-Induced Diabetic Rats

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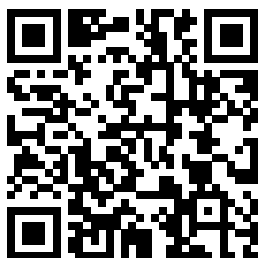
Bajakah Wood (*Spatholobus Littoralis* Hassk), Antihyperglycemic, Proximate, Phenols, Flavonoids, Tannins, Saponins, Fasting Blood Glucose.

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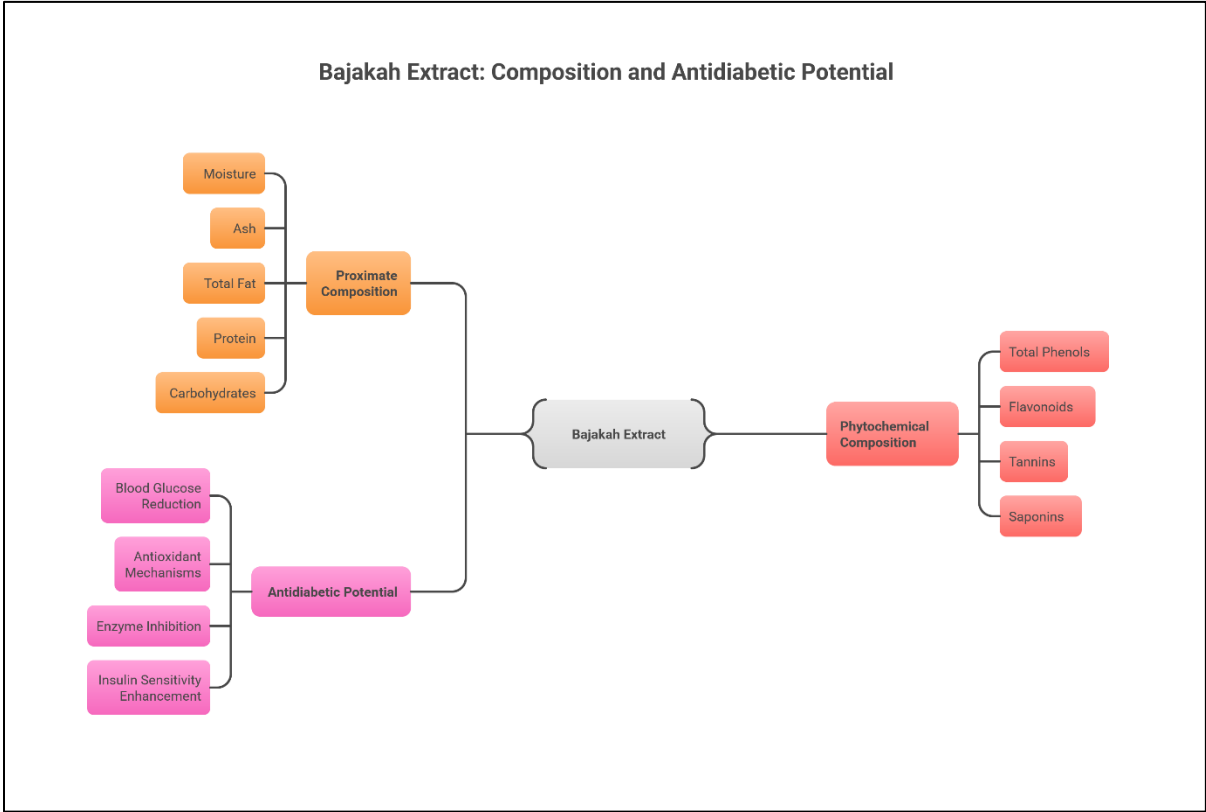
ABSTRACT

