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ORIGINAL ARTICLE

Nutraceutical Potential of *Tetracarpidium conophorum* and *Buccholzia coriacea* in Diet-induced Hyperlipidemia

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KEYWORDS

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Lipid profile;
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Marker enzymes

ABSTRACT: The nutraceutical potential of *Tetracarpidium conophorum* and *Buccholzia coriacea* in diet-induced hyperlipidemia in male Wistar rats were investigated at the Plant Science and Biotechnology department, University of Port Harcourt, Nigeria in 2016. Diet-induced type II A hyperlipidemia in rat model was achieved by oral administration of egg yolk and groundnut oil formulations for 2 wk. Rats fed with normal diet and diet formulations constituted the negative control and test control in that order for comparison. The hyperlipidemic rats were subsequently treated with normal feed supplemented with 500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$ of *T. conophorum* and *B. coriacea* for two weeks. In comparison to test control animals, administration of tried samples markedly lowered weight gain by experimental animals, total cholesterol, triglycerides, AST, ALT ALP, plasma contents of LDL, VLDL, Non-HDL and atherogenic indices in a dose- dependent fashion. Their administration also produced significantly higher ($P<0.05$) plasma HDL cholesterol levels indicating recovery. These findings underscore the nutraceutical potentials of *T. conophorum* and *B. coriacea*and suggest their possible use in management of hyperlipidemia and other related diseases.

INTRODUCTION

There has been an eruption of consumer interest in physiologically active food components commonly referred to as “functional foods” [1]. However, with an unclear mechanism, until recently, many health benefits have been connected with consistent consumption of herbs, spices vegetables, and fruits. The medicinal and therapeutic potentials of plants have long been credited to the observed bioactive compounds inherent in them [2, 3]. Aromatic and medicinal plants, by virtue of containing chemical components of therapeutic appraisal, are now widely utilized as solutions for various diseases [4]. Recently, modified derivatives and products

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from plant have been rich sources for drug formulations. More than 75% of the populace has confidence on medicinal plants for their healthcare necessities [5].

Tetracarpidium conophorum commonly known as African walnut or Nigerian walnut is said to lower the risk of heart diseases and so many scientific evidence over a decade ago has demonstrated that incorporating *T. conophorum* in a diet decreases the risk of heart diseases [6]. African walnutis domicile in the taxonomic group called Euphorbiacea in Cameroun and mostly in the southern and eastern part of Nigeria, where the consumption of this seeds is ubiquitous. It is called “UKPA” locally [7] and generally known in Nigeria as Nigerian walnuts where the plant is harvested and consumed after cooking for the nuts most importantly [8]. Abundance of alkaloids in the nuts is evident as a characteristic “bitter taste” is normally felt upon having a drink of water after consuming the seeds [7].

African walnut has been implicated in the promotion of weight loss, improvement of several physical illnesses and enhancement of overall health by several medical studies [8]. They enhance the absorption of tocopherol and provide protection against cardiovascular diseases because of the abundance of polyunsaturated fatty acids in the nuts, which are becoming extinct in our diets. *T. conophorum* [9], is widely utilized as a potent fertility herb for men.

Buccholzia coriacea, popularly known as Wonderful kola, oftentimes utilized as herb in Nigeria has lauded excellent medicinal prowess. It has been implicated to be potent in ameliorating a variety of illnesses such as syphilis, nasal congestion, sinusitis, earache, smallpox, headache, gonorrhea, and convulsion in children [10, 11]. In the eastern part of Nigeria, it is popularly known as UKE, while the Western parts of Nigeria, the Yoruba’s call it UWORO [12].

*Buchholzia coriacea*belongs to taxonomic group called Capparaceae. Their seeds are sometimes consumed to enhance memory retention that found in most countries in Africa, and utilized for myriad medicinal purposes for instance, in Gabon, commonly used to cure skin itches and treat smallpox while in Ivory Coast; the seeds are used to relieve nasal congestion, sinusitis and headache [13]. It has been implicated to be potent in ameliorating a variety of illnesses such as syphilis, nasal congestion, sinusitis, earache, smallpox, headache, gonorrhea, and convulsion in children [10]. Studies have demonstrated its antibacterial and anti-fungal potentials [14], anti-diarrhea and anti-spasmodic properties [13] and anti-diabetic potentials [15].

Hyperlipidemia is the anomalistic increase of lipids in the blood, abundantly triglycerides and cholesterol. Due to irregular elevations of lipoproteins that help in the transportation of lipids in the blood, it is also branded as hyperlipoproteinemia [16]. It is the most prevalent variety of dyslipidemia and among the critical hazard factors in the evolution and perhaps development of atherosclerosis that unavoidably leads to pancreatitis and cardiovascular diseases [17].

