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Physicochemical Properties of the Oil from the Fruit of *Blighia sapida* and Toxicological Evaluation of the Oil-Based Diet in Wistar Rats

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ABSTRACT The physicochemical properties of the oil from the fruit of *Blighia sapida* and the toxicological effect of the oil-based diet on some biochemical parameters of selected rat tissues and serum were studied. The smoke, flash, and fire points as well as peroxide, iodine, and acid values of the fruit oil were significantly lower ($P < .05$), whereas the specific gravity, relative density, saponification, and ester values compared well with soybean oil. The fruit oil yield was 20.02%. The oil consisted of 22.22% saturated, 56.43% monounsaturated, and 21.35% polyunsaturated fatty acids. It is richer than soybean oil in behenic, palmitoleic, oleic, gadoleic, erucic, and 9,12-eicosanoic acids by 15.70%, 0.89%, 7.22%, 12.05%, 8.27%, and 21.35%, respectively. The liver- and kidney-body weight ratios as well as the serum concentrations of cholesterol and high-density lipoprotein cholesterol of the rats maintained on diet formulated with the oil from the fruit of *B. sapida* increased, but the triglyceride and atherogenic index decreased. The low-density lipoprotein cholesterol concentration and the heart-body weight ratio of the rats fed with the fruit oil diet compared well with those on soybean oil-based diet. Animals fed with the fruit oil-based diet had their activities of liver glutamate oxaloacetate transaminase and glutamate pyruvate transaminase as well as alkaline phosphatase of the liver and kidney decreased with a corresponding increase in the serum enzymes. These results suggest that oil from *B. sapida* fruit could be edible and may be explored as raw materials in the paint, margarine, and soap industries. The oil is also unlikely to predispose the animals to atherogenesis, but may labilize the plasma membrane of the hepatocytes and nephrons. It may also have a negative effect on the metabolism and regulation of amino acid in the animals. Therefore, the oil from *B. sapida* fruit may not be completely safe for consumption.

KEY WORDS: • ***atherogenesis*** • **Blighia sapida** ***fruit oil*** • ***hepatocytes*** • ***labilization*** • ***nephrons*** • ***physicochemical properties*** • ***plasma membrane*** • ***soybean oil*** • ***toxicological effect***

INTRODUCTION

BLIGHIA SAPIDA K. KONG (Family Sapidaceae) is known as "Ackee" or "Akee" (English), "Isin" (Yoruba; Western Nigeria), "Gwanja kusa" (Hausa; Northern Nigeria), and "Okpu" (Ibo; Eastern Nigeria). It is an evergreen tree that grows to a height of 10–12 m at maturity. The trunk, which may be up to 1.8 m in circumference, has a dense crown of spreading branches. The leaves are compound with three to five pairs of oblong, ovate-oblong, or elliptical leaflets 1.5–3.0 cm long.[1] The seed of the fruit is not edible, whereas it is only the fleshy aril that is edible. The fruit is known to contain saponins, which are hemolytic.[1] The pulp and the leaves are used to treat eye conjunctivitis. Similarly, the ashes of the dried husks and the seeds are used in the preparation of soap.[2] The root of *B. sapida* in combination with *Xylopia aethiopica* (Dunal) A. Rich (Family Annonaceae) is used to terminate unwanted pregnancy.[3] In northern Nigeria, the stem bark of *B. sapida* in combination with *Allium cepa* L. (Family Alliaceae) and the ripe fruits of *Capsicum frutescens* L. (Family Solanaceae) are ground into powder and taken with hot pap to cure gonorrhea.[4] Although the oil is not consumed specifically as a conventional food, the aril part of the fruit from which the oil is derived is often cooked with codfish, onions, and tomatoes and consumed. The parboiled aril part of the fruits is added to stew made with beef, curried, and eaten with rice. In Africa, the aril part of the fruit may be eaten raw or in soup or after frying in oil.[5] Invariably, the oil is consumed with the aril part of the fruit.

Most of the earlier studies on the species have been on the nutritional qualities of the root[3] and the leaves as a dry season feed resource for West African dwarf goats in the northern savanna zone of Nigeria.[1] The repellant potential of the fruit part components against stored-product insect pests[6] as well as neutropenia and thrombocytopenia effects of the aqueous and lipid extracts of the unripe fruit have been investigated in mice.[7] However, the scanty information on the physicochemical properties of the oil from the fruit of the plant and the effect of the fruit oil-based diet on some

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biochemical constituents of rat tissue cellular system prompted this study.

This study was therefore aimed at providing information on the physicochemical properties of the oil from *B. sapida* fruit and the toxicological effect of the fruit oil-based diet using albino Wistar rats as the model.