The rising global prevalence of type 2 diabetes mellitus (T2DM) highlights the urgent need for plant-based therapeutic alternatives. *Spatholobus littoralis* Hassk, locally known as Bajakah, is a traditional medicinal plant from West Kalimantan, Indonesia, that is widely used by indigenous communities for regulating blood sugar levels. This study aimed to characterize the proximate and phytochemical composition of Bajakah wood extract and evaluate its antidiabetic potential in rats induced with a high-fat diet (HFD) and Streptozotocin (STZ). The extraction was performed using a 70% ethanol maceration method. Proximate analysis revealed low moisture (4.57%), ash (0.54%), total fat (0.81%), and protein (0.41%), with carbohydrates being the most abundant component (6.67%). Phytochemical screening using UV-Vis spectrophotometry identified total phenols (12.98%), flavonoids (1.16%), tannins (1.65%), and saponins (0.13%). The *in vivo* test on diabetic rats showed that the administration of Bajakah extract at a dose of 150 mg/kg body weight (BW) for 14 days significantly reduced fasting blood glucose levels from 279.46 ± 2.39 mg/dL to 115.62 ± 13.73 mg/dL ($P = 0.028$), corresponding to a 58.6% reduction. This reduction was greater than that of the positive control group, which was treated with Acarbose. The high content of phenolics and other bioactive compounds is strongly suggested to contribute to the antihyperglycemic effect through antioxidant mechanisms, inhibition of digestive enzymes, and enhancement of insulin sensitivity. This study these findings support the therapeutic potential of Bajakah wood extract from West Kalimantan as a complementary agent for management of T2DM.

Key Messages:

- Bajakah extract contains bioactive compounds, especially phenolics, flavonoids, tannins, and saponins, with potential antioxidant and antidiabetic properties.
- Flavonoids, tannins, and saponins in Bajakah extract exhibit synergistic mechanisms, such as inhibiting α -amylase and α -glucosidase enzymes, enhancing GLUT-4 activity, and stimulating insulin secretion.

GRAPHICAL ABSTRACT



INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia resulting from defects in insulin secretion, insulin action, or both. Chronic hyperglycemia generates excess reactive oxygen species (ROS), which in turn causes oxidative stress in the body (1). This oxidative stress plays a central role in the pathophysiology of diabetes by contributing to cellular and tissue damage, particularly to pancreatic β -cells. Damage to β -cells impairs the body's ability to produce and utilize insulin effectively, exacerbating insulin resistance and worsening glycemic control over time (2).

The prevalence of diabetes mellitus (DM), particularly type 2 diabetes mellitus (T2DM), has shown a continuous and alarming increase globally over the past decade. Th is trend reflects a growing public health concern that has prompted extensive research and urgent action worldwide. According to the 2021 report by the International Diabetes Federation (IDF), 2021 approximately 537 million adults worldwide live with DM. Alarmingly, this figure is projected to increase significantly, reaching an estimated 643 million cases by 2030 and further escalating to 783 million by 2045. These statistics indicate a growing disease burden and the increasing need for effective prevention and management strategies. The burden of DM is particularly pronounced in the Southeast Asian region, where demographic transitions, urbanization, lifestyle changes, and dietary habits have contributed to the rise in non-communicable diseases. In 2019, the Southeast Asian population affected by DM was reported to be around 88 million, and this number is expected to rise to 113 million by 2030 and 151 million by 2045. In Indonesia, which ranks fifth among countries with the highest number of DM cases, the number of individuals diagnosed with diabetes reached 19.5 million in 2021. Projections indicate that this number will surge to 28.6 million by 2045. Additionally, the mortality associated with DM is significant, with 433,752 deaths reported in Indonesia in 2020, expected to increase dramatically to 944,468 deaths by the year 2045 (4).

Type 2 Diabetes Mellitus (T2DM) is a progressive metabolic disorder characterized by chronic hyperglycemia resulting from a combination of insulin resistance in peripheral tissues and impaired insulin secretion by pancreatic beta cells. In insulin-sensitive tissues, such as skeletal muscle, liver, and

adipose tissue, insulin resistance impairs glucose uptake and utilization through the dysregulation of the insulin signaling cascade, particularly the IRS PI3K Akt pathway. In skeletal muscle, diminished GLUT-4 translocation reduces glucose uptake, while in adipose tissue, excessive lipolysis increases circulating free fatty acids (FFAs), exacerbating hepatic insulin resistance and promoting ectopic fat deposition. Hepatic insulin resistance further contributes to hyperglycemia by enhancing gluconeogenesis and inhibiting glycogen synthesis. Concurrently, β -cell dysfunction is driven by chronic glucotoxicity, lipotoxicity, and oxidative stress, which induce ER stress, activate the unfolded protein response (UPR), and ultimately lead to β -cell apoptosis and inadequate insulin secretion (5).