The relationship between coronary heart disease and arteriosclerosis with hyperlipidemia has been established by numerous clinical experiments. As a result, these disease conditions is a lipid metabolic and transport disorder. Increase in HDL cholesterol and reduction of levels of LDL cholesterol reduce overall mortality and risk associated with cardiovascular events [18]. On such grounds, for disease conditions associated with hyperlipidemia like coronary heart disease and arteriosclerosis to be controlled or perhaps avoided, reduction of cholesterol levels in the blood is sacrosanct.

Taking into consideration the possible side effects and high cost of drugs used in reducing high cholesterol levels in the blood, this study investigated the possible nutraceutical potentials of seeds of *T. conophorum* (African Walnut) and *B.*

coriacea (Wonderful kola) on hyperlipidemic male wistar rats.

MATERIALS AND METHODS

Sample collection

Fresh samples of *T. conophorum* and *B. coriacea* were obtained from a local market at Mile 1, Port Harcourt, Rivers state, Nigeria. These samples were authenticated at the Plant Science and Biotechnology department, University of Port Harcourt, Nigeria in 2016.

Preparation of plant samples

Obtained seeds of *T. conophorum* and *B. coriacea*and were freshly ground using a mechanical grinder, in other to stimulate a real eating state; milled samples (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) were vigorously mixed with appropriate amount of distilled water to enable easy absorption through oral gavages. The distilled water added to the sample served as a vehicle. *T. conophorum* was cooked for 2 h thirty minutes prior to grinding.

Experimental Animals

Forty-two normal male wistar rats weighing 150-160 gr were acquired from the Faculty of Science's animal house, Department of Animal and Environmental Biology, University of Port Harcourt. Six equal groups were created from these animals and were put in separate cages for the minimization of fallacies and allowed to acclimatize for two weeks. They were maintained on a commercial mash (growers feed) and water *ad libitum* throughout the experiment.

Induction of hyperlipidemia

Hyperlipidemia was induced by the technique [19], with little amendment. The animals were maintained on growers feed complemented with the formulation (egg yolk and groundnut oil) at 2% and 1%, respectively for 14 d. To confirm the induction of hyperlipidemia, 24 h after feeding, three experimental animals were painlessly sacrificed from each group and blood sample collected and assayed for TC, TG, and LDL. TC, TG and LDL levels above borderline of (200-239), (150-199) and (130-159) $mgdL^{-1}$, respectively were considered hyperlipidemia.

Experimental design

Group 1 received normal feed and water throughout the experiment and served as the control.

Group 2 received normal feed and the formulation throughout the experiment and served as the Sham.

Group 3 received normal feed and the formulation for two weeks and subsequently normal feed and 500 $mgkg^{-1}$ of *B. coriacea*.

Group 4 received normal feed and the formulation for two weeks and subsequently normal feed and 1000 $mgkg^{-1}$ of *B. coriacea*.

Group 5 received normal feed and the formulation for two weeks, subsequently normal feed, and 500 $mgkg^{-1}$ of *T. conophorum*.

Group 6 received normal feed and the formulation for two weeks, subsequently normal feed, and 1000 $mgkg^{-1}$ of *T. conophorum*.

Diet preparation for induction and treatment of hyperlipidemia

The feeding study lasted for 28 d (4 wk). The body weight after seven days of acclimatization was documented as the initial body weight for the feeding experiment. Rats were allocated into eight groups of four rats each caged with standardization of the environmental conditions for the minimization of fallacies with adequate food and water provided. Group 1 (Negative control) received growers feed and water *ad libitum* only.

The animals in group II (Test control) received growers feed complemented with egg yolk and groundnut oil formulations at (2% and 1%), respectively all through the study. The other six test groups (2 concentrations of 500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$ subgroup of tried samples) received growers feed complemented with egg yolk and groundnut oil formulations at (2% and 1%), respectively for a fortnight to induce hyperlipidemia. Afterward received only the grower's feed and 2 ml each of the sample (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) through oral gavages for the remaining two weeks of treatment. The body weights of the animals were documented three times; one week after acclimatization, two weeks after the induction of hyperlipidemia and four weeks after the treatment for the four-week period.

Collection and preparation of blood samples

The experimental animals were sacrificed twice, after 14 d, for the confirmation of hyperlipidemic condition and subsequently after two weeks of treatment. Their respective blood samples were preserved in an anti-coagulant bottle prior to analysis in the laboratory.

Determination of biochemical indices

The tissue activities of AST, ALT, ALP TG, HDL and Total Cholesterol were determined enzymatically using Randox Kits. All samples were analysed in triplicates.

