EFFECT OF *COLA PACHYCARPA* AND *COLA LEPIDOTA* FRUIT JUICES ON BODY WEIGHT AND LIPID PROFILE (CHOL, TAG, HDL, LDL) OF ALLOXAN INDUCED DIABETIC RATS

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Abstract
The plant Cola pachycarpa and Cola lepidota have been identified as some of the underutilized but important fruit trees of South Eastern Nigerian agro ecological zones. These fruits are used by locals for nutritional and medicinal purposes though much research efforts have not been extended to this plant. The study evaluated the effect of Cola pachycarpa and Cola lepidota fruit juices on the food intake, body weight and lipid profile (total cholesterol, high density lipoprotein, low density lipoprotein & triglycerides) of alloxan- induced diabetic rats. Fresh Cola pachycarpa and Cola lepidota fruits were obtained from local markets and home farms within communities in Isiala Mbano local government area of Imo State and Isiala Ngwa South local government area of Abia State. The fruits were processed into fruit juice using an electric juicer. Forty healthy adult albino male rats without any drug treatment were randomized into eight groups based on body weight. All the rats in each group were induced with alloxan to become diabetic. Samples of blood were collected for basal biochemical and lipid indices as well as after induction with diabetes. The weight of each rat was taken at the beginning of the experiment, during and after to determine the weight gain. The experiment lasted for 21days. Data was analyzed statistically using IBM-SPSS (Special Package for Social Sciences) version 20 software for means and standard deviation. The body weight and food intake of all treated rats improved (5.14% to 10.76%). Monkey Cola fruit juices significantly ($p < 0.05$) increased high density lipoproteins (198.98%, CPR1). Cholesterol values throughout the experimental period showed a very high significant ($p < 0.05$) decrease in all groups treated with Cola juices and standard drug, except for the untreated, NT which recorded elevated cholesterol levels. Although the group treated with standard drug had the highest percentage reduction in LDL value (-74.05%), all other treatment groups had statistically significant ($p <0.05$) similar percentage reduction in LDL values. All the Cola juices especially those administered at 10mls/kg body weight have demonstrated positive impact in improving body weight and lipid profile in diabetes control. Its use and efficacy in enhancing lipid profile in diabetes management demands further research work.

Keywords: *Cola pachycarpa*, *Cola lepidota*, fruit juices, body weight, alloxan-induced, diabetic rats, lipid profile.

Introduction

Researchers have demonstrated increasing interest in these lesser known fruits as a result of their nutrient and medical properties (Li, Zhang, Wang, Gregg &Yang, 2008). Monkey Cola (also known as 'achicha', 'Orji Enwe' in Igbo, Ndiyah' in Efik /Ibibio, 'Obi Edun' in Yoruba and 'Goron birri' in Hausa) belongs to the undomesticated fruits in Nigeria. There are different types within the same species which is due to little genetic differences in shape, size, colour and texture (smooth, rough, hairy)) as well as fruit taste. This plant is found in West Central tropical Africa and Nigeria. Ene-Obong, Okudu and Asumugha, (2016) noted that the fruit appears to be one of those abandoned and much work has not been done on their nutritional and useful properties. Though enough knowledge and investigation is lacking, analysis of phytochemical and nutrient content of *Cola pachycarpa* and *Cola lepidota* show that calcium, potassium, B-carotene and flavonoids were the most abundant (Ene-Obong *et al*., 2016; Essien, Peter & Akpan, 2015; Udousoro & Essien, 2017 and Ngoka, 2020). Monkey Cola falls within the group of plants that have been used by local people since long periods to treat diseases. Ngoka, Chikwendu and Maduforo, $(2021)_a$ noted that its fruits are used with the leaves and seeds in traditional medicine. Monkey Cola varieties were among some therapeutic local plants in Nigeria evaluated by Engel, Oppermann, Falodun and Kragyl, (2011) who concluded that these plants studied may demonstrate some relationship with the claims of the local people in using them in traditional medicine. Their medical properties are attributed to their ability to offer protection against the hazardous effects of free radicals on humans (Egea, Sanchez-Bel, Romojaro & Pretel, 2010). A study by Ngoka, Chikwendu and Maduforo, $(2021)_b$ on Cola (*pachycarpa* and *lepidota*) fruit juices demonstrated their ability to

decrease blood glucose level, alkaline phosphatase, aspartate transaminase and effect increase in total protein in diabetic animals. They suggested further research to ascertain its biological accessibility in well designed studies using humans.

