

RESEARCH STUDY

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Hypolipidemic Effect of Suweg Tuber Flour (*Amorphophallus paeoniifolius*) and Bogor Bean Flour (*Vigna subterranea*) Formulation on HDL and LDL Levels

*Pengaruh Hipolipidemia Formulasi Tepung Umbi Suweg (*Amorphophallus paeoniifolius*) dan Tepung Kacang Bogor (*Vigna subterranea*) terhadap Kadar HDL dan LDL*

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ABSTRACT

Background: Data from the 2023 Indonesian Health Survey indicate that diabetes mellitus (DM) affects a substantial proportion of the Indonesian among populations aged ≥ 15 years (11.7%). Among individuals with type 2 diabetes mellitus (T2DM), diabetic dyslipidemia is a prevalent metabolic disorder, particularly characterized by reduced high-density lipoprotein (HDL) levels accompanied by elevated low-density lipoprotein (LDL) levels. Improvement in blood lipid profiles may be supported by the consumption of suweg tubers and Bambara groundnuts as local food sources with high dietary fiber content.

Objectives: The present study evaluated the effectiveness of combined suweg tuber and Bambara groundnut flour formulation as dietary interventions to modulate lipid metabolism, specifically focusing on HDL and LDL levels, in rats with diabetes-induced dyslipidemia.

Methods: An experimental approach was conducted using a randomized control group with pre- and post-intervention measurements. Thirty male Sprague-Dawley rats were assigned into five groups: a negative control group (K-), a positive control group (K+), and three treatment groups (F1, F2, and F3) which received formulations at doses of 0.37 g, 0.39 g, and 0.42 g per 200 g BW, respectively. Fasting blood glucose (FBG), HDL, and LDL concentrations were assessed before and after the intervention. Statistical analyses included the Shapiro-Wilk normality test, paired t-test, homogeneity test, and one-way ANOVA, and Tukey Post Hoc analysis.

Results: The F1 group had the highest HDL (77.2 ± 2.0 mg/dL) and lowest LDL (27.0 ± 1.5 mg/dL). These differences were statistically significant across groups (p -value < 0.001).

Conclusions: The F1 formulation was effective in increasing HDL levels while reducing LDL levels, indicating the potential of suweg tuber and Bambara groundnut flours as functional dietary interventions for diabetic dyslipidemia.

INTRODUCTION

Type 2 Diabetes Mellitus (T2DM) is a major public health challenge due to its rapidly increasing global prevalence. Data from the International Diabetes Federation (IDF) in 2021 estimated that approximately 537 million adults aged 20–79 years were living with diabetes, corresponding to 10.5% of the global population, with a projected increase of nearly 46% by 2045¹. In Indonesia, the 2023 Indonesian Health Survey reported that diabetes mellitus affected 11.7% of individuals aged ≥ 15 ².

In individuals with T2DM, impaired insulin action contributes to abnormalities in lipid metabolism, especially in the regulation and clearance of circulating lipoproteins. This metabolic disruption increases lipid

mobilization from adipose tissue, leading to elevated blood cholesterol levels and the development of dyslipidemia³. The prevalence of dyslipidemia among individuals with DM has been reported to be as high as 91.4%. This condition is marked by reduced HDL levels and increased LDL levels, which promotes lipotoxicity and substantially elevates the risk of cardiovascular disease, the primary cause of mortality in diabetic populations^{4–6}.

Effective Management of dyslipidemia in diabetes is essential to reduce the risk of associated complications. While pharmacological agents, such as statins, are commonly prescribed, their use may be limited by adverse effects and economic constraints. Therefore, exploring natural and functional food-based

strategies becomes essential to support lipid control safely and sustainably. Dietary modification is a key modifiable factor in managing dyslipidemia, with increased dietary fiber intake consistently associated with improvements in blood lipid profiles⁷. Sinulingga (2020) reported that dietary fiber plays an important role in lipid regulation⁸. Dietary fiber can be obtained from various sources, including whole grains, tubers, fruits, and vegetables⁹. For individuals with diabetes mellitus, the recommended daily fiber intake ranges from 20-35 grams/per day^{10,11}.

