Journal of Healthcare and Biomedical Science, Vol. 2 No. 2 (2024) https://doi/org/10.31098/jhbs.v2i2.2208

Research Paper

In Vivo and In Vitro Anti-Hyperglycemic and Hypolipidemic Effect of Atili (Canarium Schweinfurthii) on Streptozotocin Induced Diabetic Rats

Abubakar Ibrahim Garba[1*], Agomuo Jude Kelechi[2], Nasiru Bilkisu Umar[2]
Idris Zubairu Kaida[2], Abubakar Kabir Adam[2], Maryam Gambo Abdullahi[2]
Saifullahi Abdullahi[2]

[1]Ahmadu Bello University Zaria, Nigeria
[2] Federal University Dutsinma, Nigeria

Received: January 28, 2024	Revised: February 25, 2024	Accepted: May 02, 2024	Online: June 30, 2024

Abstract

Canarium schweinfurthii is used as a traditional treatment for diabetes mellitus in Nigeria and other African countries, according to ethnobotanical records. However, scientific evidence has not yet been published. This study aimed to evaluate the antidiabetic effects of Canarium schweinfurthii fruit pulp ethanol extract in streptozotocin-induced diabetic rats. A type II diabetic rat model (TDRM) was established via high-fat diet and Streptozotocin induced diabetes. Diabetic rats were randomized into five different groups; the control group (n = 6) (common diet) and high-fat diet (HFD) groups fed with ethanolic extract at 100, 200, 400, and 600 mg/ml (n = 24). At these doses, the blood glucose was lowered by 57.68% to 80.17%. For hypolipidemic test, total cholesterol was lowered from 162.33 mg/dL to 70.19 mg/dL; Glyceride from 166.91 mg/dL to 68.61mg/dL. Creatinine from 6.77 mg/dL to 6.42 mg/dL. Alanine Aminotransferase was 151.3 to 53.31 µI/L in 600mg group. Aspartate Aminotransferase enzyme decrease from 130.4 µI/L to 40.81 µI/L. This study confirmed the antidiabetic effects of Canarium schweinfurthii fruit extract.

Keywords: *Phytochemicals, Antidiabetic, Medicinal plants, Diabetes, Functional foods, Nutraceuticals.*

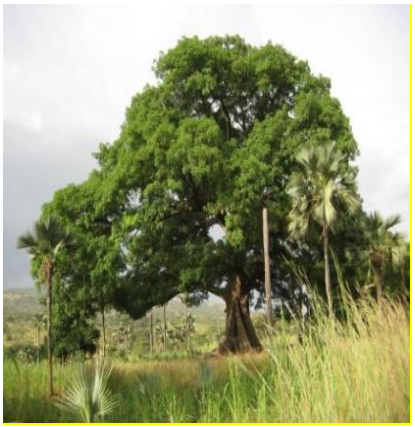
INTRODUCTION

Natural plant-based products have been utilized for millennia as a primary source of preventive medicines for the treatment and prevention of human and animal diseases (Atanasov *et al.,* 2015; Bagchi, 2006). Recently, in an effort to create products that enhance health and wellness, researchers have focused on foods that combine pharmaceutics and nutrition. According to Simmonds (2009), research on functional food ingredients indicated the potential for using ingredients in food to improve consumer health and provide value for producers (Jamal & Pareek, 2022). Around the world, numerous foods with medicinal value are currently being investigated for the management of crippling conditions like hyperglycemia (diabetes) (Kyewalabye et al., 2023; Ssenku *et al.,* 2022; Chen et al., 2020). Details regarding these plants and their therapeutic roles are reserved for the development of new therapeutic, nutraceuticals or other functional food products (Mona et al., 2017; Kakudidi et al., 2016). *Canarium schweinfurthii* belongs to the Burseraceae family, which is extensively distributed in tropical Africa, (Nyam et al. 2018). The plant is characterized by a straight and cylindrical bole, thick bark, reddish to light brown slash with turpentine-like odor, exuiding a heavy, sticky oleoresin that is yellowish in color; pinnate leaves, mostly opposite, oblong, cordite at base (Figure 1), and Its creamy white flowers are unisexual, and the fruit of *C. schweinfurthii* is a small drupe, bluish-purple, glabrous, thick, and long, containing a hard spindle-shaped that has been used traditionally in treating many ailments (Singab & Youssef,

Corresponding author's email: abubakargzango@gmail.com

2014). The ethno-botanical record of *Canarium schweinfurthii* indicates its effectiveness as an anti-diabetic agent; different parts of the plant have been reported to have anti-diabetic properties; stem bark extract of the plant can reverse hyperglycemia caused by streptozotocin (Kamtchouing et al., 2006). Idu et al. (2016) reported Canarium oil to have anti-diabetic activity and can be considered a remedy for diabetes. Despite its potential as an anti-diabetic agent, fruit pulp, which accounts for approximately 60 % of the total fruit volume, has not yet been exploited for its anti-diabetic effects.

Diabetes is a metabolic disorder characterized by high blood sugar and disrupted metabolism of fat, protein and carbohydrate. It is characterized by polydipsia (increased thirst), Polyruvia (increase urination), and polyphagia (increased appetite) (Davoud, 2015). Currently, over 170 million people globally suffer from diabetes mellitus, a serious public health issue (Ugwu et al., 2020). Diabetes affects many organs and is not gender, age, or race-specific. Over time, untreated diabetes results in increased damage to blood vessels and neurons (American Diabetes Association, 2018), which may lead to negative effects on the construction and function of micro- and macrovasculature, which affect the kidneys, heart, eyes, and nerves, and can lead to damage, malfunction, and eventually organ failure (Mujeeb et al., 2020). Despite the development of many synthetic medications, efficient medications with reduced side effects have not yet been established (Patel et al., 2012). The World Health Organization (2021) recommends assessing traditional plant therapies for diabetes because they are considered ideal for treatment because they are safe, effective, and have few to no adverse effects (Shokeen et al., 2008). Studies have indicated that a vast majority of people worldwide—roughly 50–96%—use medicinal herbs like *Canarium schweinfurthii* to cure or manage a range of conditions, including diabetes (World Health Organization, 2021). This applies to both developed and developing countries. About 60% of people in both rural and urban areas use thousands of therapeutic herbs. *Canarium schweinfurthii*, one of Nigeria's most widely used medicinal plants, has gained increased attention because all its components are used. The major phytochemicals of Canarium schweinfurthii are; flavonoids, steroids, saponnin, terpenoids, cardiac glycosides, tannin, phenolic compounds, triterpenes, balsam, triterpinoic acid, and canarenes (Ngbebe et al., 2008; Mogana et al., 2011; Atawodi, 2010; Kouambou et al., 2007; Uzama et al., 2012; Tamboue et al., , 2000; Yousuf et al., 2011; Okoli et al., 2015). Research by Yousuf et al. (2011) identified triterpenoic acids, 3α-hydroxytirucalla-7, 24-dien-21-oic acid and 3α-hydroxytirucalla-8, 24-dien-21-oic acid as major trterpenoic acids in *Atili* fruit while 3β-fluorotirucalla-7, 24-dien-21-oic acid was isolated from resins. Catechol, phydroxylbenzaldehyde, tyrosol, p-hydroxybenzoic acid, dihydroxybenzoic acid, phloretic acid, vanillic acid, secoisolariciresinol, and pinorinesinol were isolated from the mesocarp oil by Orwa et al. (2009). Atawodi (2010) identified hydroxyphenylacetuuc acid, phydroxybenzoic acid, tyrosol, dihydroxynezoic acid, vanillic acid, dihydroxyphenylacetic acid, phloretic acid, secoisolariciresinol, and pinoresil from plant seed. Ligballinol, schweinfurthinol, p-hydroxybenzaldehyde, p-hydroxycinnamaldehyde, coniferaldehyde, amantoflavone, and ligballinol were found in the mesocarp oil by Tamboue et al. (2000). According to Ngbebe et al. (2008) *C schweinfurthii* decoction has been used to treat different ailments, including yellow fever, toothache, diarrhea, goiter, helminths infection, eye disease, anemia, cardiovascular condition, and in warding off evil spirits. Oral administration of the plant stem bark extract can reverse streptozotocin-induced hyperglycemia (Kouambou et al., 2007). Orally consumed canarium oil has antidiabetic properties (Idu et al., 2016)