Diabetes is a chronic disease that portends public health problem in Nigeria (Onyechi, Ibeanu, Maduforo, Ugwuonah & Nsofor, 2018). Aetiology of diabetes mellitus is characteristic of automatic damage of the pancreatic cells, with resultant reduction in production of insulin and problems which are initiated by the poor effect of insulin on the tissues. This in turn leads to defects in the metabolism of protein, fat and carbohydrates **(**Amuzat, Gomina, Adisa, Sulaiman, Mohammed, Yusuf, Ndatsu & Ntemere, 2021)**.** Some of the harmful reactions include those involving alteration of sugar molecules by binding to proteins and lipids with resultant formation of aglycones and free radicals some of which are referred to as advanced glycosylation end-products (AGEs) (Saravanan & Pari, 2008). Continual decline of the endocrine system aggravates the existing metabolic imbalances which results in hyperglycemia and release of free radicals which in turn causes membrane lipid peroxidation and degradation (Moussa, 2008; Anyinla, Dada, Shittu, Olayaki, Akiode & Ojulari, 2011). The mode of these medical processes is not yet fully understood but much harm is done to the nervous system due to unabated hyperglycemia and resultant death of body cells. Currently, diabetes mellitus does not have any known cure but could be managed with drugs and diet (Etuk, 2010).

People plagued with diabetes mellitus may also be in danger of suffering from such diseases as hypertension, heart, arterial, atherosclerotic and cerebrovascular disease (Etuk, 2010). Infectious and inflammatory diseases, chronic or acute conditions as well as genetics are also linked with modification in lipid profile (Moussa, 2008). Sometimes if the body has a severe deficiency of insulin fatty acids begin to be degraded leading to multiplication of ketones known as diabetic ketoacidosis. There could be vulnerability to certain diseases and impaired growth due to unusually raised glucose levels in the blood (Onyechi *et al*., 2018).

Cholesterol is necessary to produce hormones such as estrogen and testosterone and for the repair and formation of cells within the body. The low-density lipoproteins (LDL) and high-density lipoproteins (HDL) are the basic types of cholesterol which have different functions in the body. The high-density lipoproteins (HDL) help to remove deposits of fat from the bloodstream, which in turn enhances a healthy heart, veins and arteries (Lewis & Radar, 2005). The low-density lipoproteins (LDL) which is called bad cholesterol have almost a contrary effect on the body, enhancing lipid to be deposited in the veins and arteries which leads to heart disease, stroke and other cardiovascular problems. The phytosterols are sterols found in many types of plants. The nutritional interest in these compounds is that they have a similar structure to cholesterol, with differences in the side-chain and have the potential to reduce the uptake of cholesterol in the diet by obstructing its absorption in the intestine. They also enhance the excretion of cholesterol from the body. Majority of the phytotherapies available are obtained from medicinal plants utilized in folk medicine. Ekweogu, Nwankpa, Egwurugwu, Etteh, Ugwuezumba & Chukwuemeka, (2018) reported significant decreases ($p>0.05$) in cholesterol and low density lipoprotein triglycerides using *Cola pachycarpa* seed ethanol extract on albino rats which they concluded is a potent antihyperlipidaemic agent which could be employed to manage diseases of the cardiovascular system.

The plant *Cola pachycarpa* and *Cola lepidota* have been identified as some of the underutilized but important fruit trees of South Eastern Nigerian agro ecological zones. This is the motivation of interest in this virgin area of study.

Design of the study: This study used experimental research design.

Materials:

Rat Study

Procurement of rats

A total of forty white albino rats without any drug treatment were used for this study. The rats were healthy adult male rats (Wistar strain) with weights between 150-345g. The rats were obtained from the animal house of the Department of Veterinary Medicine, University of Nigeria Nsukka.

Housing of the animals

The rats were kept in single iron metabolic cages and housed under standard temperature and humidity (environmental) conditions during the study period. The commercial pellet diet (rat chow) was purchased from the Vital Feed shop in Nsukka, Enugu state. This study took place in the Department of Home Sciences, Nutrition and

Dietetics, University of Nigeria, Nsukka. The rats were allotted randomly to eight groups of five rats each, based on body weight (AOAC, 1995).The differences in the weight of rats in each group did not exceed 5g.