Local food ingredients with a high fiber content, such as suweg tuber (*Amorphophallus paeoniifolius*) and bambara groundnut (*Vigna subterranea*), have the potential to be developed as functional foods. Fresh suweg tuber contains approximately 1.4 g of fiber per 100 grams, which is higher than Bogor taro (0.9 grams of fiber). Suweg tuber flour contains approximately 13.58 grams of dietary fiber^{12,13}. Additionally, Suweg tubers exhibit a low glycemic index (GI), with values below 55¹⁴. Research by Kumalasari et al. (2022) in diabetic rats demonstrated that food formulated with suweg tuber flour has the lowest glycemic index and reduced blood glucose responses¹⁵.

Bambara groundnut is a legume known for its high dietary fiber content. In its dried form, Bambara groundnut contains approximately 26.3 g of fiber per 100g, which is higher than that of dried mung beans (5.7 g) and soybeans (3.2g)¹². Bambara groundnuts exhibit a glycemic index (GI) of 66.1 and a glycemic load (GL) of 1.33¹⁶. Bambara groundnut flour is composed primarily of carbohydrates in the form of starch and dietary fiber, with a total dietary fiber content of 17.81 g per 100 g¹⁷. Previous studies have suggested that Bambara groundnut has potential benefits in supporting blood glucose management in individuals with diabetes¹⁸.

Considering the increasing prevalence of diabetic dyslipidemia, its serious health impact, and the need for affordable and natural interventions, the utilization of local functional food ingredients such as suweg tuber and Bambara groundnut holds great potential for improving lipid profiles in diabetes. However, scientific evidence on the combined formulation of these two ingredients and their effects on HDL and LDL levels remains limited. This study aimed to assess the effects of a formulated mixture of suweg tuber flour and Bambara groundnut flour on HDL and LDL levels in Sprague Dawley rats with diabetic dyslipidemia.

METHODS

Design, Time, Place of Research

This study employed a true experimental design. The research used a randomized pre-test and post-test-controlled group design comprising five groups with simple randomization. Male Sprague-Dawley rats of similar age and body weight were acclimatized for seven days under standardized environmental conditions and randomly assigned to groups to ensure homogeneity before treatment. Type 2 diabetic dyslipidemia was induced using a high-fat diet (rat feed 55%, quail egg yolk 20%, liquid margarine 20%, and cooking oil 5%) administered for seven days, followed by intraperitoneal

injections of nicotinamide (110 mg/kg BW) and streptozotocin (45 mg/kg BW) with a 15-minute interval. Three days after induction, fasting blood glucose (FBG) was measured using the GOD-PAP method to confirm diabetes (FBG $\geq$ 126 mg/dL), while HDL and LDL levels were analyzed enzymatically using the CHOD-PAP method to confirm dyslipidemia (decreased HDL and increased LDL). Environmental factors such as temperature, lighting, feeding schedule, and handling were uniformly controlled to minimize external influences and ensure data validity and reliability. The maintenance and treatment of diabetic dyslipidemia rats, as well as biochemical measurements, were conducted at the Laboratory of the Center for Food and Nutrition Studies (PSPG), Universitas Gadjah Mada (UGM), Yogyakarta. The research was conducted from September 2024 to January 2025. This study has obtained approval from the Research Ethics Committee of the Faculty of Medicine, Universitas Sebelas Maret (UNS), Surakarta, with reference number 246/UN27.06.11/KEP/EC/2024, issued on 21 November 2024.

Equipment and Materials

The tools required in this research are beaker glass, stirrer, mortars, a centrifuge, centrifuge tube, pipette, basin, spoon, label, experimental animal utensils, gloves, volumetric flask, pH strip, stopwatch, thermometer, gastric sonde, 1 cc syringe, photometer, micropipette 10 and 1000 μ l, incubator, alcohol swab, vortex, spectrophotometer UV-Vis, cuvette, and microtube. The production of suweg flour was conducted in Sleman, Yogyakarta (Moringa Pangan Aman), while bambara groundnut flour was produced in Bantul, Yogyakarta (Kusuka Ubiku).

Research	Material	Preparation
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Prepare suweg (*Amorphophallus paeoniifolius*) tuber flour. Fresh suweg tubers free from damage or decay were prepared. Then, the suweg tubers were peeled to remove the skin and washed to clean off soil residues or dirt. The tubers were sliced thinly (0.2-0.3 cm) to ensure uniform drying and flour consistency. The slices were sun-dried until completely dry, then ground into a fine powder and sieved using an 80-mesh sieve. Prepare Bambara groundnut flour. High-quality Bambara groundnuts and purchased and peeled to remove the skins of the groundnuts. The groundnuts were washed to remove any dirt or soil residues and sliced thinly. The slices were dried under sunlight, and ground into a fine powder and sieved using an 80-mesh sieve to obtain flour ready to use.