Estimation of LDL cholesterol and VLDL cholesterol [20]

Plasma levels of LDL cholesterol and VLDL cholesterol were estimated mathematically using the Friedewald equation as follows:

LDL = [TC]-[HDL]-([TG])/2.2

VLDL=Triglyceride/2.2

Estimation of Non-HDL cholesterol [21]

The plasma level of non-HDL cholesterol was calculated using the method [21] as follows:

Non-HDL cholesterol = [TC] – [HDL]

Where TC = Total cholesterol

HDL = High density lipoprotein

Estimation of Atherogenic indices [22]

Atherogenic indices were estimated using the formula [22] as follows:

Cardiac Risk Ratio = ([Total cholesterol]) / ([HDL cholesterol])

Atherogenic Coefficient = ([Total cholesterol]-[HDL cholesterol]) / ([HDL cholesterol])

Atherogenic index of plasma=log ([Triglyceride]) / ([HDL cholesterol])

STATISTICAL ANALYSIS

SPSS Software 20 (Chicago, IL, USA) was used for statistical analysis of obtained triplicate data. Mean values ± SD were calculated and One-Way ANOVA test was performed. Significance level was calculated at 95% confidence level (P<0.05).

RESULTS

Totally, 42 matured male albino rats of wistar strain were used for present study that lasted for four weeks. The hyperlipidemic conditions of the experimental animals are demonstrated in (Figure 1). Conspicuous differences were observed in the weight differences of the experimental animals as shown in (Table 1). Statistical analysis disclosed significant elevations of lipid profile markers (Table 2), atherogenic indices (Table 3) as well as tissue activities of serum hepatospecific markers (Table 4) in the test control group with concomitant complete and reversal upon administration of tried samples. As demonstrated in (Figures 2-6) most significant amelioration was observed in groups fed with (1000 $mgkg^{-1}$) of *B. coriacea.*

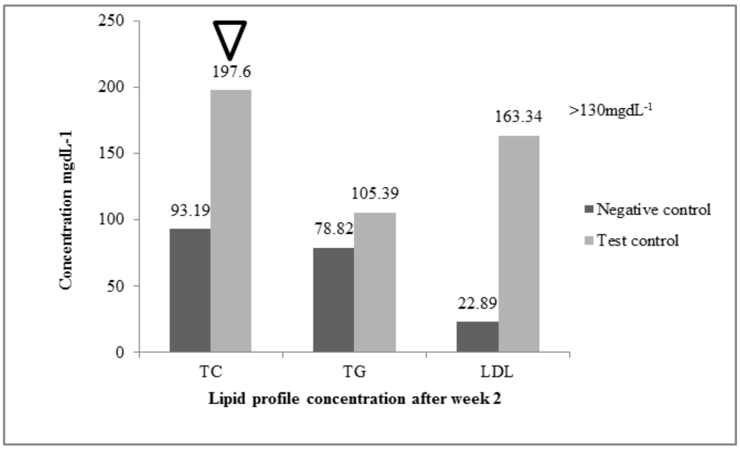

Figure 1. Hyperlipidemic conditions in Wistar rats. TC=Total Cholesterol; TG=Triglycerides; LDL=Low density Lipoprotein

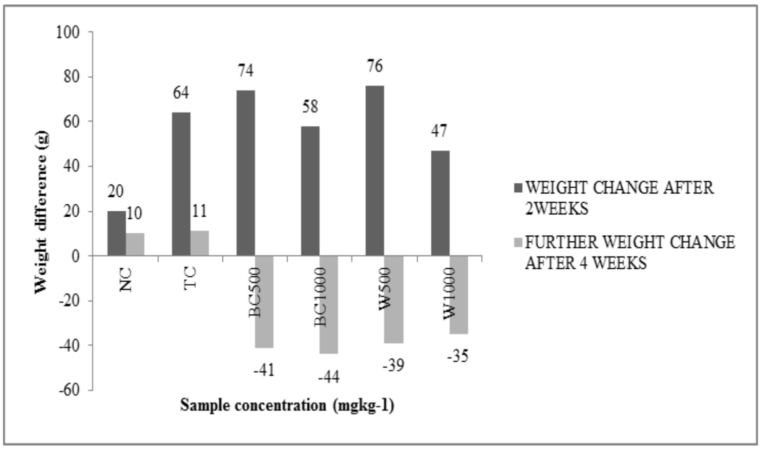

Figure 2. Performance of studied samples on the weight difference of Wistar rats BC=*B. coriacea*, W=*T. conophorum*