Processing of fruit juice from *Cola pachycarpa* and *Cola lepidota*

Fresh *Cola pachycarpa and Cola lepidota* fruits were obtained, the epicarp removed and the seed separated from the fruit. The mesocarp was washed with clean running tap water, cut into bits and its raw undiluted juice extracted using an electric juicer (Andrew James Power Juicer, PI-NO:HK8426 Model NO:QF-0614YB). This juice was packaged in small bottles for use in a freezer compartment at temperature of -4^{0}C.

Methods:

Induction of diabetes

The rats were given commercial pellet diet (rat food) and water *ad libitum* for 5 days to enable them become familiar with the laboratory conditions and the diet. The weight of each rat was taken at the beginning of the experiment, during and after to determine the weight gain. The animals were weighed after an overnight fast and basal fasting blood glucose level determined before induction of diabetes. Samples of blood were also collected for basal biochemical and lipid indices. Alloxan monohydrate powder of 150mg\kg was used to induce diabetes through the intra- peritoneal route of administration. Forty eight (48) hours after inducing the animals with diabetes, the level of blood glucose of the rats was measured using accu- check glucometer and its test strips. Rats that recorded up to 200mg\dl and above were considered diabetic (Tijjani & Luka, 2013).

The experimental animals were treated as follows: Group CPR1 (*Cola pachycarpa* rough epicarp variety, at 5mls) received *Cola pachycarpa* (rough epicarp) fruit juice, 5ml/kg body weight. Group CPR2 (*Cola pachycarpa* rough epicarp variety, at 10mls) received *Cola pachycarpa* (rough epicarp) fruit juice, 10ml/kg body weight. Group CPV1 (*Cola pachycarpa* very rough epicarp variety, at 5mls) received *Cola pachycarpa* (very rough epicarp) fruit juice, 5ml/kg body weight. Group CPV2 (*Cola pachycarpa* very rough epicarp variety, at 10mls) received *Cola pachycarpa* (very rough epicarp) fruit juice, 10ml/kg body weight. Group CL1 (Cola lepidota, at 5mls) received *Cola lepidota* fruit juice, 5ml/kg body weight. Group CL2 (*Cola lepidota*, at 10mls) received *Cola lepidota*, 10ml/kg body weight. Group TSD (Treated with standard drug) was the positive control group, received 5mg/kg body weight glibenclamide, standard diabetic drug. Group NT (Not treated) was the negative control, which was induced without treatment (See Table 3.1).The eight groups continued with the acclimatization diet. The experiment lasted for 21 days. The administration of the fruit juices was through oral routes. Samples of blood were taken every 7 days of the administration of the extracts from the animals to obtain their blood constituents.

Food intake of the animals

Intake of food by each animal was measured on a daily basis throughout the three week experimentation time**.** The food was weighed before and reweighed after feeding **.**The amount consumed was calculated by difference**.** An electronic balance (Ohaus, 730-00) was used to measure the food intake of the rats (Ulman, Compton & Kochanek, 2008).

Lipid Profile

Cholesterol

Total cholesterol was determined with the method of Roeschalu, Bernt and Gruber, (1974). The cholesterol was determined after enzymatic hydrolysis and oxidation. The indicator quinoneimine was formed from hydrogen peroxide and 4-aminoantipyrine in the presence of phenol and peroxidase. Three (3) test tubes were set up in a test tube rack and labeled blank, standard and sample respectively. To the blank sample (10 iu/l) of distilled water was added, 10 iu/l standard specimen to the standard test tube for water blank, 10 iu/l sample was added into the sample test tube.Then, 1000 iu/l of reagent R1 was added into each test tube and mixed then, incubated for 10 minutes at 37 ^{0}C. The absorbance of all the cuvettes was read and recorded at 546 nm.

Triglyceride

Triglyceride was determined with the method of Tietz, (1995).Five microlitre 5 iu/l of the distilled water was added into a test tube containing blank, 5 iu/l of the standard reagent was added into another test tube and 5 iu/l of the sample was added into another test tube. Then, 500 iu/l reagent R1 was added into each test tube and mixed. This was incubated for 5 minutes at 37 ^{0}C. The absorbance of all the cuvettes was read and recorded at 546 nm.

$$\text{TAG (mmol/l)} = \frac{\text{change in Abs sample}}{\text{change in Abs standard}} \times \text{standard conc}$$