The intervention formulations consisted of mixtures of suweg and Bambara groundnut flours at three doses (0.37, 0.39, and 0.42 g per 200 g BW; F1-F3). The doses were determined based on the average dietary fiber requirement in rats, converted from the human equivalent dose using body surface area normalization. Each dose was prepared by dissolving 2.5 g of flour per 200 g body weight in 5 mL of distilled water. Both ingredients have shown hypoglycemic and hypolipidemic potential in previous preclinical studies; however, their

combined effects had not been investigated before this research.

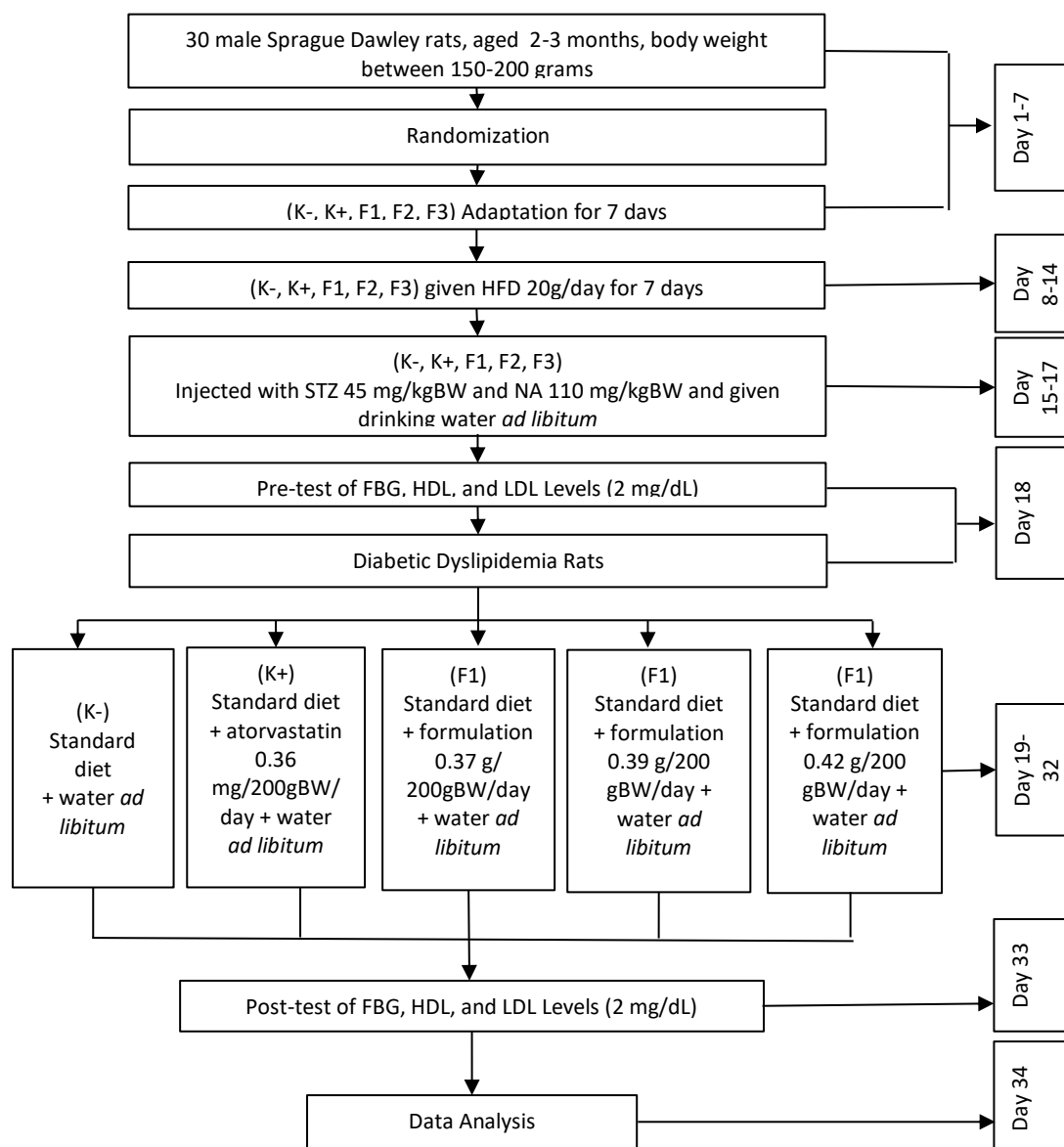


Figure. 1. Research flowchart

Research Sample

The study sample comprised Sprague Dawley rats established as a diabetic dyslipidemia model. The sample size was determined using the Resource Equation Approach based on the degrees of freedom (DF) for ANOVA. This research used 30 rats. Inclusion criteria were male Sprague Dawley rats, aged 2–3 months, with a bodyweight of 150–200 grams, in healthy condition, exhibiting normal activity and behavior during the pre-treatment observation period, and no anatomical abnormalities. Exclusion criteria were rats with diarrhea