Frame A

Frame B

Frame C

Figure 1: *C*anarium *S*chweinfurthii plant and its parts. Frame "A" *C. schweinfurthii* plant. Frame "B"C. schweinfurthii leaves. Frame "C" internal and external views of the C. *schweinfurthii* fruit.

RESEARCH METHOD

Materials

Wire cages were constructed locally, 2mls size syringes, 0.5ml needles, glucometer (AccuCheck), gluco-strips, dissecting kits, and streptozotocin were purchased from Ado Jones LTD, Kano. Rat feed (pellets) was purchased from Alheri Agro-vet at Farin-gada perishable market, Jos. Other chemicals were of analytical grade, whereas Albino rats were purchased from the National Veterinary Research Institute Vom, Plateau state.

Collection and preparation of plant materials

In February 2023, at 9:00 a.m., fresh, fully ripe fruit was manually plucked from the tops of trees in Maza Forest, Jos North Local Government, Plateau state, Nigeria, and placed in a sterile plastic bag for processing. After the fruit was sorted and cleared off debris, it was rinsed with clean water and then immersed in 30% salt solution for 15 min. We produced fruit pulp flour in accordance with Nyam et al. (2014). The cleaned fruit was soaked in water at 18–20 ^{0}C for 15 min. After cooling the fruit, the seeds and mesocarp (meat) were manually removed. The pulp that was recovered was sun-dried on spotless trays for 3 days while being constantly stirred. After drying, the pulp was pulverized again using a mechanical blender to produce flour of a consistent size before being placed in a sterile plastic bag for further examination.

Preparation of Plant Extract

Modified by Authoria et al, (2022). Pulp flour was extracted in 75% ethanol by maceration at a ratio of 1:9 for 19 h with frequent stirring. The extract was then filtered using Whatman filter paper (size 1) and evaporated at 50^{o}C in a reduced pressure using a rotatory evaporator (Made by BIBBY STERLIN LTD, ENGLAND. S. No. RE2246). After evaporation, the residue is stored at 4 ^{0}C before reconstitution (Sulong et al., 2024). Reconstitution stock was prepared by adding a few drops of dimethyl sulfoxide (DMSO) to 4g of the plant extract followed by topping up to 4ml volume to make 1000mg/l stock. Serial dilution was used to obtain the 200, 400, and 600 mg/l stock that was used in this study.

Quantitative Determination of Flavonoid

About 10g of the sample was extracted repeatedly in 100ml of 80% methanol (Oxford Laboratory, UK) at room temperature, the extract was then filtered (No. 42 125 mm) and evaporated to dryness in a water bath (Model RE100B by Bibby, UK), and the remaining sample was weighed as flavonoid in grams (Velavan, 2015).

Quantitative Determination of alkaloids

About 5g of the sample was extracted in 200 ml acetic acid in ethanol for 4 h, the extract was then filtered and concentrated in a water bath (Model RE100B by Bibby, UK) to ¼ of the original volume before evaporation. The concentrated sample is then precipitated by adding dropwise ammonium hydroxide and allowed to settle before further washing with dilute ammonium hydroxide. The remaining precipitate was then filtered, and the alkaloids were weighed (Velavan, 2015).

Quantitative Determination of Tannin

About 500 mg of the sample was mixed in a 50ml distilled water and shaken for 1 h. The aqueous mixture was then filtered into 50ml flask and topped up to the graduated mark. 5ml of the filtered aqueous solution was then mixed with 2 ml of 0.1 M $FeCl_2$ in 0.1 N HCl and 0.008 M Potassium Ferrocyanide. The absorbance of the sample was measured at 120 mn within 10 min using a spectrophotometer (Model 722-2000 by B. Bran Sci. & Ins. Co. England) (Velavan, 2015).

Quantitative Determination of Saponnin

20 g of sample was mixed in 100 cm^3 of 20 % aqueous ethanol. The mixture was then heated in a water bath (Model RE100B by Bibby, UK) for 4 h with stirring at 55 ^{0}C followed by filtration and re-extraction with 200ml of 20 % ethanol. The combined extract was then shaken and concentrated to 40 ml at 90 ^{0}C. the concentrates was then mixed with 20 ml diethyl-ether, and the aqueous layer was recovered and purified in 60 ml n-butanol before being washed twice with 10ml of 05 % aqueous sodium chloride. The purified solution was evaporated and dried in an oven until a constant weight saponin (Velavan, 2015).

Quantitative Determination of glycoside

About 10 ml of the pulp was mixed with 10 ml of Bejlet's reagent, the mixture was allowed to stand for 1 h, after which it was diluted with 20ml distilled water, and the absorbance of the mixture was determined at 495 nm using a spectrophotometer (Model 722-2000, by B. Bran Sci. & Ins. Co. England).

Preparation of Streptozotocin

Streptozotocin solution was prepared by dissolving 45 mg/ml of streptozotocin (from ENZO Life Science, UK) in 0.9% saline water (Koech, 2018).

Induction of Diabetes Mellitus

The rats were made diabetic via a single intraperitoneal injection of 50 mg/ml body weight of freshly prepared streptozotocin (Koech, 2018).