High density lipoprotein

HDL (High density lipoprotein) cholesterol level was estimated with the method of Alberts, Warmicks and Cheung, (1978) using Randox kit. . High density lipoproteins (HDL)was determined using biosystem commercial kit method which was based on the principle that very low density lipoproptein (VLDL) and low density lipoproptein (LDL) in the sample precipitated with phosphotungstate and magnesium ions. The supernatant contains high density lipoproteins (HDL). The high density lipoproteins (HDL) were spectrophotometrically measured. One hundred microlitre (100 iu/l) of the serum and standard was pipetted inside the centrifuge tube which was immediately accompanied with the addition of 500 iu/l of the diluted precipitation reagent (R1) to the centrifuge tube. The content were mixed and allowed to stand for 10 minutes at 25 ^{0}C, then, centrifuged for 15 minutes at 3500 rpm. The cholesterol concentration of the supernatant was determined after centrifugation. Into three test tubes labeled test, sample supernatant, standard and blank were added 50 iu/l of sample supernatant, 50 iu/l of standard and 50 iu/l distilled water respectively. Then, 500 iu/l CHOL reagent solution was added to each of the test tubes, mixed and incubate for 10 min at 25 ^{0}C. The absorbance was read at 500 nm after 60 minutes.

$$\text{HDL (mg/dl)} = \frac{\text{Change in Abs sample}}{\text{Change in Abs standard}} \times \text{conc of standard}$$

Low density lipoprotein

LDL-Cholesterol was determined as the difference between total cholesterol and the cholesterol content of the supernant after precipitation of the LDL fraction by polyvinyl sulphate (pvs) in the presence of polyethyleneglycol monomethyl ether (Friedewald, Levy &Fredrickson, 1972). LDL-Cholesterol could be determined as the difference between total cholesterol and the cholesterol content of the supernant after precipitation of the LDL fraction by polyvinyl sulphate (pvs) in the presence of polyethyleneglycol monomethyl ether (Friedewald *et al*., 1972).

LDL = total cholesterol – 1.5 x supernant cholesterol

Determination of the serum very low density lipoproteins (VLDL)

Very low density lipoproteins **(**VLDL**)** was determined by calculation (VLDL = HDL + LDL + total cholesterol).

Results

Food Intake and body weight of induced diabetic rats treated with different doses of Monkey Cola (*Cola pachycarpa* and *Cola lepidota*) fruit juices (g).

Table 1 shows the average food intake and body weight of induced diabetic rats treated with different dosages of *Cola pachycarpa* and *Cola lepidota* fruit juices.

Table 1: Food intake and body weight of induced diabetic rats treated with different doses of *Cola pachycarpa* and *Cola lepidota* fruit juice

		Body Weight			
Treatment Groups	Average food intake (g/rat/day)	initial weight Means ± SEM	final weight Means ± SEM	Difference in Weight	% of difference in weight
CPR1	23.89±1.73^{bc}	255.70±1.25^{e}	273.98±2.81^{e}	18.28	7.15
CPR2	24.92±2.13^{bc}	237.38±0.67^{d}	256.92±4.05^{d}	19.54	8.23
CPV1	22.24±2.57^{b}	152.86±1.83^{a}	164.18±2.12^{a}	11.32	7.41
CPV2	23.35±2.05^{b}	196.94±2.94^{c}	211.08±2.79^{c}	14.14	7.18
CL1	22.14±2.31^{b}	295.26±2.03^{g}	310.44±1.18^{f}	15.18	5.14
CL2	23.12±1.46^{b}	345.86±1.51^{h}	369.44±1.26^{g}	23.58	6.82
TSD	30.18±2.27^{b}	165.92±1.72^{e}	183.78±1.36^{b}	17.86	10.76
NT	5.70±1.93^{a}	264.84±3.58^{f}	206.54±2.84^{c}	-58.3	22.01

Means ± SEM values with different alphabets as superscripts in a column differ significantly ($p<0.05$).CPR1, Diabetic rats fed 5mls *Cola pachycarpa* rough epicarp variety juice per kg body weight; CPR2, Diabetic rats fed 10mls *Cola pachycarpa* rough epicarp variety juice per kg body weight; CPV1, Diabetic rats fed 5mls of *Cola pachycarpa rough* epicarp variety juice per kg body weight; CPV2, Diabetic rats fed 10mls *Cola pachycarpa* rough epicarp variety juice per kg body weight; CL1, Diabetic rats fed 5mls *Cola lepidota* juice per kg body weight; CL2, Diabetic rats fed 10mls *Cola lepidota* juice per kg body weight; TSD, Diabetic rats treated with standard drug, glibenclamide; NT, Diabetic rats not treated with drug or juice; sample size of rats in each is 5.