(watery stool), illness (reduced activity), decreased appetite, or bodyweight loss exceeding 10%. Drop out criteria were rats that died during the treatment period.

Research Design

This study employed a true experimental, randomized pre- and post-test-controlled group design involving five treatment groups allocated through simple randomization. The intervention was administered to the treatment groups from Day 19 to Day 32.

Table 1. Experimental design

Treatment Group	Intervention
K-	Diabetic dyslipidemia rats
K+	Diabetic dyslipidemia rats + standard diet + atorvastatin at 0.36 mg/200 g body weight/day
F1	Diabetic dyslipidemia rats + standard diet + formulation 0.37 g/200 g body weight/day
F2	Diabetic dyslipidemia rats + standard diet + formulation 0.39 g/200 g body weight/day

Treatment Group	Intervention
F3	Diabetic dyslipidemia rats + standard diet + formulation 0.42 g/200 g body weight/day

The treatment group were defined as follows: (K-) negative control group, diabetic dyslipidemia rats fed a standard diet and provided *ad libitum* drinking water; (K+): positive control group, diabetic dyslipidemia rats fed a standard diet, provided *ad libitum* drinking water, and administered atorvastatin at 0.36 mg/200 g body weight/day; (F1): treatment group 1, diabetic dyslipidemia rats fed a standard diet, given a formulation at 0.37 g/200 g weight/day, and provided *ad libitum* drinking water; (F2): treatment group 2, diabetic dyslipidemia rats fed a standard diet, given a formulation at 0.39 g/200 g/200 g weight/day, and provided *ad*

libitum drinking water; and (F3): treatment group 3, diabetic dyslipidemia rats fed a standard diet, given a formulation at 0.42 g/200 g/200 g weight/day, and provided *ad libitum* drinking water.

The formulation doses were selected to represent a graded dose-response based on the average daily dietary fiber requirement in rats, converted from the human equivalent dose using body surface area normalization. These doses were designed to identify the optimal proportion that could effectively improve lipid profiles while remaining in a physiologically safe range.

Table 2. Research time

Time	Implementation
Day 1 – day 7	Adaptation the rats
Day 8 – day 14	Given HFD 20g/ day for 7 days
Day 15 – day 34	Intervention

Data Collection

Blood samples were collected again to measure HDL and LDL levels as part of the post-test. Blood was drawn via the retro-orbital sinus (the cavity behind the eye) by gently holding the rat with the thumb for comfort, applying pressure to the jugular vein behind the jaw to facilitate blood flow, and inserting a micro-hematocrit tube into the inner corner of the eye to rupture the surrounding blood vessels, allowing blood to flow into the tube. Approximately 2 mL of blood was collected and centrifuged for 15 minutes at 4000 rpm to obtain clear serum. FBG levels were analyzed before treatment, and changes in HDL and LDL levels were assessed before and after treatment. FBG levels were measured using the Glucose Oxidase-Peroxidase Aminoantipyrine (GOD-PAP) method. In contrast, HDL and LDL levels were analyzed using the Cholesterol Oxidase Deaminase Peroxidase Aminoantipyrine (CHOD-PAP) method. This study employed an enzymatic photometric test with a UV-Vis spectrophotometer.

Data Analysis

Statistical analyses were performed using SPSS software to evaluate differences among groups before

and after intervention. Data distribution was first assessed using the Shapiro-Wilk test, given the relatively small sample size ($n < 50$). After confirming normal data distribution, one-way ANOVA was conducted to compare mean values across treatment groups, and Tukey's post hoc test was applied for multiple comparisons. Homogeneity of variance was assessed prior to analysis to ensure consistency across groups. In addition, paired t-tests were used to examine changes between pre- and post-intervention measurements within each group.