MATERIALS AND METHODS

Plant material and identification

Fresh, ripe fruits that were allowed to open naturally were plucked between May and June 2006 from the trees located within the premises of Queen Elizabeth College, Ilorin, Nigeria (latitude 08°32′N, longitude 04°34′N, temperature 30–34°C). They were identified by Prof. F.A. Oladele of the Department of Plant Biology, University of Ilorin, Ilorin, Nigeria.

Experimental animals

Weaned 21-day-old Wistar rats (*Rattus norvegicus*) of both sexes with a mean weight of 20.85 ± 2.01 g were obtained from the animal holding unit of the Department of Biochemistry, University of Ilorin. The animals were kept in a well-ventilated animal house with optimum conditions (temperature 28–31°C; photoperiod 12 hours natural light and 12 hours dark; humidity 50–55%) and were allowed free access to rat pellets (Bendel Feeds and Flour Mills Ltd., Ewu, Nigeria) and tap water.

Assay kits and other reagents

The assay kits for cholesterol, low-density lipoprotein-cholesterol (LDL-C), high-density lipoprotein-cholesterol (HDL-C), triglycerides, alkaline phosphatase (ALP), glutamate oxaloacetate transaminase (GOT), and glutamate pyruvate transaminase (GPT) were obtained from Randox Laboratories (Atrim, UK). All other reagents used were of analytical grade and were obtained from British Drug Houses Laboratory Supplies (Poole, UK).

Other materials

Yellow maize (*Zea mays* L.) seeds and rice husks (*Oriza sativa* L.) were obtained locally from the Baboko Market, Ilorin, while the soybean oil was supplied by Grand Cereals and Oil Mills Ltd. (Bukuru, Jos, Nigeria). Casilan 90 was a product of Tuco Pharmacy (Liverpool, UK). The vitamin mix was obtained from BASF Aktiengesellschaft (Ludwigshafen, Germany). Component chemicals of the mineral mix were products of Sigma Chemical Co. Ltd. (London, UK).

Extraction and purification of fruit oil

The method described by Folch *et al.*[8] was used for the extraction and purification of the fruit oil. The fruit was cut into pieces, oven-dried at 60°C for 6 hours, and pulverized with a blender. Oil was extracted from the powdered sample using chloroform:methanol mixture (2:1 vol/vol). The solvent mixture was poured into the powdered sample, covered, shaken for 5 minutes, left to settle, and then filtered with Whatman (Maidstone, UK) no. 1 filter paper to give the oil-solvent mixture. For the purification, 0.73% (wt/vol) NaCl solution was added to the oil-solvent mixture in a separating funnel, which gave two layers: upper layer (organic phase) and lower (aqueous phase). The organic phase was rinsed off, and chloroform:methanol:0.58% NaCl solution (3:48:47 by volume) was further added. This step was repeated twice, after which the solvent was drained off to obtain the purified oil.

Determination of physicochemical properties of the fruit oil

The specific gravity, boiling, smoke, flash, and fire points, and acid, saponification, ester, iodine, and peroxide values of the fruit oil from *B. sapida* were determined according to the methods described by Pearson.[9]

Determination of fatty acid constituents of the fruit oil

The fatty acid constituents of the fruit oil were determined with gas-liquid chromatography as described by Pearson.[9] A Shimadzu (Tokyo, Japan) GC-17A gas chromatograph (with flame ionization detection) was used with the temperature of the gas chromatography injector set at 230°C, whereas the detector temperature was set at 240°C. A sample (1 μL) of the oil specimen was introduced into the gas chromatograph injector. Nitrogen gas was also introduced at a pressure of 5.5 psi. The total retention time was 39 minutes, at which the fatty acids eluted as peaks relative to molecular weight. The peaks obtained were compared in retention time with those of the standard.

Feed composition and formulation

The composition of the feed per kilogram of diet is shown in Table 1. Cornstarch used as source of carbohydrate was ◀T1 prepared by soaking yellow maize (*Z. mays* L.) in water for 48 hours, sun-dried, and milled. The components of the diets were thoroughly mixed and made into pellets to ensure good handling by the animals. The feeds were packed into airtight polythene bags and stored at 4°C to prevent rancidity, autooxidation of the oil, and microbial contamination.[10]

Proximate analysis of the feeds

The proximate analysis of the fruit oil from the *B. sapida*- and soybean oil-based diets was determined as described for ash and organic mineral,[9] fat content and crude fiber,[11] crude protein, carbohydrate, and moisture contents.[12]

Animal grouping

The animals were completely randomized into two groups of six each as follows: Group A rats were maintained on the soybean oil-based diet (control), and Group B rats were maintained on the *B. sapida* fruit oil-based diet (test).