There was significant difference ($p<0.05$) in food intake of experimental animals fed Cola juices and those treated with standard drug, except for CPR1 and CPR2, though average food intake was highest in rats treated with standard drug (30.18 ± 2.27).The food intake of the untreated, NT decreased significantly ($p<0.05$); 5.70 ± 1.93; and was notably different from all the other treatment groups which enhanced weight loss and mortality in this group. Mortality was not observed in rats treated with the standard drug or the monkey cola fruit juices.

The result of the body weight changes observed in the experimental rats induced with diabetes and treated with different dosages of *Cola* fruit juices are shown in Table 1. The animals in group CPV1 recorded the least body weight in both baseline (152.86 ± 1.83) and after treatment (164.18 ± 2.12) results respectively, compared to other groups. However, group CL2 recorded higher body weights which were significant ($p<0.05$) when compared with other groups in baseline (345.86 ± 1.51) and after treatment (369.44 ± 1.26) respectively. The weights of the animals were observed to be significantly ($p < 0.05$) higher after treatment in all the groups except in group NT (infected, not treated), where the baseline result was higher than the post treatment result with significant ($p < 0.05$) differences. This group suffered a -22.01% loss in body weight.

Lipid Profile

Total cholesterol (mg/dl)

Table 2 shows the total cholesterol results of experimental rats induced with diabetes and treated with different dosages of *Cola pachycarpa* & *Cola lepidota* fruit juices.

Table 2: Effects of *Cola pachycarpa & Cola lepidota* fruit juices on the total cholesterol of diabetes-induced rats (mg/dl)

Treatment Groups	Before Treatment	After Treatment	% Change
CPR1	121.60 ± 1.91^{bcd2}	93.80 ± 33.17^{bc1}	– 22.86↓
CPR2	125.60 ± 2.31^{d4}	98.00 ± 4.37^{c2}	– 21.97↓
CPV1	115.60 ± 2.01^{ab3}	89.60 ± 1.33^{abc2}	– 22.49↓
CPV2	121.00 ± 1.26^{abcd}	91.60 ± 3.87^{abc2}	–24.29↓
CL1	117.20 ± 1.07^{abc3}	85.20 ± 3.38^{ab2}	–27.30↓
CL2	119.20 ± 2.22^{abcd4}	94.00 ± 1.41^{bc2}	– 21.14↓
TSD	114.40 ± 2.71^{a3}	83.20 ± 1.62^{a1}	– 27.27↓
NT	123.60 ± 3.26^{cd2}	131.80 ± 2.33^{d23}	+6.63↑

Mean ± SEM values with different alphabets as superscripts in a column differ significantly ($p < 0.05$).Mean ± SEM values with different numbers as superscripts in a row differ significantly ($p < 0.05$).CPR1; Diabetic rats fed *5mlsCola pachycarpa* rough epicarp variety juice per kg bogy weight.CPR2; Diabetic rats fed 10mls *Cola pachycarpa* rough epicarp variety juice per kg body weight.CPV1; Diabetic rats fed 5mls of *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CPV2;

Diabetic rats fed 10mls *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CL1; Diabetic rats fed 5mls *Cola lepidota* juice per kg body weight. CL2; Diabetic rats fed 10mls *Cola lepidota* juice per kg body weight.TSD; Diabetic rats treated with standard drug, glibenclamide. NT; Diabetic rats not treated with drug or juice; Sample size of rats in each group is 5.

The baseline cholesterol levels of the rats varied significantly ($p < 0.05$) among groups. On induction, group CPR2 recorded the highest cholesterol value (125.60 ± 2.31 mg/dl), followed by group NT, not treated (123.60 ± 3.60 mg/dl), while group TSD, treated with standard drug recorded the least result (114.40 ± 2.71 mg/dl). Cholesterol levels were significantly ($p < 0.05$) higher in group NT when compared with other groups, while the least values was observed in group TSD. Cholesterol values throughout the experimental period showed a very high significant ($p < 0.05$) decrease in all groups treated with Cola juices and standard drug, except for the untreated, NT which recorded elevated cholesterol levels by +6.63%. Other treatment groups recorded percentage decreases in cholesterol levels between -21.14% to -27.27%.