Experimental Design

As in figure 2, 40 healthy rats weighing 200–250 g (90–120 days old) were employed. The animals were kept in a typical laboratory cage with 50/50 access to light and darkness at 25±3 ^{0}C and a relative humidity of 30%–60%. They were also fed *ad libitum.* After that, the animals fasted

for 16 h while having unrestricted access to water. Six groups of five rats each were randomly assigned to fast for 12 h. The straight group (Negative control, non-diabetic) received normal saline, and the second group (un-treated diabetic, Positive control) received 100 % normal rat feed. The remaining groups (treatment groups) received *C. schweinfurthii* extract at doses of 100, 200, 400, and 600 mg/body weight, respectively. The treatment was continued once daily at 9 am for 21 days. Body weight and blood sugar levels were measured on days 0, 7th, 14th and the 21st days of treatment.

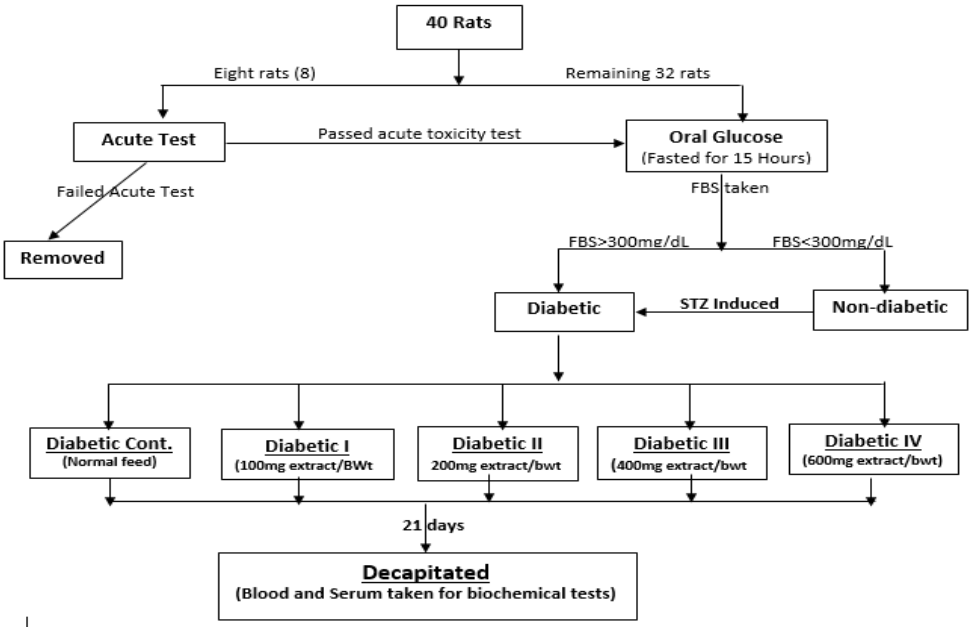


Figure 2: Experimental design.

Acute Toxicity Test

For the acute toxicity test, the up-and-down procedure outlined in the (OECD, 2017) standards was used. Six rats were chosen at random, marked for identification, and housed in clean cages for five days before the first dosing to enable acclimatization to the environment and resting. Subsequently, they were given two doses of 50-g elemi pulp flour at a rate of 10 and 20 g/kg. Every 30 min for 24 h following the dosage, an individual is observed, with special focus on the first 4 h for 14 days. Signs of toxicity are removed from rats.

Oral Glucose Tolerance Test

1.25/kg glucose was administered to each rat. After 30 min, the blood sugar level of the rats was measured, and rats with a sugar level of 200 mg/dL (11.1 mmol/L) or higher is considered diabetic (Koech, 2018).

Determination of Fasting Blood Sugar

Prior to the determination of Fasting Blood Sugar, the rats were allowed to fast for at least 12 h, and the sugar level was then determined using a glucometer (AcuCheck by ROCHE Diabetes Care Inc).

Collection of Serum Sample

The rats were given a 14-hour fast and moderate thiopental anesthesia on the 21st day. For serum analysis, carotid artery occlusion blood was drawn. The blood was allowed to coagulate at

room temperature and centrifuged for 20 min at 500 rpm to separate the serum before analysis. After centrifugation, the upper layer of serum was removed for biochemical analysis.

Serum Analysis

From the serum collected above, the lipid profile (total Cholesterol and Triglyceride), Aspertate Aminotransferase (AST), Alanine Aminotransferase (ALT) and Total Protein (TP) were analyzed using automatic Cobas Integra Plus (BECKMAN COULTER, AU480, UK) using standard operation procedure.

Data presentation and analysis

All experimental results were collected in triplicate in a Microsoft Excel 2013 sheet, the data were exported and analyzed using GraphPad Prism 5 by one-way analysis of variance (ANOVA), and means were compared at $p<0.001$ to $p<0.05$ significance.

FINDINGS AND DISCUSSION

Result of phytochemical contents of *C. schweinfurthii* fruit pulp flour

The results of the phytochemical screening of *C. schweinfurthii* revealed flavonoids (1.68 mg/g), Saponin (0.443 mg/g), alkaloid (0.69 mg/g), glycosides (0.567 mg/g), and tannin (0..8367 mg/g), as presented in table 1.

Table 1. Result of phytochemical constituents of *C. schweinfurthii* fruit extract

S/N	Constituent	Quantity (mg/g)
1	Flavonoid	1.683±0.185
2	Saponin	0.443±0.0551
3	Alkaloids	0.690±0.0794
4	Glycosides	0.567±0.0404
5	Tannin	0.8367±0.051

Note: Results were presented as mean of triplicate ± standard deviation ($p<0.05$).

Key: Normal- 100 % Normal Feed; Control- 100 % Normal Feed**;** Diabetic 1- Normal Feed + 100mg/mL**;** Diabetic I - Normal Feed + 200mg/mL; Diabetic III - Normal Feed + 400mg/mL; Diabetic IV - Normal Feed + 600mg/mL.

Result of anti-diabetic effect of *C. schweinfurthii* fruit extract

The antidiabetic activity of *C. schweinfurthii* extract is depicted in Figure 3. At $p<0.005$ after 21 days of treatment, the non-diabetic control group's blood sugar level increased by 1.23% and 8.2%, respectively, in the untreated diabetic group. The treatment group's fasting blood sugar levels decreased by 57.68, 69.11, 80.17, and 78.92% in the 100, 200, 400, and 600 mg/ml groups, respectively, demonstrating that the sample extract has antidiabetic properties in rats with diabetes. This reduction in glucose levels agrees with 36, 43, and 35% reductions at 26, 75, and 150 mg/ml doses of steam bark extract of *C. schweinfurthii* reported by Kouambou et al., (2007), who similarly found that daily treatment with 150 and 300 mg/ml of *C. schweinfurthii* water stem extract considerably reduced blood glucose levels by 74 and 65% relative to starting values. Furthermore, according to (Gbolade et al., 2010), *C. schweinfurthii* stem bark extract has a long-lasting effect on alloxan-induced diabetic rats at a dose of 400 mg/ml bwt/day, which gives the maximum percentage fall in fasting blood sugar (FBS) in diabetic rats (74.2%). This result is also comparable to the standard drug, metformin, at 100 mg/ml bwt/day, which reduced fasting blood glucose levels

by 74.3% after 21 days in (Koech, 2018) and by 71.1% after 14 days of treatment in (Kouambou et al., 2007).