Mitochondrial dysfunction serves as a central mediator in the pathogenesis of T2DM, with nutrient overload and impaired oxidative phosphorylation leading to the excessive generation of reactive oxygen species (ROS). ROS accumulation disrupts insulin signaling, promotes the formation of advanced glycation end-products (AGEs), and triggers proinflammatory pathways. Additionally, low-grade chronic inflammation primarily derived from hypertrophic adipose tissue and immune cell infiltration further impairs insulin action and perpetuates metabolic dysregulation. Collectively, these interrelated molecular and cellular disturbances establish a self-reinforcing cycle of insulin resistance and β -cell failure, underpinning the complex pathophysiology of T2DM (5)(2).

Given the chronic nature of T2DM and the complications associated with the long-term use of synthetic antidiabetic drugs, there is an increasing interest in exploring alternative therapeutic agents derived from natural sources. Natural products, especially those derived from medicinal plants, are considered safer, more accessible, and potentially effective due to their bioactive constituents. The World Health Organization (WHO) has reported that approximately 75% to 80% of the global population, particularly those in developing countries, depend primarily on plant-based traditional medicine systems (6). Plants rich in antioxidant compounds are essential in this context, as antioxidants help to neutralize oxidative stress and protect pancreatic β -cells from further damage oxidative (7). Natural antioxidants can also enhance the function of endogenous antioxidant defense systems, thereby offering therapeutic benefits in managing oxidative damage associated with diabetes (8). One such plant that has received considerable attention for its potential medicinal properties is *Spatholobus littoralis* Hassk, locally known as Bajakah. Traditionally used by indigenous communities in Kalimantan, Indonesia, Bajakah has been employed to enhance stamina and to treat a variety of chronic and degenerative diseases, including diabetes, cancer, inflammation, and cardiovascular disorders (9)(10).

Preliminary studies have demonstrated that Bajakah extract contains a variety of phytochemicals with potential health benefits. Previous research stated that the ethanol extract of this plant has antioxidant activity with an IC₅₀ value of 8.25 g/ml using the DPPH method (11). These include phenolic compounds (4.64%), flavonoids (2.48%), saponins (1.06%), and tanin 0,028% (12), all of which are known for their antioxidant, anti-inflammatory, and antidiabetic properties. Although Bajakah is widely distributed across Kalimantan, most existing studies have focused on samples collected from East Kalimantan. Considering the potential influence of geographical origin on phytochemical profiles and bioactivity, there is limited information regarding the proximate composition, specific phytochemical constituents, and antioxidant potential of Bajakah sourced from West Kalimantan.

Although conventional antidiabetic drugs like Acarbose effectively lower blood glucose levels by delaying carbohydrate absorption and indirectly improving insulin resistance (13). Their use may cause adverse gastrointestinal effects such as bloating and increased flatulence due to gas Accumulation (14). These side effects, along with the cost and limited accessibility of some pharmacological agents, underscore the need to explore safer, more affordable, and culturally accepted plant-based alternatives.

This research aims to fill that knowledge gap by analyzing the proximate composition and phytochemical content of Bajakah from West Kalimantan and evaluating its effect on blood glucose levels in STZ-HFD-induced diabetic rats. The main goal is to assess its potential as a functional food ingredient or complementary herbal therapy for managing T2DM and to provide scientific validation for its traditional use.

METHODS

This study is quantitative experimental research conducted on male Wistar rats. The research design employed is a pre- and post-test with a control group design, which enables the evaluation of changes before and after the intervention, as well as a comparison with the control group. The study was conducted over five weeks, from May to June 2025 in Center for food and Nutrition Studies, Universitas Gadjah Mada. Comprising one week of adaptation (acclimatization), two weeks of diabetes induction using a combination of a High-Fat Diet (HFD) and Streptozotocin (STZ) 35 mg/KGBB, and two weeks of intervention using Bajakah extract.

The sample size was determined using the formula (15) $n = DF/k + 1$, where n = total number of subjects, DF = Degree of freedom, k = number of groups. Resulting in a total of 24 rats. The rats were then randomly divided into four groups. Inclusion criteria were male Wistar rats, aged 2-3 months, weigh 180 - 200 grams, rats were in good health and had no anatomical abnormalities, and had never been used as experimental animals in the study. The exclusion criteria were if the rats had decreased physical condition, did not want to eat, and died.

Bajakah (*Spatholobus littoralis* Hassk.) wood samples used in this study were collected from the Ngaung Keruh Forest in Kapuas Hulu Regency, West Kalimantan, Indonesia. The extraction process was performed at the Integrated Laboratory Unit, Universitas Sebelas Maret. At the same time, phytochemical screening and proximate analyses were conducted at the Integrated Research and Testing Laboratory, Universitas Gadjah Mada. This study utilized Bajakah extracted using the maceration method. This technique involves soaking the powdered plant material (simplic) in a solvent for a defined period at room temperature. Maceration is recognized as a cost-effective and efficient method for extracting bioactive compounds, primarily from thermolabile materials (16). Sample preparation of three main stages: extraction of Bajakah wood, phytochemical screening, and proximate composition analysis.