High density lipoprotein (HDL) (mg/dl)

The HDL results of induced diabetic rats treated with different dosages of *Cola pachycarpa & Cola lepidota* fruit juices are represented in Table 3.

Table 3: Effects of *Cola pachycarpa & Cola lepidota* fruit juices on the high density lipoprotein of diabetes-induced rats (mg/dl)

Treatment Groups	Before Treatment	After Treatment	%Change
CPR1	19.60 ± 1.83^{c}	58.60 ± 1.29^{bc}	+198.98↑
CPR2	20.80 ± 0.97^{c}	67.20 ± 3.48^{d}	+223.08↑
CPV1	22.40 ± 2.78^{c}	61.60± 0.93^{bcd}	+175.00↑
CPV2	14.20 ± 1.56^{ab}	55.60 ± 2.69^{b}	+291.55↑
CL1	17.20 ± 1.02^{abc}	60.40± 3.19^{bcd}	+251.16↑
CL2	19.20 ± 0.73^{bc}	65.20 ± 2.56^{cd}	+239.58↑
TSD	21.40 ± 2.09^{c}	57.40 ± 2.86^{bc}	+168.22↑
NT	13.40 ± 1.72^{a1}	12.60 ± 1.54^{a1}	–5.97↓

Mean ± SEM values with different alphabets as superscripts in a column differ significantly ($p < 0.05$).Mean ± SEM values with different numbers as superscripts in a row differ significantly ($p < 0.05$).CPR1; Diabetic rats fed *5mlsCola pachycarpa* rough epicarp variety juice per kg bogy weight.CPR2; Diabetic rats fed 10mls *Cola pachycarpa* rough epicarp variety juice per kg body weight.CPV1; Diabetic rats fed 5mls of *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CPV2; Diabetic rats fed 10mls *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CL1; Diabetic rats fed 5mls *Cola lepidota* juice per kg body weight. CL2; Diabetic rats fed 10mls *Cola lepidota* juice per kg body weight.TSD; Diabetic rats treated with standard drug, glibenclamide. NT; Diabetic rats not treated with drug or juice; Sample size of rats in each group is 5.

HDL values decreased significantly ($p<0.05$) in all groups on induction with diabetes. Similarly, significant ($p < 0.05$) increases in HDL were also observed on treatment in all the groups that received Cola juices and standard drug, TSD. Group CPR2 (67.20 ± 3.48 mg/dl) recorded the highest end value of HDL. The group of rats that were not treated, NT presented a -5.97% decrease in HDL by the end of the experimental period. All other groups had significant increases in HDL values ranging from +168.22% to +291.55%.

Low density lipoprotein (LDL) (mg/dl)

Table 4: Effects of *Cola pachycarpa* & *Cola lepidota* fruit juices on the low density lipoprotein of diabetes-induced rats (mg/dl)

Treatment Groups	Before Treatment	After Treatment	% Change
CPR1	63.80 ± 1.50^{b}	18.60 ± 1.60^{ab}	–70.85↓
CPR2	60.40 ± 3.75^{ab}	19.60 ± 1.33^{ab}	–67.55↓
CPV1	54.60 ± 1.83^{a}	17.40 ± 2.64^{ab}	–68.13↓
CPV2	59.20 ± 2.96^{ab}	16.60 ± 1.89^{a}	–71.96↓
CL1	62.60 ± 1.89^{b}	17.80 ± 1.28^{ab}	–71.57↓
CL2	61.40 ± 1.21^{ab}	22.60 ± 1.54^{b}	–63.19↓
TSD	57.80 ± 1.28^{ab}	15.00 ± 1.67^{a}	–74.05↓
NT	61.40 ± 2.13^{ab2}	62.60± 1.89^{c2}	+1.95↑

Mean ± SEM values with different alphabets as superscripts in a column differ significantly ($p < 0.05$).Mean ± SEM values with different numbers as superscripts in a row differ significantly ($p < 0.05$).CPR1; Diabetic rats fed *5mlsCola pachycarpa* rough epicarp variety juice per kg bogy weight.CPR2; Diabetic rats fed 10mls *Cola pachycarpa* rough epicarp variety juice per kg body weight.CPV1; Diabetic rats fed 5mls of *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CPV2; Diabetic rats fed 10mls *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CL1; Diabetic rats fed 5mls *Cola lepidota* juice per kg body weight. CL2; Diabetic rats fed 10mls *Cola lepidota* juice per kg body weight.TSD; Diabetic rats treated with standard drug, glibenclamide. NT; Diabetic rats not treated with drug or juice; Sample size of rats in each group is 5.