Prior to the commencement of the experiment, the conventional rat feed was withdrawn from the animals for

Table 1. Feed Composition of the Diets

	Composition (g/kg)	
Feed component	*Test diet*	*Control diet*
Cornstarch	516	516
Casilan 90[a]	250	250
B. sapida fruit oil	40	—
Soybean oil[b]	—	40
Sucrose	100	100
Rice husk	40	40
DL-Methionine	4	4
Lysine	10	10
Vitamin mix[c]	10	10
Mineral mix[d]	40	40

[a]Casilan 90 (g/100 g): energy (1,572 kg/100 g), protein (90 g), carbohydrate (0.3 g), fat (1.0 g), fiber (trace), sodium (0.03 mg), and calcium (1,400 mg).

[b]Polyunsaturated fatty acids (58%), monounsaturated fatty acids (29%), and saturated fatty acids (13%).

[c]Vitamin mix (per kg of diet): thiamine hydrochloride (6 mg), pyridoxine hydrochloride (7 mg), nicotine acid (30 mg), calcium pantothenate (16 mg), folic acid (2 mg), biotin (0.2 mg), cyanocobalanin (0.01 mg), retinol palmitate (4,000 IU), cholecalciferol (100 IU), α-tocopherol acetate (50 IU), menadine (0.05 mg), and choline chloride (2 g).

[d]Mineral mix (g/kg): $CoCl_2 \cdot 6H_2O$ (0.001), $CuSO_4 \cdot 5H_2O$ (0.079), $MnSO_4 \cdot 7H_2O$ (0.178), KI (0.033), NaCl (3.573), $ZnCO_3$ (1.60), $CaSO_4$ (11.61), $MgSO_4 \cdot 7H_2O$ (2.292), K_2HPO_4 (10.559), $FeSO_4 \cdot 7H_2O$ (1.075).

6 hours, but water was supplied *ad libitum*. The rats were later maintained on their respective, compounded diets for 6 weeks. The weights of the rats were recorded on weekly basis for the 6-week feeding period. This study was carried out following approval from the Ethical Committee on Animal Use and Care of the Department of Biochemistry, University of Ilorin.

Preparation of serum and tissue homogenates

The methods described by Akanji and Yakubu[13] and Yakubu *et al.*[14] was used for the preparation of serum and tissue homogenates. In brief, with the animal under ether anesthesia, the neck area was quickly shaved to expose the jugular veins. The veins after being slightly displaced (to avoid contamination with interstitial fluid) were then sharply cut with a sterile scalpel blade. Blood collected into clean and dry centrifuge tubes was allowed to clot for 30 minutes. This was then centrifuged at 33.5 *g* for 15 minutes using a Uniscope Laboratory Centrifuge (model SM800B, Surgifriend Medicals, Essex, UK). The sera were aspirated with Pasteur pipettes and stored frozen overnight at −20°C before being used for the biochemical analyses. The animals were quickly dissected, and the liver, kidney, and heart were removed, after which the tissues were blotted with clean tissue paper, weighed, and homogenized in 0.25 *M* sucrose solution (1:5 wt/vol). The homogenates were kept frozen for 24 hours before being used for the analyses.

Determination of biochemical parameters

The concentrations of the biochemical parameters were determined as described for total cholesterol,[15] LDL-C,[16] HDL-C,[17] triglycerides,[18] and atherogenic index.[19] The activities of GOT and GPT were assayed according to the methods described by Rietman and Frankel,[20] and the method described by Wright *et al.*[21] was used for the determination of ALP activity. The organ-body weight ratio was computed as described by Yakubu *et al.*[22]

Table 2. Physicochemical Properties of Soybean Oil and Fruit Oil of *B. sapida*

Physicochemical parameter	*Soybean oil*	B. sapida *fruit oil*
Smoke point (°C)	250.00 ± 5.77^a	220.00 ± 2.88^b
Flash point (°C)	270.00 ± 5.42^a	240.00 ± 2.84^b
Fire point (°C)	285.00 ± 5.35^a	265.00 ± 2.45^b
Specific gravity	0.92 ± 0.00^a	0.91 ± 0.00^a
Relative density	0.94 ± 0.00^a	0.93 ± 0.00^a
Acid value (mg/g)	0.90 ± 1.12^a	0.67 ± 0.08^b
Iodine value (mg/g)	131.07 ± 0.13^a	125.53 ± 0.00^b
Peroxide value (mEq/kg)	7.60 ± 0.00^a	0.041 ± 0.01^b
Saponification value (mg/g)	188.40 ± 2.14^a	190.27 ± 2.14^a
Ester value (mg/g)	187.46 ± 2.18^a	180.14 ± 6.26^a

Data are mean ± SEM values of three determinations.