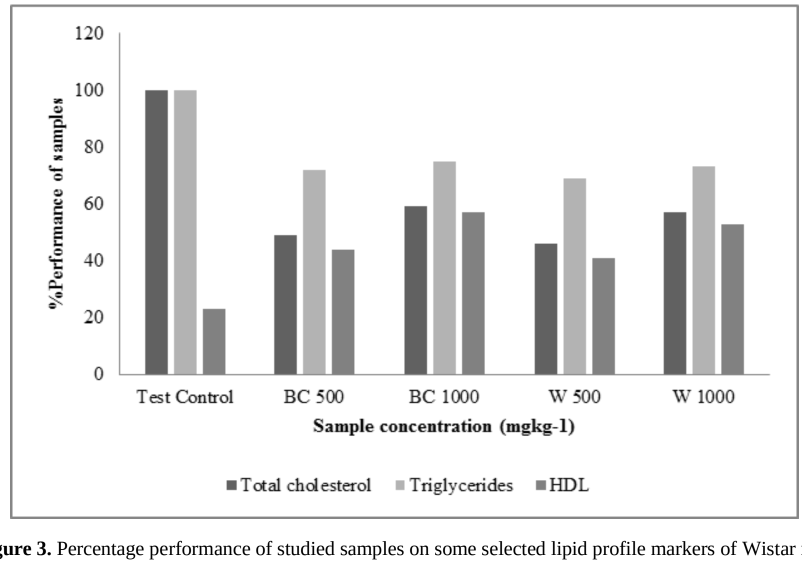

Figure 3. Percentage performance of studied samples on some selected lipid profile markers of Wistar rats. BC=*B. coriacea*, W=*T. conophorum*, HDL=High density lipoprotein cholesterol

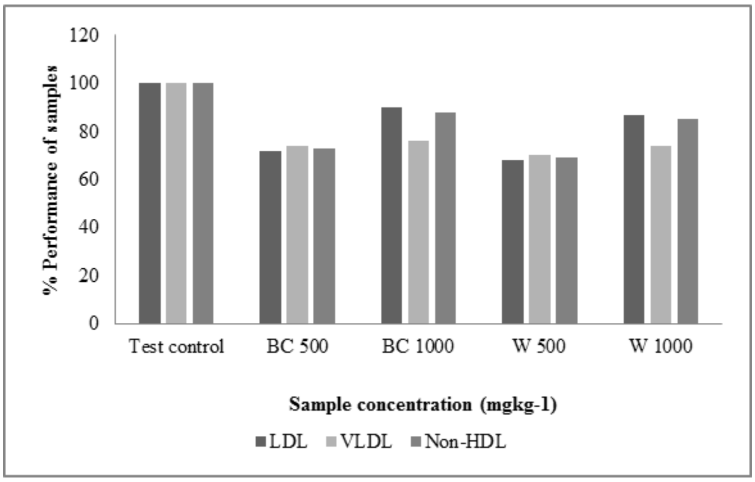

Figure 4. Percentage performance of studied samples on some selected lipid profile markers of Wistar rats. BC=*B. coriacea*, W=*T. conophorum.*

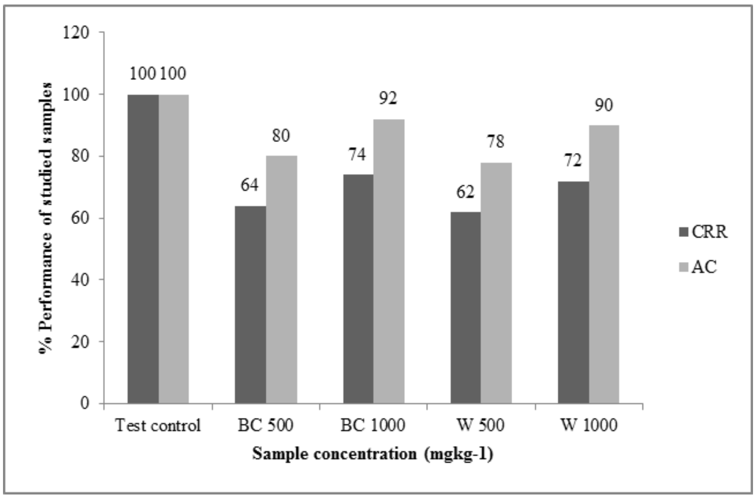

Figure 5. Percentage Performance of studied samples on some selected Atherogenic indices of Wistar rats. BC=*B. coriacea*, W=*T. conophorum*, CRR=cardiac risk ratio, AC=atherogenic coefficient.

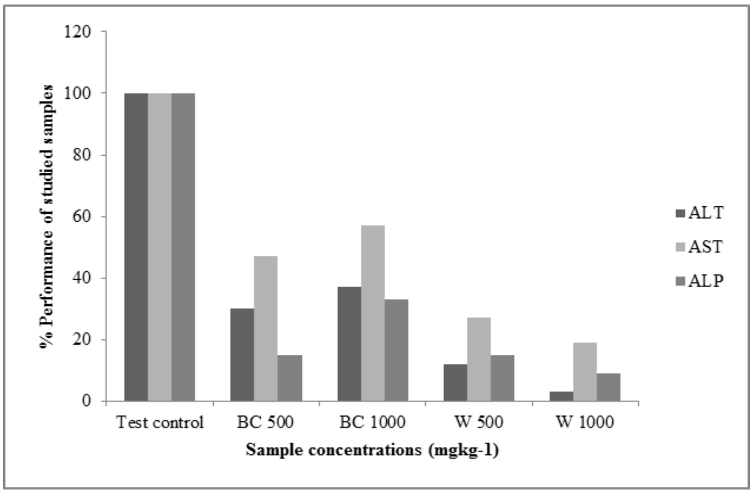

Figure 6. Percentage Performance of studied samples on hepatospecific markers of wistar rats, BC=*B. coriacea*, W=*T. conophorum*.