Preparation of Bajakah Extract

The extraction process used the maceration method with 70% ethanol as the solvent. Total of 1500 gr of dried Bajakah wood ground into powder was macerated in 70% ethanol at 1:3 in a tightly sealed container for three days. The mixture was stirred daily and kept closed throughout the process. After maceration, the mixture was filtered to separate the filtrate from the residue. The residue was re-macerated using the same volume of 70% ethanol, with intermittent stirring. All filtrates were combined and concentrated using a rotary evaporator and a water bath to obtain a viscous extract.

Phytochemical Screening Analysis

Determination of Total Phenolic Content

The sample was extracted using 50% ethanol with sonication for 10 minutes. Then, 1 mL of ethanol was added to 0.5 mL of the extract. The solution was treated with 0.5 mL of Folin-Ciocalteu reagent and 5 mL of distilled water, then left at room temperature for 10 minutes to initiate the reaction. Subsequently, 1.5 mL of 20% sodium carbonate was added, followed by dilution with distilled water to a final volume of 10 mL, with further adjustments as needed. The absorbance was measured at 760 nm using a UV-Vis spectrophotometer (17).

Determination of Flavonoid Content

Following sample preparation, a 0.5 mL aliquot of the extract was mixed with 2 mL of 4 N hydrochloric acid and hydrolyzed in an autoclave at 110°C for 2 hours. The filtrate was extracted three times with ether, and the ether phase was dried. The dry residue was treated with 0.3 mL of 5% sodium nitrite and incubated for 5 minutes. Then, 0.6 mL of 10% aluminum chloride was added and incubated for 5 minutes. Subsequently, 2 mL of 1 M sodium hydroxide and distilled water were added to bring the volume to 5 mL. The mixture was diluted as necessary, and the absorbance was read at 510 nm using a spectrophotometer (18).

Determination of Tannin Content

The 0.25 mL sample was extracted with 10 mL of diethyl ether for 20 hours. The mixture was filtered, and the solvent was evaporated. The remaining residue was diluted with distilled water to 10 mL. From this solution, 1 mL was taken and reacted with 0.1 mL of Folin–Ciocalteu reagent, then vortexed and left for 5 minutes. Afterward, 2 mL of 20% sodium carbonate was added, remixed, and allowed to stand for 5 minutes. The solution was then diluted to a final volume of 10 mL, further diluted 20-fold, and the absorbance was measured at 760 nm after incubation for 30 minutes at room temperature (19).

Determination of Saponin Content

The 0.25 mL aliquot of the sample was mixed with 2 mL of 25% sulfuric acid and heated in an autoclave at 110°C for 120 minutes. The resulting solution was extracted with ether, and the ether phase was dried. Then, 1 mL of distilled water was added, and the mixture was vortexed for 5 minutes. Afterward, 50 µL of anisaldehyde was added and allowed to stand for 10 minutes, followed by 2 mL of 50% sulfuric acid. The solution was heated in a 60°C water bath for 10 minutes. The final mixture was diluted to 10 mL and diluted five times, and its absorbance was measured at 435 nm using a UV-Vis spectrophotometer (20).

Animal Study Intervention procedures

The experimental animals were given a HFD containing 60% of calories from fat for 14 days. The rats were then fasted for 6–8 hours before being induced with STZ injection at a dose of 35 mg/kg body weight via intraperitoneal route. Hyperglycemic conditions were confirmed 72 hours after injection, and rats with blood glucose levels of ≥ 250 mg/dL were considered to have T2DM (21).

The combination of a high-fat diet (providing 40–60% of calories from fat) with low-dose STZ injection (ranging from 20–50 mg/kg BW) not only mimics the clinical progression of T2DM, but also reflects a condition where reduced insulin production is no longer sufficient to compensate for insulin resistance. The advantages of this induction model include a relatively short induction time compared to other diabetic models, as well as its flexibility to replicate the gradual pathogenesis of T2DM in humans. This model results in significantly elevated glucose levels in both fasting and postprandial states. It has been widely used for evaluating pharmacological interventions, vascular biology studies, atherosclerosis, cardiomyocyte hypertrophy, and β -cell function (22).