Values for the fruit oil of *B. sapida* in the same row for each parameter with superscripts different from soybean oil are significantly different ($P < .05$).

Statistical analysis

Data are mean ± SEM of six determinations except where otherwise specified. Means were analyzed using the Duncan Multiple Range Test, complemented with Student's *t* test. Differences with values of $P < .05$ were considered statistically significant.[23] Bars shown in the figures that are significantly different ($P < .05$) between the *B. sapida* fruit oil-based diet and the soybean oil-based diet are designated by superscripts.

RESULTS

Compared with the soybean oil, the parameters of thermal stability (smoke point, flash point, and fire point) as well as peroxide, iodine, and acid values were significantly lower ($P < .05$) in the oil from *B. sapida* fruit, whereas the specific gravity, relative density, saponification, and ester values of the fruit oil compared favorably with the soybean oil (Table 2).

The fruit oil, which was pale yellow, yielded 20.02% (wt/vol) of the starting material. It also consisted of 22.22% saturated fatty acids, 56.43% monounsaturated fatty acids, and 21.35% polyunsaturated fatty acids. Analysis of fatty acid constituents of *B. sapida* fruit oil revealed the presence of palmitic, behenic, palmitoleic, oleic, gadoleic, erucic, and 9,12-eicosadienoic acids. The fruit oil from *B. sapida* is richer than soybean oil in behenic, palmitoleic, oleic, gadoleic, erucic, and 9,12-eicosadienoic acids by 15.70%, 0.89%, 7.22%, 12.05%, 8.27%, and 21.35%, respectively (Table 3).

Table 4 gives the proximate composition of the soybean oil-based (control) and *B. sapida* fruit oil-based (test) diets. The amount of crude lipid, protein, fiber, carbohydrate,

TABLE 3. PERCENTAGE FATTY ACID COMPOSITION OF SOYBEAN OIL AND FRUIT OIL OF *B. SAPIDA*

	Soybean oil (%)	B. sapida *fruit oil (%)*
Saturated fatty acid		
Myristic (14:0)	0.10	—
Palmitic (16:0)	10.30	6.52
Stearic (18:0)	3.80	—
Arachidic (20:0)	—	—
Behenic (22:0)	—	15.70
Monounsaturated fatty acid		
Palmitoleic (16:1)	5.20	6.09
Oleic (18:1)	22.80	30.02
Gadoleic (20:1)	—	12.05
Erucic (22:1)	—	8.27
Polyunsaturated fatty acid		
Linoleic (18:2)	51.00	—
Linolenic (18:3)	6.80	—
9,12-Eicosadienoic (20:2)	—	21.35
Arachidonic (20:4)	—	—

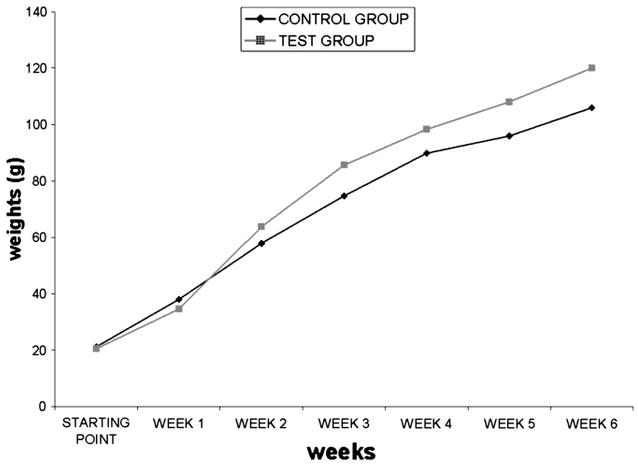

FIG. 1. Growth curve of rats placed on *B. sapida* fruit oil- and soybean oil-based diets for 6 weeks.

moisture, ash, and dry matter in the test diet compared favorably ($P > .05$) with the control diet.

Although there was consistent weight gain as revealed by the increase in the pattern of the growth curve, this, however, was not significantly different ($P > .05$) between the two formulated oil-based diets (Fig. 1).

The liver- and kidney-body weight ratios of the rats maintained on the fruit oil-based diet for 6 weeks were higher than those of the animals fed with the control diet. The heart-body weight ratio of the animals placed on *B. sapida* fruit oil-based diet compared favorably with that of animals on the soybean oil-based diet (Table 5).

Rats maintained on the fruit oil-based diet showed higher concentrations of serum total cholesterol and HDL-C than those on the soybean oil-based diet. The serum concentration of triglycerides and the computed atherogenic index of animals placed on the fruit oil-based diet were lower than those of animals on the soybean oil-based diet. However, the LDL-C concentration of animals maintained on the test diet was not significantly altered compared with that of animals on the control diet (Fig. 2).