RESULTS AND DISCUSSIONS

Sample Characteristics

In this study, the characteristics of the rat samples before treatment were as follows. Pre-treatment characteristics, including body weight, FBG levels, and HDL levels, showed homogeneity, with no significant differences between groups. Body weight (p -value=0.861), FBG levels (p -value=0.585), and HDL levels (p -value = 0.660) were not significantly different. In contrast, LDL levels showed a significant difference between two groups (p -value < 0.001).

Table 3. Sample characteristics

Component	Mean $\pm$ SD					p-value
	K- (n=6)	K+ (n=6)	F1 (n=6)	F2 (n=6)	F3 (n=6)	
Body Weight	175.1 $\pm$ 4.2	175.5 $\pm$ 4.3	175.3 $\pm$ 3.9	176.1 $\pm$ 3.7	177 $\pm$ 2.5	0.861
FBG Levels	266.7 $\pm$ 2.9	267.2 $\pm$ 3.5	268.2 $\pm$ 5.1	270.0 $\pm$ 7.5	270.6 $\pm$ 3.7	0.585
HDL Levels	45.3 $\pm$ 1.3	45.0 $\pm$ 1.3	45.3 $\pm$ 1.6	44.2 $\pm$ 1.7	45.3 $\pm$ 1.3	0.660
LDL Levels	61.0 $\pm$ 1.3	63.2 $\pm$ 1.9	65.7 $\pm$ 2.8	67.1 $\pm$ 1.6	63.2 $\pm$ 2.0	<0.001*

Note:

p-value: One-Way ANOVA Test

*: Significant (p -value < 0.05)

K-: Negative Control (STZ-NA+HFD)

K+: Positive Control (STZ-NA+HFD+Atorvastatin 0.36 mg/200 g BW/day)

F1: Treatment 1 (STZ-NA+HFD+formulation 1 (75% suweg tuber flour:25% bambara groundnut flour))

F2: Treatment 2 (STZ-NA+HFD+formulation 2 (50% suweg tuber flour:50% bambara groundnut flour))

F3: Treatment 3 (STZ-NA+HFD+formulation 3 (25% suweg tuber flour:75% bambara groundnut flour))

The study on the effects of suweg tuber flour and bambara groundnut flour formulations on HDL and LDL levels in STZ-NA-induced diabetic dyslipidemic rats was conducted using white rats (*Rattus norvegicus*), Sprague-Dawley strain. Rats share genetic similarities with humans and represent various biological aspects relevant to human health and diseases. They are also known for their docile nature and metabolic similarities to humans¹⁹. The initial stage involved a 7-day adaptation period, from November 22 to 28, 2024, before inducing diabetic dyslipidemia. The rats were housed individually, with one rat per cage. After adaptation, the rats were fed a High-Fat Diet (HFD) from November 29 to December 5, 2024, to induce obesity, impaired glucose tolerance, and insulin resistance.

In this study, rat body weight increased following HFD administration and decreased after treatment with suweg tuber flour and bambara groundnut flour formulations. This increase aligns with the findings of Nissa and Madjid (2016), who reported an increase in average rat body weight after HFD administration²⁰. According to Indriputri and Maulana (2022), HFD administration affects lipid profile (HDL and LDL) and FBG levels in rat serum²¹. A significant increase in LDL levels and a decrease in HDL levels were observed in rats fed an HFD after 8 weeks of treatment²².

Rats in all experimental groups experienced moderate hyperglycemia, with blood glucose levels ranging from 200 to 400 mg/dL²³. The increase in FBG levels before the intervention resulted from

intraperitoneal injection of STZ at a dose of 45 mg/kg BW and NA at a dose of 110 mg/kg BW on December 6, 2024. STZ induction in pancreatic β -cells alters insulin characteristics in the blood, leading to decreased insulin levels and changes in blood glucose levels, thereby inducing hyperglycemia. Following STZ induction, the sensitivity of peripheral insulin receptors decreases, resulting in increased insulin resistance²⁴. Administration of NA before STZ induction can protect pancreatic cells from the toxic effects of STZ, which causes massive cell damage²⁵.

Effects of Suweg Tuber Flour and Bambara Groundnut Flour on HDL and LDL Levels

The effect of suweg tuber flour and Bambara groundnut flour on HDL levels in diabetic dyslipidemic rats was evaluated. Statistical analysis showed no significant differences in HDL levels among groups prior to the intervention. Following the intervention, HDL levels increased in all treatment groups. The highest increase was observed in group F1 (31.8 mg/dL), followed by F2 (27.7 mg/dL), K+ (26.1 mg/dL), and F3 (23.3 mg/dL). In contrast, the negative control group (K-) showed a decrease in HDL levels of 1.2 mg/dL. One-way ANOVA test showed that HDL levels were homogeneous before treatment, with no significant differences among groups (p -value = 0.660). After treatment, a significant difference in HDL levels was observed among the five groups (p -value < 0.001). Therefore, post hoc analysis was conducted to identify specific intergroup differences.