Table 2. Effects of *C. schweinfurthii* pulp extract on fasting blood sugar levels

Group	Fasting blood glucose (mg/dL)		Net Variation
	Initial	Final	(%)
Control	86.06±1.665[a]	87.12±1.085[c]	+1.23
Diabetic Cont.	431.80±1.770[b]	467.25±10.291[b]	+8.2
Diabetic I	433.48±1.792[b]	183.45±10.167[d]	-57.68
Diabetic II	432.10±1.893[b]	133.47±11.840[c]	-69.11
Diabetic III	434.42±1.777[b]	86.167±5.164[c]	-80.17
Diabetic IV	433.07±1.908[b]	91.283±10.846[c]	-78.92
P value	=0.0001	<0.0001	
Mean Difference	4.314	4.314	

Results were presented as mean of n=6 ± standard deviation. All value on the same column with the same superscript are not significantly different at p<0.05.

Key to samples: Normal -100 % Normal Feed; Control - 100 % Normal Feed; Diabetic 1 - Normal Feed + 100 mg/mL ; Diabetic I - Normal Feed + 200 mg/mL; Diabetic III - Normal Feed + 400 mg/mL; Diabetic IV - Normal Feed + 600 mg/mL..

Effects of C. schweinfurthii extract on growth parameters

The effects of African Black Elemi pulp flour extract on growth parameters are shown in Table 2. The result shows a significant decrease in body weight in the non-treated group from 229.4 g to 196.13 g. Weight gain in the non-diabetic group from 221.3 to 247.48 g in treated group. Fluid intake increased from 206.23 mL to 369.84 mL per day in diabetic untreated group. 53.065 to 49.285 mL in the non-diabetic group, and 179 to 307.75 mL in the diabetic treatment group. Feed intake increased from 47.55g to 53.42 g in the non-diabetic group, from 92.3 to 102.7 g in the untreated diabetic group, and from 87.25 g to 104.8 g in the treated diabetic group.

Result of hypolipidemic activity of *C. schweinfurthii* fruit extract

The results of the hypolipidemic study (Table 3) showed a significant increase in total protein from 80.77 mg/dL in the normal non-diabetic group and 58.94 mg/dL in the positive control (un-treated diabetic) to 88.16 mg/dL in the diabetic group treated with 400 mg/mL extract. Total Triglycerides was found to range from 55.62 mg/dL in non-diabetic and 166.91 mg/dL in diabetic controls to 68.61 mg/dL in diabetic treatment group IV. Creatinine levels were 6.01 mg/dL in the non-diabetic group and 6.77 mg/dL in the diabetic control group and reduced to 6.42 mg/dL in the diabetic treatment group treated with 600 mg extract. Total cholesterol levels were 85.41 in the untreated group and 162.33 mg/dL in the untreated diabetic group and reduced to 70.19 mg/dL in the diabetic group treated with 600 mg/mL extract. AST enzymes was 56.33 µI/L in the non-diabetic group, 151.3 in diabetic untreated group and 53.31 µI/L in the diabetic treatment group treated with 600 mg/mL extract. ALT enzyme was 35.10 µI/L in the non-diabetic control, 130.4 µI/L in diabetic untreated group and 40.81 µI/L in the 600 mg/mL group.

Table 3. Effects of *C. schweinfurthii* extract on growth parameters

Group	Body weight (g)		Water intake (ml/rat/day)		Feed intake (g/rat/day)	
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**
Control	221.3±11.91[a]	231.95±16.5[a]	53.065±2.454[a]	49.285±1.209[a]	47.55±2.758[a]	53.42±4.639[a]
Diabetic Cont.	229.4±2.94[ab]	196.13±8.53[b]	206.23±5.56[b]	369.84±9.54[b]	92.30±2.121[b]	102.70±4.10[b]
Diabetic I	224.09±4.2[b]	232.33±5.8[a]	179.00±15.7[b]	184.00±4.808[c]	87.25±1.061[c]	81.70±3.253[c]
Diabetic II	232.95±2.8[b]	243.58±2.8[c]	189.45±1.20[b]	147.15±4.738d	79.1±1.697[c]	71.20±2.404[d]
Diabetic III	232.60±1.35[b]	247.48±3.58[c]	189.85±16.9[b]	214.50±6.788[e]	98.75±1.909[b]	100.3±0.849[b]
Diabetic IV	231.65±1.9[b]	241.43±4.1[c]	191.55±12.37[b]	307.75±3.182[f]	97.60±0.9899[b]	104.8±7.354[b]
P value	= 0.0021	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001

Note: Results were presented as mean of n=6 ± standard deviation. All value on the same column with the same superscript are not significantly different at p<0.05.

Keys: Normal- 100 % Normal Feed; Control- 100 % Normal Feed**;** Diabetic 1- Normal Feed + 100mg/mL**;** Diabetic I - Normal Feed + 200mg/mL; Diabetic III - Normal Feed + 400mg/mL; Diabetic IV - Normal Feed + 600mg/mL.

Table 4. Results of Serum Analysis after sub-chronic treatment

Group	Total protein (mg/dL)	Creatinine (mg/dL)	Triglyceride (mg/dL)	Total cholesterol (mg/dL)	AST (µl/L)	ALT (µl/L)
Control	80.77±1.212[a]	6.01±0.747[a]	55.62±2.911[b]	85.41±3.143[a]	56.33±1.001[a]	35.10±2.34[a]
Diabetic Cont.	58.94±2.002[b]	6.77±0.992[a]	166.91±3.882[c]	162.33±4.111[b]	151.3±3.183[b]	130.4±2.77[b]
Diabetic I	86.82±0.941[c]	5.59±1.184[b]	50.79±2.113[d]	66.14±2.394[c]	44.38±0.104[c]	30.31±0.24[c]
Diabetic II	88.16±3.081[d]	6.21±0.414[a]	54.33±0.044[b]	71.08±1.111[d]	50.12±1.100[d]	32.52±2.52[d]
Diabetic III	86.03±2.212[c]	6.07±0.728[a]	69.92±0.291[a]	70.70±0.919[d]	51.04±0.989[d]	32.01±2.77[d]
Diabetic IV	85.12±3.413[c]	6.42±0.888[a]	68.61±0.097[a]	70.19±1.561[d]	53.31±0.534[e]	40.81±2.05[e]
P value	= 0.0018	<0.0001	<0.0001	< 0.0001	<0.0001	<0.0001

Note: Results were presented as mean of n=6 ± standard deviation. All value on the same column with the same superscript are not significantly different at p<0.001.