There was no effect on the activities of ALP, GOT, and GPT from the heart of rats maintained on *B. sapida* fruit-oil based diet for 6 weeks, but the activities of ALP, GOT, and GPT of liver as well as the kidney ALP of rats maintained on the test diet decreased significantly. These reductions were accompanied by a corresponding increase in the respective serum enzymes (Figs. 3–5).

DISCUSSION

Parameters of thermal stability such as the smoke, flash, and fire points measure the effect of heating on an oil sample. The lower value for the smoke point obtained with *B. sapida* fruit oil is an indication that the fruit oil will break down more readily than soybean oil (Table 1). The flash point is the lowest temperature at which oil will form an ignitable mixture in air.[24] Therefore, the decreased flash point observed with *B. sapida* fruit oil shows that it is ignitable and will support combustion more readily than soybean oil. This was also supported by the reduced fire point of the fruit oil. All these are indications that the oil may not be used at relatively very high temperatures such as in deep frying.

TABLE 4. PROXIMATE ANALYSIS OF SOYBEAN OIL- AND *B. SAPIDA* FRUIT OIL-BASED DIETS

Proximate component	*Control feed (%)*	*Test feed (%)*
Crude lipid	19.70 ± 0.42^a	18.70 ± 0.14^a
Crude protein	22.60 ± 0.20^a	23.00 ± 0.01^a
Carbohydrate	41.80 ± 0.06^a	43.10 ± 0.45^a
Moisture	10.90 ± 0.05^a	10.70 ± 0.01^a
Crude fiber	4.60 ± 0.10^a	4.00 ± 0.06^a
Ash	5.00 ± 0.06^a	4.50 ± 0.43^a
Dry matter	89.10 ± 0.15^a	89.30 ± 063^a

Data are mean ± SEM values of three determinations.

[a]Values of the test feed are not significantly different from the control feed ($P > .05$).

TABLE 5. PERCENTAGE ORGAN TO BODY WEIGHT RATIO OF RATS MAINTAINED ON SOYBEAN OIL-AND *B. SAPIDA* FRUIT OIL-BASED DIETS FOR 6 WEEKS

	Diet based on	
Organ	*Soybean oil*	B. sapida *fruit oil*
Liver	4.50 ± 0.09^a	5.50 ± 0.19^b
Kidney	1.22 ± 0.06^a	1.53 ± 0.02^b
Heart	0.30 ± 0.07^a	0.36 ± 0.09^a

Data are mean ± SEM values of six determinations.

Values of the fruit oil of *B. sapida*-based diet in the same row for each organ with superscripts different from soybean oil-based diet are significantly different ($P < .05$).

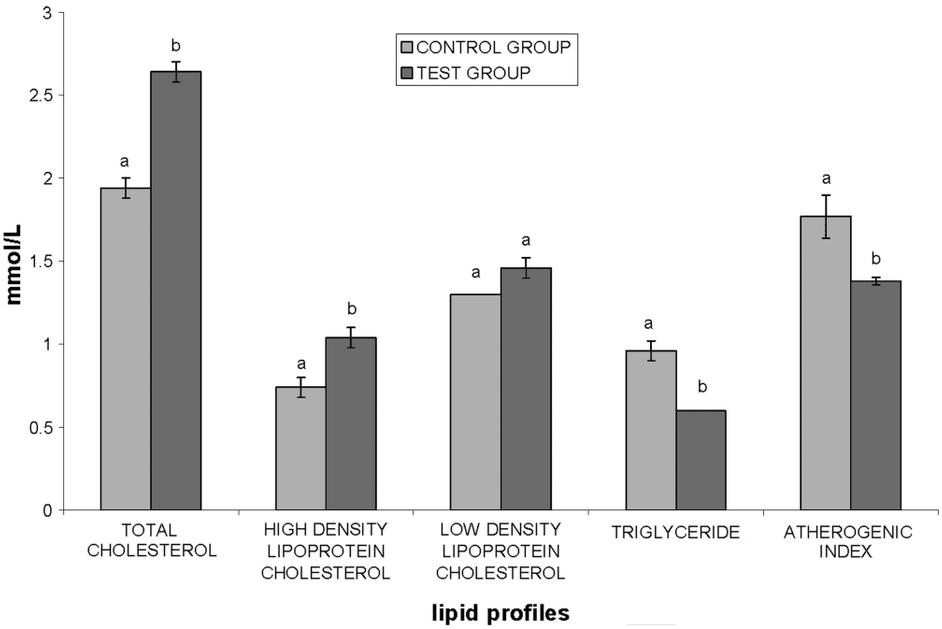

FIG. 2. Serum lipid profile (mmol/L) of rats placed on *B. sapida* fruit oil- and soybean oil-based diets for 6 weeks. Values of the fruit oil of *B. sapida*-based diet with superscripts different from soybean oil-based diet are significantly different ($P < .05$).