Table 4. Mean HDL level analysis results

Experimental group	Before (Mean $\pm$ SD)	p-value ^b (Before)	After (Mean $\pm$ SD)	p-value ^b (After)	Δ (mg/dL)	p-value ^b (Δ)	p-value ^a
K-	45.3 $\pm$ 1.3		44.1 $\pm$ 1.7 ^c		-1.2 ^c		0.006*
K+	45.0 $\pm$ 1.3		71.1 $\pm$ 1.3 ^{d,e}		26.1 ^d		<0.001*
F1	45.3 $\pm$ 1.6	0.660	77.2 $\pm$ 2.0 ^f	<0.001*	31.8 ^e	<0.001*	<0.001*
F2	44.2 $\pm$ 1.7		72.0 $\pm$ 1.5 ^d		27.7 ^d		<0.001*
F3	45.3 $\pm$ 1.3		68.7 $\pm$ 1.6 ^e		23.3 ^f		<0.001*

Note: *Significant (<0.05); p-value^a = Paired T-Test; p-value^b = One-Way ANOVA Test; Δ = Difference between pre and post-intervention; c,d,e,f = Similar superscript letters indicate no significant difference in the post hoc Tukey test at a 5% significance level.

Post hoc analysis identified statistically significant differences in post-treatment HDL levels between K- and the K+, as well as all treatment groups (F1, F2, and F3) (p -value < 0.001). Significant differences were also observed between the K+ and F1 groups (p -value < 0.001), between F1 and both F2 and F3 (p -value < 0.001), and between F2 and F3 (p -value = 0.021). In contrast, no significant differences were found between the K+ and F2 groups (p -value = 0.909) or between the K+ and F3 groups (p -value = 0.133). Further post hoc analysis of changes in HDL levels before and after the intervention demonstrated significant differences among the five groups. ANOVA result indicated significant differences between the K-group and K+, F1, F2, and F3 groups (p -value < 0.001); between the K+ group and the F1 and F3 groups (p -value < 0.001); between the F1 group and the F2 and F3 groups (p -value < 0.001); and between the F2 and F3 groups (p -value < 0.001). The difference in HDL levels between K+ and F2 (p -value = 0.246) was not statistically significant. Based on HDL level differences, the F1 was the most

effective formulation for increasing HDL levels.

Although the F1 formulation contained lower fiber content than F2 and F3, suweg tuber contains various nutritional components involved in lipid metabolism, such as glucomannan and antioxidant compounds. Research by Yuzammi and Handayani (2019) indicates that suweg tuber may help prevent degenerative diseases, including coronary heart disease and diabetes mellitus, through mechanisms that reduce blood cholesterol levels. This is because suweg tuber contains abundant fiber capable of binding large amounts of cholesterol²⁶.

The dietary fiber contained in suweg tuber and bambara groundnut is considered to contribute to improvements in lipid profiles. Previous findings have indicated that insufficient fiber intake is associated with unfavorable blood lipid parameters, whereas adequate fiber consumption is commonly observed among individuals with normal HDL levels²⁷. In addition, studies by Abed et al. (2023) and Hayudanti et al. (2016) reported

that high-fiber dietary interventions are associated with increased HDL levels in individuals with dyslipidemia^{28,29}. The effects of dietary fiber intake are partly mediated by the production of short-chain fatty acids (SCFAs), such as propionate, acetate, and butyrate, generated through fermentation by gut microbiota. These metabolites activate free fatty acid receptors, including FFAR2 and FFAR3, which stimulate glucagon-like peptide-1 (GLP-1) secretion and contribute to improved insulin sensitivity and better regulation of glucose and lipid metabolism. In addition, SCFAs have been linked to reduced systemic inflammation and improved metabolic homeostasis, mechanisms that collectively support enhanced lipid metabolism and may reduce cardiovascular disease risk^{30–33}.