In this study, a total of 24 male Wistar rats were initially subjected to a 7-day adaptation period. After adaptation, the rats were fed a HFD for 14 days to induce insulin resistance. Following this period, the rats were fasted for 6–8 hours, then induced with STZ at a dose of 35 mg/kg body weight via intraperitoneal injection. After 72 hours post-induction, fasting blood glucose (FBG) levels were measured. Rats with FBG levels below 250 mg/dL were considered not to have developed hyperglycemia and were therefore excluded from the study. The remaining rats that met the hyperglycemia criteria were randomly assigned to four treatment groups. KN (Normal Group) rats received a standard diet without HFD-STZ induction or any treatment. K- (Negative Control Group) rats were induced with HFD and STZ without receiving any therapy. K+ (Positive Control Group): rats were induced with HFD and STZ and treated with Acarbose at a dose of 1.8 mg/200 g body weight per day. KB (Bajakah Group): rats were induced with HFD and STZ and treated with Bajakah wood extract at a dose of 150 mg/kg body weight per day. Subsequently, pre- and post-intervention blood glucose measurements were conducted to evaluate the effect of the treatment on blood glucose levels.

The measurement results were analyzed using the SPSS program with Paired T-Test. Normality testing was conducted to determine whether the data were normally distributed. If the data were normally distributed (p value > 0.05), a paired t-test was used for the groups KN, K-, and K+. For data that were not normally distributed (p value < 0.05), the Wilcoxon test was used for the KB group.

CODE OF HEALTH ETHICS

All procedures involving animals were approved by the Health Research Ethics Committee (KEPK) of the Faculty of Medicine, Sebelas Maret University (Number: 61/UN27.06.11/KEP/EC/2025) and received administrative clearance from the Surakarta City Health Office.

RESULTS

Ethanol 70% is solution was used as the extraction solvent. From 1,500 grams of Bajakah wood powder, 80.5 grams of concentrated extract was obtained, yielding a percentage of 5.3%. Proximate analysis was conducted to determine the elemental chemical composition of the extract, including moisture, ash, total fat, protein, and carbohydrate content. The results are presented in Table 1.

Table 1. Proximate Composition of Bajakah Extract

Parameter	Result	Unit	Method
Moisture	4,57	% b/v	Gravimetri
Ash	0,54	% b/v	Gravimetri
Total Fat	0,81	% b/v	Gravimetri
Protein	0,41	% b/v	Kjeldahl
Carbohydrates	6,67	% b/v	By Difference

The proximate analysis showed a moisture content of 4.57%, which may contribute to inhibiting microbial growth and reducing enzymatic activity that could degrade the extract. A low moisture level also improves extract stability and shelf life. The ash content was 0.54%, indicating the presence of inorganic minerals, which is typical for wood-based plant material. The total fat content was 0.81%, which aligns with the structural nature of wood tissues that are not primary lipid storage sites. A low-fat content can help minimize rancidity and maintain product stability. Protein content was measured at 0.41%. This value is consistent with the composition of plant stems, where proteins serve structural and enzymatic roles. The carbohydrate content was 6.67% suggesting that the majority of the extract's dry matter consists of carbohydrates, mainly in the form of structural polysaccharides such as cellulose and hemicellulose, which contribute to the mechanical strength of the plant.

Phytochemical screening of the Bajakah extract revealed the presence of several secondary metabolites, including phenolics, flavonoids, tannins, and saponins, as determined by UV-visible spectrophotometry. The quantitative results are summarized in Table 2.

Table 2. Phytochemical Content Test Results of Bajakah Extract

Parameter	Result	Unit	Method
Total Phenolic	12,98	% b/v	Spektrofotometri UV-vis
Flavonoids	1,16	% b/v	Spektrofotometri UV-vis
Tannins	1,65	% b/v	Spektrofotometri UV-vis
Saponins	0,13	% b/v	Spektrofotometri UV-vis