There were very high increases in LDL results which were significant ($p < 0.05$) among all the rat groups after induction with diabetes (Table 4). Group CPR1 had the highest value of LDL on induction. Upon treatment these LDL values decreased in all treatment groups except for the untreated group NT, which had the highest ($p < 0.05$) values of LDL as well as a +1.95% increase in LDL by the end of the experimental period. Although the group treated with standard drug had the highest percentage reduction in LDL value (-74.05%), all other treatment groups had statistically significant ($p <0.05$) similar percentage reduction in LDL values.

Triglyceride concentration (TG) (mg/dl)

Table 5: Effects of *Cola pachycarpa* & *Cola lepidota* fruit juices on the triglyceride concentration of diabetes-induced rats (mg/dl)

Treatment Groups	Before Treatment	After Treatment	%Change
CPR1	154.40 ± 4.66^{d2}	106.40±2.62^{bc}	–31.08↓
CPR2	139.40 ± 3.76^{c3}	107.20 ± 3.01^{bc}	–23.10↓
CPV1	133.40± 5.95^{abc3}	109.80 ± 1.68^{c}	–17.69↓
CPV2	126.20 ± 2.97^{ab3}	109.80 ± 1.56^{c}	–12.99↓
CL1	136.40 ± 2.62^{bc2}	113.00 ± 2.91^{c}	–16.86↓
CL2	130.60± 2.00^{abc2}	100.40 ± 3.06^{ab}	–23.12↓
TSD	123.60 ± 3.11^{a3}	94.40 ± 2.56^{a}	–23.62↓
NT	123.60 ± 2.79^{a2}	141.80 ± 1.85^{d}	+14.72↑

Mean ± SEM values with different alphabets as superscripts in a column differ significantly ($p < 0.05$) Mean ± SEM values with different numbers as superscripts in a row differ significantly ($p < 0.05$).CPR1; Diabetic rats fed *5mlsCola pachycarpa* rough epicarp variety juice per kg bogy weight.CPR2; Diabetic rats fed 10mls *Cola pachycarpa* rough epicarp variety juice per kg body weight.CPV1; Diabetic rats fed 5mls of *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CPV2; Diabetic rats fed 10mls *Cola pachycarpa* very rough epicarp variety juice per kg body weight.CL1; Diabetic rats fed 5mls *Cola lepidota* juice per kg body weight. CL2; Diabetic rats fed 10mls *Cola lepidota* juice per kg body weight.TSD; Diabetic rats treated with standard drug, glibenclamide. NT; Diabetic rats not treated with drug or juice; Sample size of rats in each group is 5.

On induction, all treatment groups experienced increments in TAG concentration significantly ($p<0.05$), with CPR1 showing highest value of TAG (154.40±4.66). TAG values decreased on treatment for all groups, with significant ($p < 0.05$) differences, except for group NT (not treated),whose TAG levels soared by +14.72% (Table 5). Percentage triglyceride concentration reduction were highest for *Cola pachycarpa*, group CPR1(-31.08%).

Discussion

The results in this study indicated that average food intake of rats treated with standard drug was higher than those given other forms of treatment. Food intake of rats treated with different monkey cola fruit juices were similar but different from those of rats not treated with standard drug or fruit juice. The average food intake of the untreated rats (Not Treated, NT) was very low compared to all other groups. Body weight of rats not given any form of treatment (NT) also declined significantly ($p<0.05$) while those of all treated groups improved. This decline in body weight could be as a result of low food consumption, use of stored energy and possible intestinal disturbances (Adetuyibi, 1976). Abnormally high blood glucose levels as a result of initial diagnosis of diabetes include fatigue, serious and rapid loss of weight which could lead to death if there is no rapid intervention (Geiss *et al*., 2006). Weight loss in chronic hyperglycaemia is connected with resultant imbalances in the metabolism of fat, protein and carbohydrate as a result of deficiencies in insulin secretion or action (Nwanjo & Oze, 2007; Amuzat *et al*., 2021). Body weight increases in the treated groups were between 5.14-10.76% while the untreated rats suffered a -22.01% decrease in body weight. It was not surprising then to observe that morbidity and mortality rates were high amongst the untreated rats while the diabetic drugs and the fruit juices helped to ameliorate the effects of the diabetic condition by improving the quantity of food taken and subsequently body weight of the rats administered standard diabetic drug and *Cola pachycarpa* and *Cola lepidota* fruit juices.