In addition, high dietary fiber intake has been associated with beneficial effects on body weight regulation, partly through improved glycemic and insulin responses in individuals with T2DM³⁴. Additional benefits include enhanced gut health, improved blood lipid profiles in dyslipidemia and cardiovascular conditions, increasing satiety, and improved micronutrient absorption³⁵. Research by Maharani et al. (2024) further indicates that fiber content increases proportionally with the amount used in food formulations.³⁶ In addition to dietary fiber, suweg tuber contains various bioactive compounds, including flavonoids, phenols, and phenolic acids, which exhibit antioxidant properties. These compounds protect HDL from oxidation and improve lipid metabolism. Research by Setyawati (2020) revealed that suweg tuber flour at a dose of 2.5 grams per day reduces TNF- α (Tumor Necrosis Factor- α) levels³⁷. This study aligns with the findings of Inoue et al. (2018), which showed that increased TNF- α levels induce inflammatory effects that disrupt lipid transport and HDL metabolism, thereby reducing circulating HDL levels³⁸.

Bambara groundnut has also been reported to exert favorable effects on lipid profiles, particularly by increasing HDL levels and reducing LDL levels. These effects are attributed to its relatively high fiber content (17,81%) and the presence of bioactive compounds, including flavonoids and alkaloids, which exhibit

hypolipidemic properties.³⁹. Studies have demonstrated that regular consumption of Bambara groundnut improves blood lipid parameters, supporting its potential role as a functional food in lipid management⁴⁰. Previous research has revealed that fiber consumption can reduce HbA1c and triglyceride levels, contributing to overall lipid profile improvement. Fiber binds cholesterol in the digestive tract, thereby increasing the HDL proportion and enhancing lipid profile⁴¹. Based on these findings, the combination of suweg tuber flour and bambara groundnut flour has strong potential as an effective dietary intervention for increasing HDL levels and may serve as a preventive and therapeutic approach in managing dyslipidemia and other metabolic diseases.

The effects of suweg tuber flour and Bambara groundnut flour on LDL levels in diabetic dyslipidemic rats were analyzed, with the following results. Paired t-test analysis demonstrated significant differences in LDL levels before and after the intervention across all groups. Reductions in LDL concentrations were observed in groups F1 (38.7 mg/dL), F2 (37.0 mg/dL), K+ (30.9 mg/dL), and F3 (25.3 mg/dL), whereas a slight increase in LDL levels was detected in the negative control group (K-) (1.0 mg/dL). One-way ANOVA revealed significant differences in LDL levels among groups prior to the intervention (p -value <0.001), and post intervention analysis also demonstrated significant differences across the five groups (p -value <0.001). Consequently, Tukey's post hoc test was performed to determine pairwise differences. The results indicated significant differences in LDL levels among groups before the intervention. Post hoc analysis demonstrated significant differences in post-treatment LDL levels between the K- and the K+, as well as all treatment groups (F1, F2, and F3) (p -value <0.001). Significant differences were also observed between the K+ and F1 groups (p -value= 0.019), between the K+ and F3 groups (p -value= 0.013), between the F1 and F3 groups (p -value <0.001), and between the F2 and F3 groups (p -value <0.001). In contrast, no significant differences were detected between the K+ and F2 groups (p -value = 0.617) or between the F1 and F2 groups (p -value= 0.318).

Table 5. Mean LDL level analysis results

Experimental group	Before (Mean $\pm$ SD)	p-value ^b (Before)	After (Mean $\pm$ SD)	p-value ^b (After)	Δ (mg/dL)	p-value ^b (Δ)	p-value ^a
K-	61.0 $\pm$ 1.3 ^{c,d}		62.0 $\pm$ 1.8 ^c		1.0 ^c		0.004*
K+	63.2 $\pm$ 1.9 ^{d,e,f}		32.3 $\pm$ 2.8 ^d		-30.9 ^d		<0.001*
F1	65.7 $\pm$ 2.8 ^{e,g}	<0.001*	27.0 $\pm$ 1.5 ^{d,e}	<0.001*	-38.7 ^e	<0.001*	<0.001*
F2	67.1 $\pm$ 1.6 ^g		30.1 $\pm$ 2.1 ^e		-37.0 ^e		<0.001*
F3	63.2 $\pm$ 2.0 ^{d,f}		37.9 $\pm$ 4.2 ^f		-25.3 ^e		<0.001*

Note: *Significant (<0.05); p-value^a = Paired T-Test; p-value^b = One-Way ANOVA Test; Δ = Difference between pre and post-intervention; c,d,e,f = Similar superscript letters indicate no significant difference in the post hoc Tukey test at a 5% significance level.