The analysis showed that the total phenolic content was 12.98%, indicating a high concentration of these compounds in the extract. Phenolics are well-known secondary metabolites with vigorous antioxidant activity, suggesting that Bajakah extract may have the potential as a natural antioxidant to scavenge free radicals and prevent cellular damage (23). The flavonoid content was measured at 1.16%. Flavonoids are polyphenolic compounds that act as antioxidants and exhibit various biological effects, including anti-inflammatory, anticancer, and antimicrobial properties. Despite their lower concentration compared to total phenolics, flavonoids still contribute significantly to the extract's therapeutic potential (24). Tannins were present at a concentration of 1.65%, these actions by inhibiting α -amylase and α -glucosidase, delaying glucose absorption in the intestine, and stimulating insulin secretion. These polyphenolic compounds have demonstrated antibacterial and antimicrobial activity and are commonly used in natural preservation. Their presence further supports the possible application of Bajakah extract in traditional medicine and as an active ingredient in herbal-based formulations (25). The saponin content was 0.13% (equivalent to 1292.93 $\mu\text{g/mL}$). Saponins are known for their antimicrobial, anti-inflammatory, and immunomodulatory properties. The notable saponin level in this extract may play a key role in its biological activity and potential use in functional health products (25).

Fasting blood glucose levels were measured at the beginning and end of the study using blood samples from the experimental animals. The number of animals in each group remained unchanged throughout the

study, with no exclusions or mortality. Routine clinical observations revealed no signs of distress or adverse effects. Minor inter-individual behavioral variations were within normal biological limits and did not impact the integrity of the results. The mean blood glucose levels after 14 days of Bajakah extract intervention in each group are presented in Table 3.

Table 3. The Data of Blood Glucose Pre and Post Intervention of Bajakah Extract

Group	Mean $\pm$ SD			<i>p</i>
	H0	H14	Δ H14-H0	
KN	68,98 $\pm$ 0,88	69,65 $\pm$ 0,91	0,67 $\pm$ 0,18	0,016
K-	277,50 $\pm$ 3,66	279,55 $\pm$ 3,16	2,04 $\pm$ 0,27	0,001
K+	278,98 $\pm$ 3,28	130,83 $\pm$ 3,76	-148,15 $\pm$ 2,43	0,000
KB	279,46 $\pm$ 2,39	115,62 $\pm$ 13,73	-163,83 $\pm$ 5,98	0,028

Description: KN : Normal Group, K-: Negative Control Group (HFD+STZ induction), K+: Positive control Group (HFD-STZ induction and Acarbose), KB : (HFD- STZ induction and intervention of Bajakah extract 150 mg/kg BW).

The results of fasting blood glucose (FBG) measurements before (H0) and after (H14) a 14-day intervention are presented in Table 3. In the normal group (KN), there was a slight increase in mean FBG from 68.98 $\pm$ 0.88 mg/dL to 69.65 $\pm$ 0.91 mg/dL, with a difference of 0.67 $\pm$ 0.18 mg/dL (p = 0.016), indicating a statistically significant change, though clinically still within the normal range. In the negative control group (K-), which received HFD-STZ induction without any treatment, the mean FBG increased from 277.50 $\pm$ 3.66 mg/dL to 279.55 $\pm$ 3.16 mg/dL, with a difference of 2.04 $\pm$ 0.27 mg/dL (p = 0.001). This result indicates that hyperglycemia persisted and slightly worsened in the absence of intervention.

In the positive control group (K+), which was treated with Acarbose, there was a significant decrease in mean FBG from 278.98 $\pm$ 3.28 mg/dL to 130.83 $\pm$ 3.76 mg/dL, with a reduction of -148.15 $\pm$ 2.43 mg/dL (p = 0.000), demonstrating the effectiveness of Acarbose in lowering fasting blood glucose levels. Meanwhile, in the Bajakah treatment group (KB), which received Bajakah wood extract at a dose of 150 mg/kg BW, FBG decreased from 279.46 $\pm$ 2.39 mg/dL to 115.62 $\pm$ 13.73 mg/dL, with a mean reduction of -163.83 $\pm$ 5.98 mg/dL, and a statistically significant result (p = 0.028) using the Wilcoxon test. This reduction was even greater than that observed in the Acarbose group, indicating the strong potential of Bajakah extract to effectively reduce fasting blood glucose in T2DM model rats. Overall, these results suggest that Bajakah extract exhibits a significant antihyperglycemic effect, with performance comparable to or even exceeding that of standard antidiabetic treatment (Acarbose).

DISCUSSION

This study demonstrated that using 70% ethanol as the solvent, the maceration extraction method yielded 5.3% Bajakah extract, equivalent to 80.5 grams obtained from 1,500 grams of powdered wood. This yield is comparable to that reported in a previous study, which achieved a 5.4% yield using the same solvent (26). Maceration was selected due to its simplicity, cost-effectiveness, and ability to preserve thermolabile bioactive compounds.