Table 1. Initial and final body weights (g) of rats fed formulations and ground samples of *T. conophorum* and *B. coriacea*

Diet groups	Initial weight	After 2 weeks	After 4 weeks
Negative control	151.3±1.52	171.3±4.16	181.6±10.21
Test control	161.6±1.52	225.6±12.89	236.0±15.09
500 mg BC	155.0±1.03	229.6±26.27	188.6±23.18
1000 mg BC	159.1±1.00	217.3±21.82	173.6±23.54
500 mg W	155.3±1.15	231.0±50.58	192.6±41.58
1000 mg W	159.3±0.57	206.0±14.10	171.3±16.28

Values are means ±SD of three determinations, BC = *B. coriacea;* W = *T. conophorum*

Table 2. Plasma lipid profiles ($mmolL^{-1}$) of rats fed formulations and ground samples of *T. conophorum* and *B. coriacea*

Diet group	TC	TG	HDL	LDL	VLDL	Non-HDL
Negative control	$2.41±0.03^{a}$	$0.89±0.02^{a}$	$1.32±0.01^{a}$	$0.68±0.05^{a}$	0.40±0.00	$1.08±0.04^{a}$
Test control	$5.11±0.07^{a,b}$	$1.19±0.04^{a,b}$	$1.02±0.01^{a,b}$	$3.5±0.07^{a,b}$	$0.54±0.01^{b}$	$4.09±0.06^{a,b}$
500mg BC	$2.59±0.24^{b}$	$0.33±0.02^{b}$	$1.47±0.01^{b}$	$0.97±0.25^{b}$	$0.14±0.00^{b}$	$1.12±0.25^{b}$
1000mg BC	$2.09±0.05^{b}$	$0.29±0.01^{b}$	$1.60±0.02^{b}$	$0.35±0.08^{b}$	$0.13±0.01^{b}$	$0.48±0.07^{b}$
500mg W	$2.71±0.19^{b}$	$0.36±0.02^{b}$	$1.44±0.04^{b}$	$1.11±0.20^{b}$	$0.16±0.01^{b}$	$1.27±0.21^{b}$
1000mg W	$2.17±0.05^{b}$	$0.32±0.01^{b}$	$1.56±0.02^{b}$	$0.46±0.06^{b}$	$0.14±0.00^{b}$	$0.61±0.06^{b}$

BC=*B. coriacea*, W = *T. conophorum*. Data are Mean ± SD of three determinations. Values found in a column and bearing common superscript letters (a, b) are significantly different. Superscript A (a) denotes significant difference when the negative control group are compared with the test control group. Superscript B (b) denotes significant difference when the test control group is compared with the hyperlipidemic treated groups. Values without superscripts indicate no difference significantly when compared to the control and hyperlipidemic treated group.

Table 3. Atherogenic indices of rats fed formulations and ground samples of *T. conophorum* and *B. coriacea*

Diet group	Cardiac risk ratio	Atherogenic coefficient	Atherogenic index of plasma
Negative control	$1.81±0.04^{a}$	$0.81±0.04^{a}$	-0.16±0.00
Test control	$4.96±0.06^{a,b}$	$3.96±0.06^{a,b}$	$0.05±0.00^{b}$
500mg BC	$1.75±0.06^{b}$	$0.77±0.15^{b}$	$-0.64±0.03^{b}$
1000mg BC	$1.29±0.05^{b}$	$0.29±0.05^{b}$	$-0.73±0.01^{b}$
500mg W	$1.87±0.16^{b}$	$0.87±0.16^{b}$	$-0.59±0.02^{b}$
1000mg W	$1.38±0.04^{b}$	$0.38±0.04^{b}$	$-0.67±0.01^{b}$

BC = *B. coriacea*, W = *T. conophorum*. Data are Mean ± SD of three determinations. Values found in a column and bearing common superscript letters (a, b) are significantly different. Superscript A (a) denotes significant difference when the negative control group is compared with the test control group. Superscript B (b) denotes significant difference when the test control group is compared with the hyperlipidemic treated groups. Values without superscripts indicate no difference significantly when compared to the control and hyperlipidemic treated group

Table 4. Plasma hepatospecific markers of rats fed formulations and ground samples of *T. conophorum* and *B. coriacea*