A post hoc test was also conducted on changes in LDL levels before and after the intervention because the One-Way ANOVA results showed significant differences in LDL level changes among the five groups (p -value <0.001). Significant differences were found between the K- and K+, F1, F2, and F3 (p -value <0.001), between the K+ and F1 groups (p -value= 0.004) and F2 groups (p -value= 0.030), between the F1 and F3 groups (p -value

<0.001), and between the F2 and F3 groups (p -value <0.001). No statistically significant differences were observed in LDL level changes between the K+ and F3 groups (p -value= 0.057) and between the F1 and F2 groups (p -value= 0.902). Based on the differences in LDL levels, it can be concluded that F1 was the most effective formulation for reducing LDL levels.

Research by Yulianto et al. (2023) reported that

suweg tuber may provide metabolic benefits, particularly in suppressing increases in blood glucose levels and reducing serum cholesterol concentrations. These effects are associated with its low glycemic index, high dietary fiber content, and hypoglycemic and hypolipidemic properties⁴². In addition, suweg tuber contains various phenolic compounds, including flavonoids, phenolic acids, and diterpenes, which exhibit strong antioxidant activity and contribute to lipid metabolism regulation, especially through the reduction of circulating LDL levels⁴³. Flavonoids have been reported to inhibit cholesterol synthesis in the liver by modulating enzymatic activity involved in lipid metabolism. These compounds may also prevent excessive lipid accumulation in blood vessels and adipose tissue, thereby supporting improved lipid homeostasis^{44,45}.

According to a study by Muyassaroh and Muhtadi (2022), suweg tuber contains a low-fat content and glucomannan⁴⁶. Glucomannan is a low-calorie, fiber-rich food that promotes satiety⁴⁷. Bioactive components in suweg tuber have been associated with anti-diabetic, anti-obesity, prebiotic, and anti-inflammatory effects, collectively supporting improved metabolic regulation⁴⁸. Glucomannan forms a viscous gel in the digestive tract and binds bile acids, reducing their reabsorption and promoting fecal excretion. This mechanism decreases intestinal cholesterol absorption and lowers circulating LDL Levels. In addition, Glucomannan has been reported to enhance hepatic LDL receptor expression, facilitating the clearance of LDL from the bloodstream^{49,50}.

According to Maryusman (2020), dietary fiber intake has consistently been associated with reductions in LDL levels, partly through direct binding of dietary cholesterol and enhanced fecal excretion⁵¹. This aligns with research conducted by Ridwan et al. (2024), which showed that fiber significantly affects blood LDL levels. Fiber binds bile acids and prevents reabsorption in the intestines, thereby reducing blood LDL levels^{30,52}. Increasing fiber intake is therefore considered an effective dietary strategy for lowering LDL levels in individuals with dyslipidemia⁵³. Bambara groundnut has also been identified as a potential functional food due to its relatively high fiber content (17.81%) and favorable effects on lipid metabolism.

Previous studies have shown that bambara groundnut has potential as a functional food for managing liver and kidney complications in individuals with diabetes⁵⁴. Although its glycemic index is slightly higher than that of suweg tuber, Bambara groundnut remains within the low glycemic index category. Research by Amina et al. (2017) demonstrated that the low glycemic index of bambara groundnut is important for managing hyperglycemia and hyperinsulinemia⁵⁵. According to Syahrin (2020), poor glycemic control is associated with insulin resistance and impaired lipid metabolism, which may increase Free Fatty Acids (FFAs) flux from adipose tissue to the liver, thereby enhancing triglyceride synthesis and VLDL secretion. VLDL then interacts with HDL through Cholesteryl Ester Transfer Protein (CETP), ultimately increasing LDL blood levels^{10,56}. This study uses local food ingredients that have never been tested on rats with dyslipidemia diabetes. Therefore, toxicity tests of suweg tuber flour and

bambara groundnut formulations are recommended to analyze safety limits and long-term effects.

CONCLUSIONS

The most effective formulation for increasing HDL levels and reducing LDL levels was formulation 1 (F1), with a suweg tuber flour and Bambara groundnut flour dose of 0.37 g per 200 g BW/day. This study highlights the potential of local functional foods as natural hypolipidemic agents. However, the short intervention period and limited biochemical parameters represent notable limitations. Future studies should include longer treatment durations, broader lipid markers, and mechanistic evaluations to strengthen the findings.

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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AUTHOR CONTRIBUTIONS

RAR: conceptualization, investigation, methodology and original draft preparation; QFR: data analysis, manuscript writing, writing review, and editing; LP: methodology, review, and editing; LL: review, and editing.

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