Phytochemical analysis revealed that the Bajakah extract from West Kalimantan contained a high total phenolic content of 12.98%, which is notably greater than the 4.64% reported in a previous study using samples from East Kalimantan (12). Phenolic compounds are well-known for their strong antioxidant capacity, primarily due to their ability to donate electrons and neutralize free radicals, thereby preventing the formation of reactive oxygen species (ROS) (23). This antioxidant activity is crucial in managing diabetes mellitus by protecting pancreatic β -cells from oxidative stress, a key factor contributing to insulin dysfunction and resistance (27).

In addition to their antioxidant effects, phenolics have been shown to exert antidiabetic properties through the inhibition of α -amylase and α -glucosidase, two key enzymes involved in carbohydrate digestion. By suppressing these enzymatic activities, phenolic compounds help delay glucose absorption in the intestine, thereby reducing postprandial blood glucose spikes (28). Consequently, the high phenolic content observed in the Bajakah extract suggests significant potential for lowering blood glucose levels and

enhancing insulin sensitivity.

Phytochemical analysis showed that the flavonoid content in Bajakah extract was 1.16%, slightly lower than the 2.48% reported in a previous study (12). Flavonoids are polyphenolic compounds complex and multifunctional antidiabetic mechanisms. Primarily, they act as antioxidants by donating hydrogen ions to neutralize free radicals, thereby reducing oxidative stress that can impair pancreatic β -cells and other insulin sensitive tissues. Beyond their antioxidant properties, flavonoids exert anti-inflammatory and antihyperglycemic effects through several key molecular pathways, including activation of the PI3K/Akt signaling cascade, upregulation of GLUT-4 glucose transporters, inhibition of hepatic gluconeogenesis, and promotion of glycogen synthesis. Certain flavonoids, such as quercetin, have also been shown to inhibit α -glucosidase, an essential enzyme involved in carbohydrate digestion, thus attenuating postprandial hyperglycemia (29). However, it is important to note that the therapeutic effectiveness of flavonoids largely depends on their bioavailability, which can be limited by factors such as poor absorption, rapid metabolism, and excretion. Therefore, while the presence of flavonoids in Bajakah extract supports its potential as a natural antidiabetic agent, further studies are needed to enhance and evaluate their bioavailability to maximize therapeutic outcomes in the management of T2DM.

The phytochemical test revealed that the Bajakah extract contained 1.65% tannins. Tannins are polyphenolic compounds known for inhibiting the activity of digestive enzymes such as α -amylase and α -glucosidase. This mechanism delays the breakdown of polysaccharides into simple glucose molecules, thereby reducing glucose absorption in the intestine and preventing postprandial hyperglycemia (2). Their action is comparable to other antioxidant compounds like phenolics and flavonoids. Tannins help regulate blood glucose levels and support glycemic control by slowing glucose release.

In addition to their enzyme-inhibitory activity, tannins exert significant anti-inflammatory and antioxidant effects. They protect pancreatic β -cells from oxidative damage by suppressing lipid peroxidation and forming reactive oxygen species (ROS), central to the inflammatory cascade in diabetogenic conditions. Tannins may promote β -cell regeneration and enhance insulin sensitivity in peripheral tissues, particularly adipose tissue, thereby improving glucose uptake via insulin-mediated pathways. Altogether, tannins in Bajakah extract strengthens its potential as a complementary therapeutic agent for diabetes management. Their multifunctional roles including enzyme inhibition, antioxidative action, anti-inflammation, and insulin sensitization underscore their value in counteracting both hyperglycemia and cellular stress in diabetes pathogenesis (30).

Saponins, identified as one of the bioactive compounds in Bajakah extract, was present at a concentration of 0.13%. Although relatively lower than other phytochemicals, this level is still considered pharmacologically significant due to the wide range of biological activities attributed to saponins. These compounds are known to exhibit antidiabetic potential through multiple mechanisms.

Primarily, saponins act by inhibiting carbohydrate-digesting enzymes, namely α -amylase and α -glucosidase, which slows glucose absorption in the digestive tract and helps regulate postprandial blood glucose levels (31). Additionally, saponins enhance insulin sensitivity by upregulating GLUT-4 expression and improving insulin signaling pathways in peripheral tissues. They also stimulate insulin secretion by directly activating pancreatic β -cells, thus improving glycemic control (31). Given these multifunctional actions, saponins in Bajakah extract reinforces its therapeutic relevance in type 2 diabetes mellitus management. Despite its relatively lower concentration, its physiological effects may be synergistically enhanced when combined with other active compounds such as phenolics and flavonoids.