Key: Normal -100 % Normal Feed; Control - 100 % Normal Feed; Diabetic 1 - Normal Feed + 100 mg/mL; Diabetic I - Normal Feed + 200 mg/mL; Diabetic III - Normal Feed + 400 mg/mL; Diabetic IV - Normal Feed + 600 mg/mL

Discussion of antidiabetic effect of *C. schweinfurthii* pulp extract

Studies on acute toxicity of C. schweinfurthii's crude extract (100–1000 mg/ml) showed no behavioral abnormalities in all rats, as evidenced by the absence of paroxysms, struggling, altered reflex activity, respiratory distress, or mortality. In three of the rats tested, a minor increase in irritability and escape behavior was noted at 2000 mg. All animals appeared healthy and showed no signs of behavioral or physical changes between 24 h and 1 week. The phytochemical screening of the extract revealed the highest amount of flavonoid, followed by saponin, alkaloid, glycoside, and tannin. This agrees with Kyewalabye et al. (2023); Idu et al. (2016); Kamtchouing et al., (2006), who reported the same phytochemicals in *Canarium schweinfurthii.*

The results of this study concur with numerous other studies conducted worldwide that have documented the existence of phytochemicals in medicinal plants. Yadav et al., (2017) and Uzama et al., (2016) stated that these phytochemical elements have physiological and therapeutic properties, and their existence may indicate that *C. schweinfurthii* has antidiabetic potential ($p<0.001$). Presence of phytochemical such as flavonoid, saponin and glycoside have been found in other medicinal plants which suggest their usage in in the treatment of chronic illnesses (Kumar et al., 2014). To control blood sugar levels in a living system, the body needs to coordinate a number of processes regulating the secretion, absorption, and/or breakdown of insulin, which if not properly coordinated will result in injury to beta cells and subsequently diabetes (Wahren & Ekberg, 2007). The 400 and 200 mg/ml extract doses of *C. schweinfurthii* fruit pulp extract differ from one another; this discrepancy may be explained by the higher concentration of the phytochemicals that cause a greater drop in fasting blood glucose than the latter. According to Rawi et al., (2011); Andre-Cetto and Youssef,(2010); and Daisy et al. (2010), the biochemical mechanism of *C. schweinfurthii* fruit pulp feed extract's anti-hyperglycemic actions may be caused by insulin mimicking effect on muscle and adipose tissues, stimulating glucose uptake and metabolism, inhibiting hepatic gluconeogenesis and or glucogenolysis, or by the stimulation or regeneration process of remnant beta cells. Additionally, it may have inhibited the activity of α-glucosidase enzymes in the small intestine, which convert disaccharides into monosaccharides for their absorption (Shinde et al., 2008). (Sengupta et al., 2011) reported similar results, indicating a drop in blood glucose levels following Psidium guajava leaf extract intake. In addition to a decrease in fasting blood sugar, the treatment groups showed a significant ($p<0.001$) increase in body weight at varying dosages of C. *schweinfurthii* fruit pulp extract. This steady increase in body weight suggests that *C. schweinfurthii* fruit pulp extract, as opposed to synthetic medications, which are also frequently associated with weight gain during the course of treating diabetes mellitus (Prabhakar & Doble, 2011), may be an excellent option for diabetes treatment. According to earlier research, rats with STZ diabetes had reduced body weights (King, 2012). Additionally, the untreated group exhibited a sharp decline in body weight, which may be brought on by a rise in muscle atrophy (Ravi et al., 2004). Furthermore, dehydration, a decrease in carbs, or increased tissue protein and lipid breakdown may potentially contribute to the weight loss observed in diabetic rats (Kurup & Mini, 2017). Comparing the body weights of the treatment and untreated diabetic groups, the *C. schweinfurthii* fruit ethanol extract improved the body weight. The extract's protective effect against muscle atrophy and protein turnover, as well as its potential to improve conditions related to diabetes mellitus, may be the reason for its ability to prevent massive weight loss, which is an indicator of appropriate glucose utilization.

Discussion of Hepatoprotective effect of *C. schweinfurthii* pulp extract

The hepatoprotective effect was promising. Specifically, the administration of *C. schweinfurthii* fruit pulp extract normalized the levels of AST and ALT enzymes, with the maximum effect at 400 mg/ml, which may be attributed to the increased phytochemical concentration. There was an increase in AST and ALT levels in the untreated groups, which implies leakage of these enzymes from the live cytosol into the blood stream, indicating hepatotoxicity (Kazeem et al., 2013), possibly caused by streptozotocin. However, diabetes is known to increase the production of free radicals, thereby creating oxidative stress, which may lead to cellular damage and the ability of the body, which is explained by the functionality of AST and ALT enzymes. The regulatory potential of the extract on elevated AST and ALT levels in the untreated group (130-150 mg/dL) indicate hepatoprotection potential against liver toxicity. Toxicity in the liver is explained by the elevated activity of these enzymes (increase in serum quantity) caused by oxidative stress/hyperglycemia (Kurup & Mini, 2017). Diabetes is associated with elevated levels of liver toxicity markers, including

AST and ALT in blood serum, which must be regulated to protect against cellular damage/injury. Although the liver naturally maintains glucoregulation, carbohydrate homeostesis, and insulin deterioration through MAPK signaling as potent regulators of insulin signal transduction and glucose and insulin transduction (Wang et al., 2018), diabetes alone decreases hepatic insulin sensitivity, which can be augumented by the estimation of serum AST, ALT and protein (Chaudhury et al., 2017). While ALT participate in gluconeogensis by catalyzing the transfer of amino acid groups from aspartic acid or alanine to ketoglutaric acid to produce oxaloacetic acid and pyruvic acid, respectively, AST is present as cystosolic and mitochondrial isoenzymes and is found in the liver, cardiac muscle, skeletal muscle, kidney, brain, pancreas, lungs, leucocytes, and red cells (Ray et al., 2006). Therefore, assessment of AST and ALT can explain the severity of diabetes damage(Nondo et al., 2015).