Relative density, which is a measure of qualitative changes in oils, decreases with increasing chain length and decreasing degree of unsaturation.[25] The absence of significant difference in the relative density of the fruit oil and soybean oil implies similarity in chain length of oils. This was further supported by the specific gravity of the fruit oil, which also compared well with soybean oil.

Acid value is an important indicator of quality, age, edibility, and suitability of an oil for use in the paint industry.[26,27] The lower acid value of the fruit oil suggests reduced susceptibility to lipase action. Although the acid value of the fruit oil is lower than that of soybean oil, it is still within the allowable limit or recommended value of 0.6 mg/g for edible vegetable oil.[28] Therefore, the fruit oil could be edible. The low acid value, which agrees with the findings of Popoola and Yangomodou,[29] who obtained 0.70 mg/g for cassava seed oil, could be of significance in the manufacture of paints and varnishes. The relatively lower iodine value in the fruit oil may be indicative of the presence of fewer unsaturated bonds and low susceptibility to oxidative rancidity.[30] This, however, was supported by the value of 77.68% unsaturated fatty acids (mono- and polyunsaturated) in the fruit oil compared with 86.80% for soybean oil. The low peroxide value for *B. sapida* fruit oil is

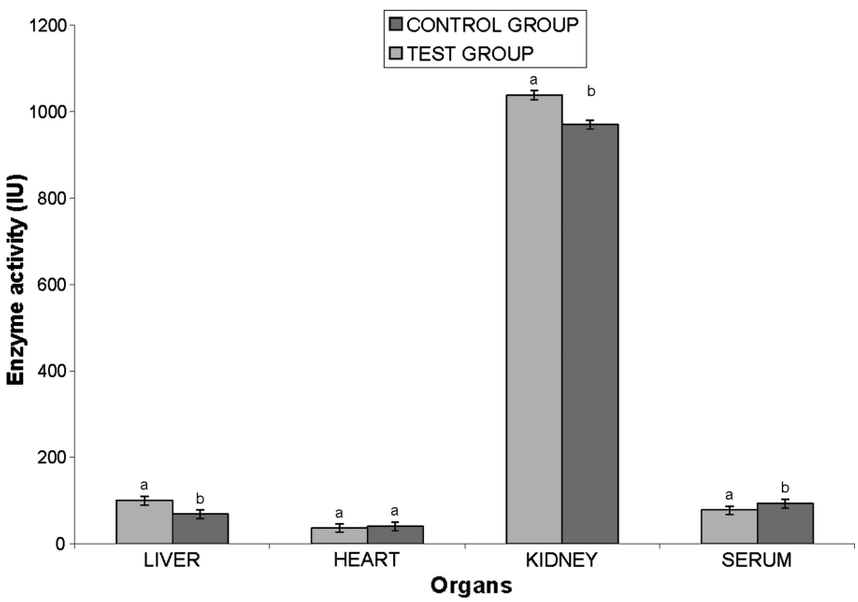

FIG. 3. ALP activity (IU) in the organs of rats placed on *B. sapida* fruit oil- and soybean oil-based diets for 6 weeks. Values of the fruit oil of *B. sapida*-based diet with superscripts different from soybean oil-based diet are significantly different ($P < .05$).

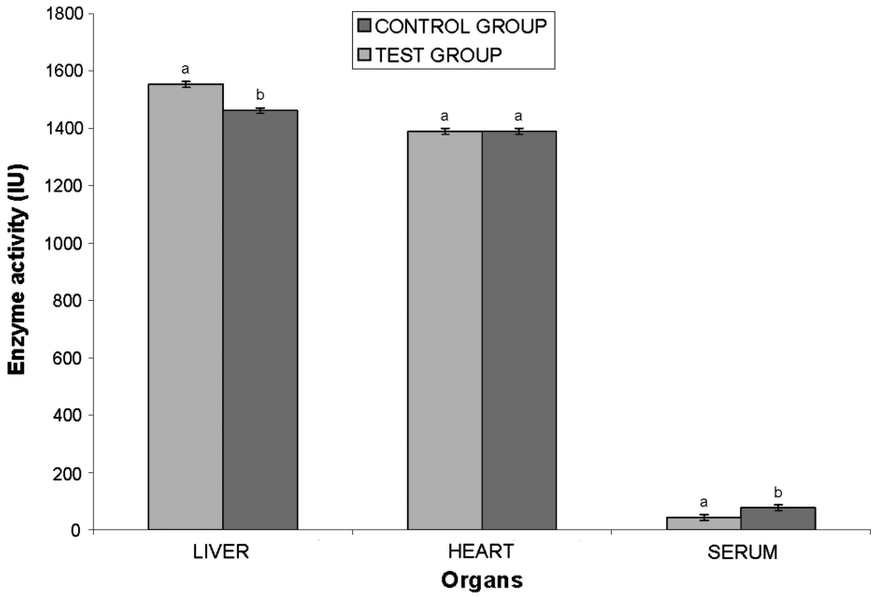

FIG. 4. GOT activity (IU) in the organs of rats placed on *B. sapida* fruit oil- and soybean oil-based diets for 6 weeks. Values of the fruit oil of *B. sapida*-based diet with superscripts different from soybean oil-based diet are significantly different ($P < .05$).