The active compounds found in Bajakah extract including phenolics, flavonoids, tannins, and saponins are believed to act synergistically through multiple biological mechanisms. These mechanisms collectively contribute to blood glucose regulation and insulin function, highlighting the extract's potential as a complementary phytotherapeutic agent for managing T2DM (32). The compounds exert their effects by enhancing endogenous antioxidant defenses, protecting pancreatic β -cells, reducing oxidative stress, inhibiting carbohydrate-digesting enzymes, and improving insulin signaling pathways. Phenolics and flavonoids, in particular, are known to neutralize reactive oxygen species (ROS), thereby reducing oxidative damage and preventing β -cell dysfunction. These polyphenolic compounds also play a role in improving insulin sensitivity and modulating glucose metabolism by upregulating glucose transporter proteins such

as GLUT-4 (33).

Tannins and saponins complement these actions by inhibiting α -amylase and α -glucosidase, delaying glucose absorption in the intestine, and stimulating insulin secretion. Together, these actions help reduce postprandial hyperglycemia and support better glycemic control. Moreover, the compounds may contribute to the repair and regeneration of pancreatic β -cells, enhancing both insulin release and cellular responsiveness. Flavonoids, in particular, have been shown to protect the structural integrity of pancreatic islets, especially the Langerhans cells, from oxidative degeneration. This protection helps sustain insulin production and preserve endocrine pancreatic function (34). The body's endogenous antioxidant system also plays a vital role in maintaining redox balance by neutralizing excess ROS, thus shielding cells and organs from free radical-induced damage. This integrated antioxidant mechanism is essential for preserving cellular homeostasis under hyperglycemic conditions (35).

The results of this study demonstrate that administration of Bajakah extract (*Spatholobus littoralis* Hassk.) significantly reduced fasting blood glucose (FBG) levels in diabetic Wistar rats induced with HFD and STZ. The KB group, which received Bajakah extract at a dose of 150 mg/kg BW for 14 days, showed a marked decrease in FBG (from 279.46 ± 2.39 mg/dL to 115.62 ± 13.73 mg/dL), indicating potent antihyperglycemic activity of the extract.

Compared to the positive control group (K+), which was treated with Acarbose, the Bajakah group showed an even greater reduction in FBG. This suggests that Bajakah extract may possess comparable or superior efficacy to conventional antidiabetic drugs in improving glycemic control. In contrast, the negative control group (K-) showed no significant improvement, confirming the persistent hyperglycemia in the absence of treatment. The significant reduction in the KB group also supports the synergistic potential of Bajakah extract in addressing both insulin resistance (induced by HFD) and β -cell damage (induced by STZ), thereby mimicking the pathophysiology of T2DM.

These findings are consistent with previous studies that highlighted the antidiabetic potential of plant-based antioxidants in lowering blood glucose levels and protecting pancreatic β -cells from oxidative stress-induced damage. Thus, Bajakah extract could be considered a promising natural therapeutic agent or complementary treatment for managing T2DM, particularly in populations with limited access to synthetic medications (32). The synergistic actions of phenolics, flavonoids, tannins, and saponins in Bajakah extract underscore its potential as a natural, multi-targeted therapeutic agent. By improving insulin signaling, inhibiting key digestive enzymes, reducing oxidative stress, and supporting pancreatic function, Bajakah extract may serve as a viable complementary strategy for managing T2DM, especially in regions with limited access to conventional pharmacotherapy.

CONCLUSION

Based on the research results, it can be concluded that Bajakah wood extract (*Spatholobus littoralis* Hassk), obtained through maceration using 70% ethanol, has a significant phytochemical composition. The extract was found to contain a high level of phenolics (12.98%), as well as flavonoids (1.16%), tannins (1.65%), and saponins (0.13%). These bioactive compounds demonstrated strong antihyperglycemic effects in diabetic rats induced with STZ-HFD. Specifically, administration of Bajakah extract at a dose of 150 mg/kg body weight effectively reduced fasting blood glucose levels (-163.83 ± 5.98 mg/dL). This finding provides strong scientific evidence to support the traditional use of Bajakah and confirms its potential as an effective complementary therapeutic agent for managing type 2 diabetes mellitus. Further research is recommended to isolate specific active compounds, investigate their pharmacological mechanisms, and conduct toxicological and clinical studies to develop standardized and safe herbal products.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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