Hypolipidemic potentials of *C. schweinfurthii* fruit extract

There was a general increase in triglyceride and cholesterol levels in untreated diabetic rats, which is not surprising, as diabetes is reported to cause general rise in triglycerides above cholesterol level (166.91>162.33mg/dL) in the blood stream, which increases the risk of heart disease and stroke. The hypolipidemic potential of Canarium extract shows a general reduction in triglyceride up to a limit within the <150mg/dL for a healthy non-diabetic state; the triglyceride was reduced from 166.91 mg/dL (in negative control) to 50.79, 54.33, and 68.61 at 100, 200, and 400 mg/mL doses of *C. schweinfurthii* pulp extract, indicating that the extract has hypolipidemic effect. Triglycerides are common gyslipidemic features accompanying type II diabetic which has been used as criteria for defining individuals who are at risk of for cardiovascular disease due to diabetic, arguably called “metabolic syndrome”, with acceptable limit of <150 mg/dL, the triglyceride in this research was dropped from 166.91 in diabetic un-treated group (Positive control) to 68.61 mg/dL at 600mg/ml dose, indicating excellent performance of the extract in increasing triglyceride digestion/utilization. Conversely, to be non-diabetic, one must have a total cholesterol must be ≤200 mg/dl. The untreated group's cholesterol level of 162.33 mg/dL decreased to 66.14, 71.05., 70.70, and 70.19 mg/dL at 100, 200, 300, and 400 mg/L doses of extract. This demonstrates the extract's capacity to lower cholesterol (hypolipidemic) and serve as an antidiuretic because elevated blood cholesterol levels can cause atherosclerosis or artery blockage, which can lead to organ failure. Research has established a connection between diabetic dyslipidemia, atherosclerosis, blood vessel disease, and insulin resistance, which is prelude to type II diabetes. Together with cholesterol, triglycerides or blood fats are circulated in the bloodstream as proteins, which are usually metabolized from foods (especially meats and plant oils) or produced by the liver. Serum protein is an important index for cholesterol and triglyceride maintenance in the body system, which was found to increase from 58.94 mg/dL in untreated diabetic rats to 86.82, 88.16, 86.03, and 85.12 mg/dL in the diabetic treatment group with 100, 200, 400, and 600 mg extract. Changes in protein levels after treatment with *C. schweinfurthii* fruit in diabetic rats are important because diabetic living rats are reported to have serious issues with protein digestion and absorption. Serum creatinine is a major metabolite of creatine in the skeletal muscle and plays an excellent role in maintaining insulin-mediated glucose intake; therefore, low serum creatinine levels are associated with type II diabetes. The ability of the extract to maintain serum creatinine levels from 6.01 mg/dL in the negative control and 6.77 mg/dL in the positive control to 5.59 – 6.42 mg/dL in the treatment group shows a good effect, possibly explained by the extract’s ability to regulate insulin-mediated glucose uptake and peripheral insulin resistance (IR). Low creatinine levels indicate increased insulin resistance, which is linked to a higher risk of type II diabetes and low muscle mass.

CONCLUSIONS

In conclusion, our findings corroborate the antidiabetic properties of *C. schweinfurthii* fruit, thereby endorsing its application in the management of diabetes. As demonstrated in this research, administering the extract from *C. schweinfurthii* fruit to individuals with diabetes will cause a considerable decrease in blood glucose (sugar) with minor body weight gain thus, hepatoprotection, hypoglycemic, and hypolipidemic properties. The potential of *C. schweinfurthii* fruit pulp extract as an alternative medication for the treatment of diabetes (type II) has been proven by this research, as the most effective dose identified. This natural agent's potent hypoglycemic effects were likely caused by additional pancreatic activities, as demonstrated by the significant balance of blood serum enzymes, enhanced beta-cell function, and islet destruction, as well as by its pancreatic actions, which were evident from decreasing insulin resistance glucose utilization by the skeletal muscle. *C. schweinfurthii's* proven ability to lower blood cholesterol levels may be explained by its increased release of insulin, which inhibits lipoprotein lipase and stops lipolysis.

LIMITATIONS AND FURTHER RESEARCH

This research was limited to a laboratory experiment using laboratory-grown rats. It also relied only on the selected procedure, there was no direct comparison with standard drugs or with other extracts; therefore, further study may involve clinical study maybe through development of nutraceuticals after further fractionation to identify the active compound(s) responsible for the anti-diabetic and hepato-protective activity of the fruit extract. In addition, other studies should be conducted to determine the histopathological characteristics of the liver in STZ-induced rats treated with the fruit pulp extract of African Black Elemi. Toxicological studies should be conducted on African Black Elemi fruit pulp extract, and an effective dose should be established for administration in patients with diabetes and/or for disease prevention.

CONFLICT OF INTEREST

The authors declare no conflicts of interest.

ACKNOWLEDGMENT

The authors acknowledge the support of family members and friends at Federal University Dutsin-Ma**.**

AUTHOR CONTRIBUTIONS

The drafting and the subsequent preparation of this manuscript was done by AI Garba and was agreed by all the authors. Conceptualization by Abubakar Ibrahim, Data collection and Analysis by Abubakar Ibrahim Garba, Draft Preparation by Dr. Nasiru Balkisu Umar and Dr. Agomuo Jude Kelechi. Proofreading and laboratory research was assisted by Idris Zubairu Kaida, Abubakar Kabir Adam, Maryam Gambo Abdullahi and Saifullahi Abdullahi Haladu.

REFERENCES

American Diabetes Association. (2018). *Classification and Diagnosis of Diabetes: Standards of Medical Care in Diabetes*. Diabetes Care, 41 S13-17. https://doi.org/10.2337/dc18-s002

Andre-Cetto S., & Youssef F. (2010). Inhibition and Phytochemical Composition of Two Cecropia Species. *Journal of Ethnopharmacology, 130*(1):93-97. https://doi.org/10.1016/j.jep.2010.04.016

Atanasov AG., Waltenberger B., Pferschy-Wenzig FM. (2015). Discovery and Resupply of Pharmacologically Active Plat-Driven Natural Products: A Review. *Biotechnology Advances, 3*(8): 1582-1614. https://doi.org/10.1016/j.biotechadv.2015.08.001

Atawodi SE., (2010): Polyphenol Composition And In Vitro Antioxidant Potential of Nigerian Canarium Schweinfurthii Engl. Oil. *Advances in Biological Research, 4*(6):314-322. https://doi.org/10.1371/journal.pone.0122733

Authoria, N., Wijayanti, L., & Febrinasari, R. P. (2022). Differences of Quercetin Content in Fresh and Extracts Local Apples using High Performance Liquid Chromatography Method. *Journal of Healthcare and Biomedical Science*, *1*(1), 24-35. https://doi/org/10.31098/jhbs.v1i1.1369

Bagchi D.; (2006). Nutraceuticals and Functional Foods Regulations in the United States and Around the World. *Toxicology, 221*(1), 1-3. https://doi.org/10.1016/j.tox.2006.01.001

Chaudhury, A., Duvoor, C., Reddy Dendi, V. S., Kraleti, S., Chada, A., Ravilla, R., ... & Mirza, W. (2017). Clinical Review of Antidiabetic Drugs: Implications for Type 2 Diabetes Mellitus Management. *Frontiers in Endocrinology*, *8*, 6. https://doi.org/10.3389/fendo.2017.00006

Chen Y, Lee K., Ni Z., & He J. (2020). Diabetic Kidney Disease: Challenges, Advances, and Opportunities. *Kidney Diseases, 6*(4):215-225. https://doi.org/10.1159/000506634

Daisy P., Balasubramanian K., Rajalakshmi M., Eliza J., & Selvaraj J. (2010). Insulin Mimetic Impact of Catechin Isolated from Cassia Fistula on the Glucose Oxidation and Molecular Mechanisms of Glucose Uptake on Streptozotocin-Induced Diabetic Wistar Rats. *Phytomedicine, 17*(1):28-36.

Davoud R. (2015). *Isolation and Characterization of Anti-Diabetic Pharmacological Activities of Phytoestrogens and Components of Moringa Peregrine (Forssk) Fiori*. A thesis submitted for the Degree of Doctor of Philosophy.