an indication that the oil can resist lipolytic hydrolysis and oxidative deterioration.[29] This may imply that it is relatively more stable than soybean oil and could be stored for a relatively longer time. The peroxide value of the fruit oil (0.041 mEq of O_2/kg) is lower than that obtained for cassava seed oil (2.5 mEq of O_2/kg) by Popoola and Yangomodou,[29] and also contrasts with commonly consumed oils such as palm, coconut, groundnut, and melon oils, which have higher peroxide values (4.0, 10.0, 18.2, and 2.0 mEq/kg of oil, respectively).[21] Therefore, the fruit oil may be explored in the manufacture of margarine. The similarity in the saponification value of the two oils is an indication that the average molecular masses of fatty acids in the oils are within the same range. The value compared well with those recorded for corn oil, cotton seed oil, and sunflower oil.[32] The similarities in the ester values of the oils imply that the amount of glycerides compared well with each other.[33]

The yield of the fruit oil (20.02%) compares well with 18–20% reported for soybean oil but is lower than that (43.00%) for groundnut.[34,35] The oil yield of the *B. sapida* fruit may thus be classified as average.

Saturated fatty acids have been implicated as increasing the risk of atherosclerosis by elevating blood cholesterol concentration.[36] However, not all the saturated fatty acids are capable of raising the cholesterol concentration of the

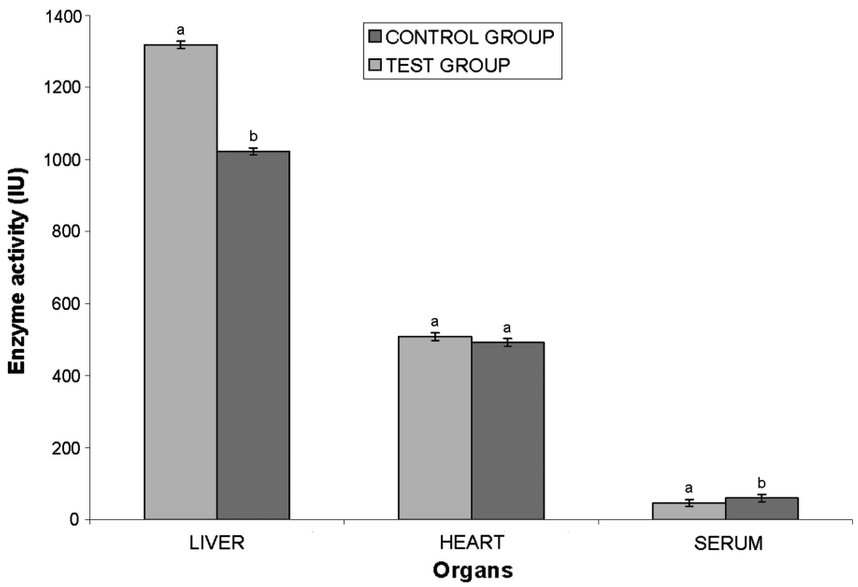

FIG. 5. GPT activity (IU) in the organs of rats placed on *B. sapida* fruit oil- and soybean oil-based diets for 6 weeks. Values of the fruit oil of *B. sapida*-based diet with superscripts different from soybean oil-based diet are significantly different ($P < .05$).

blood. Of these, it is only those of chain length 12, 14, and 16 (lauric, myrisitic, and palmitic acids) that have been shown to elevate blood cholesterol.[37] Stearic acids, on the other hand, have been shown to lower cholesterol by 21% more than oleic acid, which reduced the blood lipid level by 15%.[38] Therefore, the higher amount of saturated fatty acids in *B. sapida* fruit oil could pose a health risk when consumed as it may predispose to atherosclerosis and associated coronary heart disease. Similarly, the presence of polyunsaturated fatty acids in the fruit oil may constitute a health hazard as the carbon-carbon double bond may generate free radicals, which have been implicated as an etiological factor in organ dysfunction and a number of diseases such as cancer.[39,40] Therefore, the fruit may constitute health problems if consumed. The presence of palmitic, linolenic, and oleic acids in the fruit oil, which are important for dietary purposes, further confirms that the oil is likely to be useful in the diets.[29] The high content of oleic acid suggests the possibility of the oil from the *B. sapida* fruit being used in dietary formulations and in the manufacture of margarine.