Diet group	ALT (μmol/L)	AST (μmol/L)	ALP (μmol/L)
Negative control	$56.46±2.31^{a}$	$16.05±2.04^{a}$	$38.76±1.20^{a}$
Test control	$92.40±2.52^{a,b}$	$50.50±3.59^{a,b}$	$109.90±95.23^{a,b}$
500mg BC	64.53±2.34	26.60±1.60	93.04±0.42
1000mg BC	$58.10±1.35^{b}$	$21.33±1.60^{b}$	$72.99±2.32^{b}$
500mg W	80.83±8.62	36.40±2.83	93.23±3.15
1000mg W	89.62±1.84	40.70±2.45	98.96±2.15

BC=*B. coriacea*, W=*T. conophorum*. Data are Mean ± SD of three determinations. Values found in a column and bearing common superscript letters (a, b) are significantly different. Superscript A (a) denotes significant difference when the negative control group is compared with the test control group. Superscript B (b) denotes significant difference when the test control group is compared with the hyperlipidemic treated groups. Values without superscripts indicate no significant difference when compared to the control and hyperlipidemic treated group.

DISCUSSION

The ubiquity of cardiovascular disease associated deaths in the world has unavoidably escalated and one of the major contributors of these diseases is high blood pressure. The clinical penalties of these health conditions are terrible and generate research efforts to provide a novel approach for its treatment and management. Although one study has established the hypocholesterolemic potential of ethanolic extract of seeds of *B. coriacea* in experimental animal, there is no mention in the literature on the effect of incorporating ground samples of the seed in diet as in this study in animal experimentation. This is the pioneer examination of the anti-hyperlipidemic potentials of *T. conophorum*.

The normal levels of total cholesterol, triglycerides, and low-density lipoprotein cholesterol in mgdL^{-1} is <200, <150, and <130, respectively and individual with levels above the borderline level of 200-239 for total cholesterol, 150-199 for triglycerides and 130-159 for low-density lipoprotein are considered hyperlipidemic [23]. From this study, the levels of low-density lipoprotein were above the borderline level of 130-159 and elevation of only LDL levels above the normal and borderline range is an indication of type II A hyperlipidemia [24] (Figure 1). On such grounds, the adjustment of the method (2.1.4) [19] was a success as we were able to achieve type II A hyperlipidemia in two weeks with 2% egg yolk and 1% groundnut oil formulation.

Prior to initiating the experiment, the animals were weighed to obtain the initial weight and subsequently after two weeks of induction of hyperlipidemia and finally after four weeks of proposed treatment as demonstrated in (Table 1). The weights were obtained using a manual weighing balance. As envisaged there was a significant increase in body weight of the animals after two weeks of feeding with high-fat diet (Figure 2) not be unconnected with elevated level of lipid sediments in the adipose tissue of the experimental animals. Weight gain is one of the characteristics of hyperlipidemia as evidenced (Figure 2). Weight loss is among the adopted strategies of improving dyslipidemia and risk of coronary heart diseases [25]. It is also among the tactics for enhancing low levels of HDL cholesterol in the body [23, 26]. In the present study, substitution of cholesterol and groundnut oil supplemented diet with normal diet and different concentrations (500mgkg^{-1} and 1000mgkg^{-1}) of the ground seeds of *T. conophorum* and *B. coriacea* significantly reduced the weight gained by the experimental animals after 2 weeks (Figure 2). This may not be unconnected to the diuretic potentials produced by saponins inherent in the seeds of *B. coriacea* [27] and *T. conophorum* [7]. More reduction that is significant was observed in the groups fed with 1000 mgkg^{-1}*B. coriacea* than the groups fed with 500 mgkg^{-1} of the sample while the groups fed with 500 mgkg^{-1} of *T. conophorum* had a better reduction that the group fed with 1000 mgkg^{-1} *T. conophorum*. Overall, the group fed with 1000 mgkg^{-1} of *B. coriacea* had the demonstrated highest weight reduction capacity (Figure 2) when you juxtapose both treatment groups. This supports the use of these seeds in the control of dyslipidemia and diabetes and to an extent, the diminution of cardiovascular risk. The decreased weight gain signify that incorporating the seeds of *T. conophorum* and *B. coriacea* in our normal diet can be used to manage weight gain by obese patients hence corroborating previous reports of the use of some plant supplements and low cholesterol diet for diet weight control [28, 29].