Gbolade A, Adeyemi A, & Gbolade A. (2010). Antihyperglycaemic and Hypolipidemic Studies of Three Medicinal Plants on Alloxan-Induced Diabetic Rats*. Journal of Pharmaceutical Research, 9*(2):81. https://doi.org/10.18579/jpcrkc/2010/9/2/7949

Idu M., OvuakporieUvo O., & Olajesu S. (2016). Anti-Hyperglycemic Effect of Canarium Schwenfurthii Fruit Oil on Wistar Rats. *Applied Medical Research, 2*(1):6. https://doi.org/10.5455/amr.20160320075556

Jamal, A., & Pareek, N. (2022). Purslane (Portulaca Oleracea): A Prospective Plant Source of Nutrition and its Waste Utilization in Traditional Product. *Journal of Healthcare and Biomedical Science*, *1*(1), 11-16. https://doi.org/10.31098/jhbs.v1i1.849

Kakudidi E, Kirimuhuzya C, Anywar G, Katuura E, Kiguli J (2016). Medicinal Plants Used in the Management of Non-Communicable Diseases in Uganda. *Medicinal Plants-Recent Advances in Research and Development, 2* (2):397-418. https://doi.org/10.1007/978-981-10-1085-9_17

Kamtchouing P., Kahpui S. M., Dzeufiet P. D, Tedong D., Asongalem E. A., & Dimo T. (2006). Anti-Diabetic Activity of Methanol/Methylene Chloride Stem Bark Extracts of Terminalia Superba and Canarium Schweinfurthii on Streptozotocin-Induced Diabetic Rats. *Journal of Ethnopharmacology, 104*(3):306-309. https://doi.org/10.1016/j.jep.2005.08.075

Kazeem M., Akanji MA., Yakubu MT., & Ashafa AO. (2013). Protective Effect of Free and Bound Polyphenol Extracts from Ginger (Zingiber officinaleRoscoe) on the Hepatic Antioxidant and Some Carbohydrate Metabolizing Enzymes of Streptozotocin-Induced Diabetic Rats. *Evidence-Based Complementary and Alternative Medicine*, 1-7. https://doi.org/10.1155/2013/935486

King AJ. (2012). The Use of Animal Models in Diabetes Research. *British Journal of Pharmacology, 166*(3):877-894. https://doi.org/10.1111/j.1476-5381.2012.01911.x

Koech K. J. (2018). *Hypoglycemic, Hypolipidemic and Hepatoprotective Effects of Polyscias Fulva Ethanolic Bark Extract in Diabetic Rats*. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in biochemistry, 40-85.

Kouambou CN., Dimo T., Dzeufiet PD., Ngeueguim FT., Tchamadeu MC., Wembe EF., & Kamtchouing P. (2007). Antidiabetic and Hypolipidemic Effects of Canarium Schweinfurthii Hexane Bark

Extract in Streptozotocin-Diabetic Rats. *Pharmacologyonline, 1*:209-219.

Kumar V., Anwar F., Ahmed D., Verma A., Ahmed A., Damanhouri ZA., Mujeeb M. (2014). Paederia Foetida Linn. Leaf Extract: An Antihyperlipidemic, Antihyperglycaemic and Antioxidant Activity. *BMC Complementary and Alternative Medicine, 14*(1). https://doi.org/10.1186/1472-6882-14-76

Kurup SB., & Mini S. (2017). Protective Potential of Averrhoa Bilimbi Fruits in Ameliorating the Hepatic Key Enzymes in Streptozotocin-Induced Diabetic Rats. *Biomedicine and Pharmacotherapy, 85*:725-732. https://doi.org/10.1016/j.biopha.2016.11.088

Kyewalabye JC., Kasolo, JN., Lugaajju AK., Kirenga B., Batte C., Lubega A. (2023). Effect of Canarium Schweinfurthii Leaf and Pulp Extracts on Blood Glucose Levels in Oral Glucose Load - Induced Hyperglycemia in Wistar Albino Rats. *Journal of Medicinal Plants Research, 17*(9):249-257. https://doi.org/10.5897/jmpr2023.7310

Mogana, R., Bradshaw, T. D., Jin, K. T., & Wiart, C. (2011). In Vitro Antitumor Potential of Canarium Patentinervium Miq. *Academic Journal of Cancer Research*, *4*(1), 1-4. https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/8321051

Mona MF. El-Ashry FE. El-Maraghy NN. & Fahmy A. (2017). Studies on the Antidiabetic Activities of Momordica Charantia Fruit Juice in Streptozotocin-Induced Diabetic Rats. *Pharmaceutical Biology, 55*(1):758–765. https://doi.org/10.1080/13880209.2016.1275026

Mujeeb Z., Sameer A., Banday M., & Nissar S. (2020). Pathophysiology of Diabetes: An overview. *Avicenna Journal of Medicine, 10*(4):174. https://doi.org/10.4103/ajm.ajm_53_20

Ngbebe J, Yakubu RA, Nyam DA. (2008): Phytochemical Screening for Active Compounds in Canarium Schweinfurthii (Atile) Leaves from Joss North, Plateau State Nigeria. *Res J Biol Sci. 3*(9):1076-1078.

Nondo, R. S., Zofou, D., Moshi, M. J., Erasto, P., Wanji, S., Ngemenya, M. N., ... & Masimba, P. J. (2015). Ethnobotanical Survey and in Vitro Antiplasmodial Activity of Medicinal Plants Used to Treat Malaria in Kagera and Lindi Regions, Tanzania. *Journal of Medicinal Plants Research*, *9*(6), 179-192. https://doi.org/10.5897/jmpr2014.5685

Nyam M., Wonang D., Ogbonna C., Ochekpe N., Dapiya H. (2014). Effects of Extraction Method on the Physicochemical and Mycological Qualities of Canarium Schweinfurthii Fruit Oil. *Bayero Journal of Pure and Applied Sciences, 6*(1):169. https://doi.org/10.4314/bajopas.v6i1.32

Nyam MA. Obashola OE. and Dawang S. (2018): A Survey of Some Varieties of Canarium schweinfurthii (C. schweinfurthii) Grown in of Some of Jos LGA, Plateau state, Nigeria and their Antibacterial Activities. *Journal of Microbiology and Laboratory Science, 1*(102):1-8.

OECD. (2017). *Guidance Document on Acute Oral Toxicity*. Environmental Health and Safety Monograph Series on Testing and Assessment, 24. https://doi.org/10.1787/9789264078413-en

Okoli B., Ndukwe G., Ayo R., Habila J. (2015). Inhibition of the Developmental Stages of Ascaris Suum and Antimicrobial Activity of 3β-Hydroxylolean-12,18-Diene Isolated from the Aerial Parts of Canarium Schweinfurthii (Engl). *American Chemical Science Journal, 11*(3):1-11. https://doi.org/10.9734/acsj/2016/21377

Orwa C, Mutua A, Kindt R, Jamnadass R, Simons A. (2009). *Agroforestree Database: A Tree Reference and Selection Guide Version 4*. World Agroforestry Centre, Nairobi, Kenya, 2.