In this study, the proximate composition of the diets formulated with the oils from soybean and *B. sapida* fruit were not different from each other. The similarity in the components of the oil diets shows that no extraneous factor was introduced during the feeding experiment.

The consistent gain in weight throughout the experimental period shown by the rats maintained on the oil-based diets could imply that the oil supports the growth of the animals.

Organ-body weight ratio may be used as an index of organ swelling, atrophy, or inflammation.[41] The absence of difference in the heart-body weight ratio of the oil-based diet is an indication that the diet did not produce any swelling or atrophy of the organ. In contrast, the increase in the liver- and kidney-body weight ratio of the rats maintained on the fruit oil-based diet may imply swelling or hypertrophy of the organs.

Alterations in the concentrations of major lipids like cholesterol, HDL-C, LDL-C, and triglycerides can give useful information on the lipid metabolism and predisposition of an animal to atherosclerosis.[42] The increase in serum cholesterol concentration in animals maintained on the *B. sapida* fruit oil-based diet could be due to enhanced β-oxidation of fatty acids, which consequently will produce more acetyl-coenzyme A, a key substrate in the biosynthesis of cholesterol.[43] In contrast, the increase in serum HDL-C concentration observed in the rats maintained on the *B. sapida* fruit oil-based diet may be beneficial to the animals as it could possibly help in the removal of cholesterol to the liver for excretion. Therefore, the increase in HDL-C content of the serum may well be appropriate for the increased total cholesterol as this may reduce the risk of coronary artery disease.[42] The reduction in the levels of triacylglycerols of rats fed the fruit oil-based diet could possibly be due to reduced lipolysis.[42] LDL-C molecules are primary carriers of plasma cholesterol, which builds up slowly to form plaque in the walls of the arteries feeding the heart and brain. The lack of effect on LDL-C by the fruit oil-based diet suggests that it is unlikely to pose a health hazard. This was further corroborated by the reduced atherogenic index, an indicator of cardiovascular disease.[19] Therefore, despite the presence of a higher amount of saturated fatty acid in the fruit oil and the alterations in serum lipids, the consumption of the oil from *B. sapida* fruit is not likely to predispose the animals to atherosclerosis.

ALP is a ''marker'' enzyme for the plasma membrane and endoplasmic reticulum.[44] It is often used to assess the integrity of the plasma membrane.[45] The decrease in the ALP activity of the liver and kidney of rats maintained on the fruit oil-based diet, which was accompanied by a corresponding increase in the serum enzyme, may be adduced to loss of membrane components (including ALP) from the tissues to the serum.[46,47] This is an indication that the ordered lipid bilayer of the membrane structure has been damaged or disrupted, leading to the escape of detectable quantity of the enzyme molecules out of the cells of the hepactocytes and nephrons into the extracellular fluid, the serum.[47] Because ALP is known to be involved in the transportation of required ions or molecules across the cell membrane, such loss of tissue enzymes may impair this transportation function.[45]

GOT and GPT are normally localized within the cells of the liver, heart, and muscles and are useful ''marker'' enzymes for assessing damage to the liver and heart.[48] These enzymes play important roles in metabolism of amino acids and provide necessary intermediates for gluconeogenesis. The decrease in liver GOT and GPT accompanied by a corresponding increase in the serum enzymes of rats maintained on the fruit oil-based diet is quite understandable because the enzymes are cytosolic in origin, and any damage to the plasma membrane will consequently lead to escape of the cytosolic enzymes.[13] Such elevation of the serum enzymes suggests organ dysfunction.[49] This will consequently affect amino acid metabolism in the liver. Because the activities of the enzymes were not altered in the rat heart by the fruit oil-based diet, it may be logical to conclude that transamination reaction was not adversely affected in this organ.

The available evidence in this study suggests that oil from *B. sapida* fruit could be explored as raw materials in the paint, varnish, margarine, soap, food, and other related industries. The consumption of the fruit oil also supported growth of the animals. Despite the high amount of saturated fatty acids in the fruit oil and the alterations in the serum lipids of the animals fed with the oil-based diet from the fruit of *B. sapida*, the oil is unlikely to predispose the animals to atherogenesis, but may labilize the plasma membrane of the hepatocytes and nephrons. It may also have a negative effect on the metabolism and regulation of amino acid in the animals. Although the oil from *B. sapida* fruit is average yielding and may be edible, it may not be completely safe for consumption.

AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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AU1: Please cite superscript a & b in table 5 & table 2 footnote.