Many clinical trials repeatedly report an increased possibility of death from cardiovascular disease with an elevated concentration of total cholesterol (200 mgdL^{-1} and above) in the blood. From this experimental study, when hyperlipidemia condition was confirmed (Figure 1), total cholesterol levels significantly increased after two weeks of administration of cholesterol and groundnut oil supplemented diet and was marginally below bar (197 $mgdL^{-1}$). Nevertheless, substitution of the cholesterol and groundnut oil supplemented diet with normal diet and different concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* and *T. conophorum* significantly reduced total cholesterol levels by (49% and 59%), respectively for *B. coriacea* and (46% and 57%), respectively for *T. conophorum* (Figure 3) and compared favorably with that fed normal diet. This advocates that the consumption of seeds of *B. coriacea, T. conophorum* and *P. excelsia* may have affected *in vivo* biosynthesis of cholesterol which led to the decrease of cholesterol concentration in the blood of the experimental animals. The values for the respectively treated groups (Table 2) at the fourth week were significantly different and lower from those of the test control. The results of this present finding are in consonance with another work [30] that reported the seeds of *B. coriacea* possess potent anti-hypercholesterolemia agent.

High plasma triglyceride levels (Table 2) has been implicated as a synergistic and as well as an independent marker for predicting cardiovascular diseases [31-33]. The level of triglyceride significantly increased after two weeks of feeding with cholesterol and groundnut oil supplemented diet (Figure 1). However, in this study, replacement of the cholesterol and groundnut oil supplemented diet with normal diet and different concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* and *T. conophorum* for two weeks markedly decreased triglyceride levels by (72% and 75%), respectively for groups feed with *B. coriacea* and (69% and 73%) correspondingly for *T. conophorum* feed groups (Figure 3). Notably, the decrease was concentration dependent for all the tried samples. This observation is in affirmative of the view that complete elimination or perhaps reduced consumption of cholesterol from diet will result in a natural reduction in cholesterol and triglyceride levels [34].

Reduced plasma concentration of HDL cholesterol is a hazard factor associated with cardiovascular diseases [33, 35 and 36]. Notwithstanding, elevation of plasma HDL cholesterol reduces the risk cardiovascular diseases [26, 35]. Elevated plasma concentration of HDL cholesterol exert a defensive potential by promoting reverse cholesterol transport by foraging surplus cholesterol from other tissues, and subsequently esterifying them to the steroidogenic organs and hepatocytes for the synthesis of lipoproteins, bile acids and ultimate elimination from the body [26, 37]. It also exerts is protective effect by preventing LDL cholesterol from oxidation because of its anti-oxidant [26] and anti-inflammatory properties [37].

The level of HDL concentration decreased significantly (Table 2) by (23%) after 4 weeks of feeding with cholesterol and groundnut oil supplemented diet (Figure 3) in the test control group. However, in this study, replacement of the cholesterol and groundnut oil supplemented diet with normal diet and different concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *T. conophorum* and *B. coriacea* for two weeks markedly elevated HDL levels by (44% and 54%), respectively in the groups fed with *B. coriacea* and (41 and 53 %) correspondingly in the *T. conophorum* fed group (Figure 3) indicating recovery. For that reason, the elevated levels of HDL cholesterol in the plasma recorded for the treated groups (Table 2) in this study is a likely indication of the cardioprotective potentials of the different concentrations of *B. coriacea*and *T. conophorum*. Most significant improvement was seen in the groups fed with 1000 $mgkg^{-1}$ of *B. coriacea* and *T. conophorum*.

The levels of low-density lipoprotein increased above the borderline levels (Figure 1), indicating the presence of type II A hyperlipidemia [24]. This disease condition is sporadic and is among the tremendous hazard factors causing the ubiquity of coronary heart diseases [38], about 45%-73% of death has been attributed to it annually in Nigeria [38]. Elevated concentrations of LDL cholesterol and VLDL cholesterol in the plasma is a risk marker associated with the ubiquity of cardiovascular disease [39]. On the other hand, a reduced level of LDL cholesterol and VLDL cholesterol in the plasma reduces the risk of cardiovascular diseases [40]. In this study, substitution of the cholesterol and groundnut oil supplemented diet with normal diet and different concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* and *T. conophorum* markedly reduced LDL cholesterol levels by (72% and 90%), respectively for *B. coriacea* fed groups and (68% and 87%), respectively for the groups fed with *T. conophorum* (Figure 4) indicating a total recovery from type II A hyperlipidemia induced in the experimental animals. In a similar fashion, after administration of different concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* and *T. conophorum* for two weeks, the levels of VLDL cholesterol were also reduced markedly by (74% and 76%) for *B. coriacea* fed groups and (70% and 74%) for the groups fed with *T. conophorum* (Figure 4) demonstrating the possible cardio-protective potentials of the tried samples at those concentrations.