Patel D., Kumar R., Laloo D., Hemalatha S. (2012). Natural Medicines from Plant Source Used for Therapy of Diabetes Mellitus: An Overview of its Pharmacological Aspects. *Asian Pacific Journal of Tropical Disease, 2*(3):239–250. https://doi.org/10.1016/s2222-1808(12)60054-1

Prabhakar PK., Doble M. (2011). Mechanism of Action of Natural Products Used in the Treatment of Diabetes Mellitus. *Chinese Journal of Integrative Medicine, 17*(8):563-574. https://doi.org/10.1007/s11655-011-0810-3

Ravi K., Ramachandran B., Subramanian S. (2004). Protective Effect of Eugenia Jambolana Seed Kernel on Tissue Antioxidants in Streptozotocin-Induced Diabetic Rats. *Biological and Pharmaceutical Bulletin, 27*(8):1212–1217. https://doi.org/10.1248/bpb.27.1212

Rawi SM., Mourad IM. Sayed DA. (2011). Biochemical and Changes in Experimental Diabetes Before and After Treatment with *Mangifera Indica Psidium* Guava Extracts. Int. *J. Pharm. Bio Sci., 2*(2):29-41.

Ray D., Shartchandra KH. & Thokchom I. (2006). Antipyretic, Antidiarrhoeal, Hypoglycaemic and Hepatoprotective Activities of Ethyl Acetate Extract of Acacia Catechuwilld.in Albino Rats. *Indian Journal of Pharmacology, 38*(6):408. https://doi.org/10.4103/0253-7613.28207

Sengupta R., Sawant CS., Karmarkar S., Bhagwat A. (2011). Antihyperglycaemic and Antidiabetic Effect of the Leaf Extracts of Albizzia Lebbeck Linn. (Benth) and Psidium Guajava Linn. On Alloxan and Streptozotocin Induced Diabetic Mice. *Asian Journal of Pharmaceutical and Clinical Research, 4*(1):129-131.

Shinde J., Taldone T., Barletta M., Kunaparaju N., Hu B., Kumar S., Zito SW. (2008). A-Glucosidase Inhibitory Activity of Syzygium Cumini (Linn.) Skeels Seed Kernel in Vitro and in Goto–Kakizaki (GK) Rats. *Carbohydrate Research, 343*(7):1278-1281. https://doi.org/10.1016/j.carres.2008.03.003

Shokeen P., Anand P., Murali YK. Tandon V. (2008). Antidiabetic Activity of 50% Ethanolic Extract of Ricinus Communis and its Purified Fractions. *Food and Chemical Toxicology, 46*(11):3458-3466. https://doi.org/10.1016/j.fct.2008.08.020

Simmonds MS. (2009). *Duke's Handbook of Medicinal Plants of Latin America. In F. J. A. Duke with M. J. Bogenschultz-Godwin and A. R. Ottesen. Boca Raton*, Handbook of Medicinal Plant of Latin America. pp. 111-111. USA: CRC Press. https://doi.org/10.1017/s0014479709990585

Singab NA., & Youssef FS. (2014). Medicinal Plants with Potential Antidiabetic Activity and their Assessment. *Medicinal plant; Aromatic Plants, 03*(01). https://doi.org/10.4172/2167-0412.1000151

Ssenku JE., Okurut SA., Namuli A., Kudamba A., Tugume P., Matovu P., Walusansa A. (2022). Medicinal Plant Use, Conservation, and the Associated Traditional Knowledge in Rural Communities in Eastern Uganda. *Tropical Medicine and Health, 50*(1). https://doi.org/10.1186/s41182-022-00428-1

Sulong, M. R., Mansor, F. N., Hazman, S. A. H., & Alias, R. (2024). Utilizing Anacardium occidentale Leaves Extract as an Alternative to Conventional Antibiotics Against Antimicrobial-Resistant Microorganisms. *Journal of Halal Science, Industry, and Business*, *2*(1), 79-89. https://doi.org/10.31098/jhasib.v2i1.2326

Tamboue H., Fotso S., Ngadjui B. T., Dongo E., Abegaz B. (2000). Phenolic Metabolites from Seed of *Canarium Schweinfurthii*. *Bull Chem. Soci. Of Ethiopia*. 14:155-159.

Ugwu E., Young E., Nkpozi M. (2020). Diabetes Care Knowledge and Practice Among Primary Care Physicians in Southeast Nigeria: A Cross-Sectional Study. *BMC Family Practice, 21*(1). https://doi.org/10.1186/s12875-020-01202-0

Uzama D., Bwai MD., Olajide OO., Ikokoh PP., Oguntokun OJ. (2016). Antioxidant and Phytochemicals of Hexane and Ethanolic Extracts of *Canarium Schweinfurthii* Burseraceae. *Asian Journal of Pharmaceutical and Biological Research, 2*(3):188-190. https://openurl.ebsco.com/EPDB%3Agcd%3A4%3A1351236/detailv2?sid=ebsco%3Aplink%3Ascholar&id=ebsco%3Agcd%3A90539937&crl=c

Uzama D., Bwai M. D., Olajide O. O., Ikokoh P. P., Oguntokun O. J. (2012). Antioxidant and Phytochemicals of Hexane and Ethanolic Extract of *Canarium Schweinfurthii* Burseraceae. *Asian Journal of Pharmaceutical and Biological Research. 2*(3): 188-190.

Velavan S. (2015). Phytochemical Techniques - A Review. *World Journal of Science and Research*, 80-91.

Wahren J., Ekberg K. (2007). Splanchnic Regulation of Glucose Production. *Annual Review of Nutrition, 27*(1):329-345. https://doi.org/10.1146/annurev.nutr.27.061406.093806

Wang S., Yan Z, Yang X., An S., Zhang K., Qi Y., Tang Y. (2018). Hepatocyte DUSP14 Maintains Metabolic Homeostasis and Suppresses Inflammation in the Liver. *Hepatology, 67*(4):1320-1338. https://doi.org/10.1002/hep.29616

World Health Organization. (2021, October 23). *Media Center*. Diabetes. Retrieved October 23, 2021, from http://who.int/mediacentre/factsheets.html. (Accessed: October, 2021).

Yadav R., Khare RK., Shinghal A. (2017). Qualitative Phytochemical Screening of Some Selected Medicinal Plants of Shivpuri District (M.P.). *International Journal of Life-Sciences Scientific Research, 3*(1). https://doi.org/10.21276/ijlssr.2017.3.1.16

Yousuf S, Kamdem RS, Wafo P, Ngadjui BT, Fun HK. (2011): 3a-Hydroxytirucalla-8, 24-dien-21-oic acid. Acta Cryst 2011;E67:o937-o8. *Nature and Science, 14*(11).