Furthermore, non-HDL cholesterol is a more reliable marker for predicting risks associated with cardiovascular disease than is LDL cholesterol [41, 42]. Administration of both concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* and *T. conophorum* for 2 wk dose-dependently reduced the non-HDL cholesterol levels by (73% and 88%) respectively for the groups fed with *B. coriacea* and (69% and 85%) for the *T. conophorum* fed groups (Figure 4). Therefore, the markedly decreased plasma non-HDL cholesterol (Table 2) experienced in the experimental animals indicates the capacity of the ground samples of *B. coriacea* and *T. conophorum* to reduce cardiovascular risk when incorporated in our diets. Remarkably, 1000 $mgkg^{-1}$ of *B. coriacea* was most effective in ameliorating the diet-induced type II A hyperlipidemia followed by 1000 $mgkg^{-1}$ of *T. conophorum* respectively.

Atherogenic indices are influential markers of risk associated with heart disease: the bigger the value, the higher the possibility of developing coronary heart disease and so on [43, 44]. High levels (0.24 and above) of atherogenic index of plasma was associated with high cardiovascular disease risk [45]. This study showed that replacement of the cholesterol and groundnut oil supplemented diet with normal diet and both concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* and *T. conophorum* for two weeks markedly reduced cardiac risk ratio by (64% and 74%) for groups fed with *B. coriacea*and (62% and 72%) for *T. conophorum* fed groups and atherogenic coefficient by (80% and 92%) for *B. coriacea* treated group and (78 and 90 %) for the group treated with *T. conophorum* (Figure 5) respectively. This finding suggests the anti-atherogenic potentials of the tried samples and hence reducing the progression of atherosclerosis and coronary heart diseases [46].

Furthermore, the present study provides us information about the serum enzymes, which are basic indicators of liver function; it will be helpful to devise some strategies to protect the liver before they are fully or irreversibly damaged. The liver is a vital organ in the body as it is the site of detoxification and removal of lethal materials [47]. Therefore, many disease conditions are injurious to the liver of which hyperlipidemia is amongst them; now and then, fatty infiltration of the liver occurs which leads to non-alcoholic fatty liver, a known disease condition [48]. Fatty liver is an elevation of fats and triglycerides in the hepatocytes, if not managed, results in severe inflammation of the hepatocyte [49]. It is described by unstable levels of liver injury from fibrosis to necrosis, steatosis, and hepatitis. In this study, the resultant significant elevations in the levels of AST, ALP and ALT (Table 4) in the test control when compared to the negative control may not be unconnected to injuries imposed to the liver traceable to the buildup of fats notable triglycerides in the hepatocytes and these report corroborate with other findings [50]. The activities of the hepatic enzymes AST and ALT in the tissue is widely used as an indicator for assessing the integrity and function of the liver and heart [51, 52]. They are known to reorganize proteins' building blocks. Damaged cells of the liver release them [53, 54]. Increased concentrations of these enzymes in the blood are suggestive of a potential possibility for cardiovascular disease, tissue necrosis and cellular damage [55].

However, in this study, substitution of the cholesterol and groundnut oil supplemented diet with normal diet and both concentrations (500 $mgkg^{-1}$ and 1000 $mgkg^{-1}$) of the ground samples of *B. coriacea* markedly reduced ALT levels by (30 and 37%) and AST levels (47% and 57%) in a dose-dependent fashion respectively (Figure 6). Particularly, 1000 $mgkg^{-1}$ of *B. coriacea* had the most effective and statistically significant (Table 4) ameliorative effect.

This finding is in consonance with the globally acknowledged perspective that serum concentration of transaminases revert to normalcy when the hepatocytes are regenerated and the hepatic parenchyma healed [56]. Consequently, this is a clear manifestation of hepatoprotective benefits of incorporating the seeds of *B. coriacea* in diets.

Serum ALP in rats treated with 1000 $mgkg^{-1}$ of *B. coriacea* decreased significantly (Table 4) by (33%) compared to the control animals while the groups treated with 500 $mgkg^{-1}$ of *B. coriacea* decreased insignificantly by (15%) (Figure 6). The level of ALP in the serum is measured to ascertain plasma membrane's integrity [57] and endoplasmic reticulum [58, 59]. An elevated concentration of ALP function in the serum is noticed usually in damage of the liver, cancer, and infections of the heart [60].

On the contrary, consistent partial restoration of the elevated marker enzymes was observed in the groups treated with *T. conophorum* at all concentrations (Table 4) and they reluctantly reduced ALT levels by (12% and 13%), AST levels by (27% and 19%) and ALP levels by (15% and 19%) (Figure 6), respectively.

CONCLUSIONS

Type II A hyperlipidemia achieved in this study with egg yolk and groundnut oil formulations caused definite alteration in the liver enzyme, atherogenic indices and lipid profile parameters of the Wistar rats. Treatment with *T. conophorum* demonstrated recovery in all the parameters but the liver enzymes, which is an indication of possible hepatotoxicity and suggests possible varied toxicity on consumption. Whereas, treatment with *B. coriacea* revealed a significant recovery in all the parameters monitored which suggests that the effects induced by the high-fat diet were temporary and reversible hence no permanent damage occurred.

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