Changes in blood lipid profile have been linked with inflammatory and infectious diseases as well genetical considerations (Devalaraja, Jain & Yadav, 2011). The high values of total cholesterol in rats induced with diabetes before treatment is same with reports of other researchers who have observed that an increase in serum lipids on induction of diabetes is associated with the accompanying rise in blood glucose level (Nerurkar *et al*., 2015). It was also observed that on treatment, monkey cola fruit juices were effective in significantly ($p<0.05$) lowering low density lipoprotein, total cholesterol and triglycerides of diabetic animals, while increases were recorded in values of high density lipoprotein. Percentage decreases in total cholesterol ranged from 21.14-27.30%. The untreated group suffered increased triglycerides, blood cholesterol and low density lipoproteins with decreases in high density lipoproteins (Tables 4.27- 4.30).

Devalaraja *et al*., (2011) also reported the effectiveness of exotic fruits such as Litchi, Goji & Persimmon in significantly reducing total cholesterol in diabetic rats. Ekweogu, Nwankpa, Egwurugwu, Etteh, Ugwuezumba and Chukwuemeka, (2018) reported similar hyperglycaemic effect of ethanol extract of *Cola lepidota* seeds which reduced cholesterol, triglycerides and low density lipoproteins in albino rats. They attributed it to the saponins content of the extracts. Dietary saponins have been gaining special interest in human nutrition because of their ability to lower blood cholesterol. Saponins lower blood cholesterol by increasing its excretion from the body, preventing its uptake in a way which is similar to the activity of drugs that lower cholesterol like cholestyramine (Bruce *et al*., 2000). These reductions in total cholesterol could be beneficial in building and repairing damaged tissues associated with the disease condition.

The high density lipoproteins help in the removal of fatty deposits from the bloodstream, thereby improving healthy veins and arteries and supporting general cardiovascular health (Lewis & Radar, 2005). They transport cholesterol esters and cholesterol from the cells and peripheral tissues into the liver where they are degraded to form bile acids. Reduction in levels of blood cholesterol and associated tissues helps to inhibit the formation of

atherosclerosis in the aorta. The results from this study showed general decreases in HDL values on induction with diabetes. On treatment HDL values of experimental animals fed monkey cola fruit juices as well as standard drug, TSD increased significantly ($p<0.05$). Group CPR2 (67.20±3.48mg/dl) recorded the highest end value of HDL while the untreated rats had as much as 5.97% decrease in HDL. According to Rotimi *et al*., (2011) rise in high-density lipoprotein cholesterol is a suitable condition involving chemical processes in living organisms which helps to prevent atherosclerosis and pathologic conditions. Onyechi, Ibeanu, Maduforo, Ugwuonah and Nsofor, (2018) noted that the presence of certain compounds such as alkaloids, saponins, flavonoids and polyphenols in foods have been linked to low serum lipid levels in animals. The earlier observed lowered total cholesterol levels on treatment of the diabetic animals might have added to the increase in levels of serum high density lipoprotein in the experimental animals. This increase in HDL values of induced diabetic rats treated with monkey cola fruit juices were indicative of the potential of *Cola pachycarpa* and *Cola lepidota* fruit juices in enhancing cardiovascular health by reducing fatty deposits in the bloodstream which in turn aids the reduction of levels of cholesterol in the blood as demonstrated in this study.

The low-density lipoprotein particles tend to be less compact than other kinds of cholesterol particles. These low-density lipoproteins (LDL) are considered to be a bad type of cholesterol because they almost have the opposite effect of the high density lipoproteins on the body as they enhance deposits of lipids in the blood vessels which could lead to stroke and heart diseases. The result in the present study showed very high increases in the LDL (low density lipoproteins) of rats induced with diabetes. Elevated levels of cholesterol, triglycerides, phospholipids and other lipoproteins have been identified as characteristics of diabetes mellitus by different researchers. These changes in lipid profile have also been linked with genetics and diseases caused by infection and inflammation (Anyinla, Dada, Shittu, Olayaki, Akiode & Ojulari, 2011). Low density lipoprotein cholesterol of the diabetic rats given monkey cola fruit juices decreased significantly ($p>0.05$) similar to those treated with standard diabetic drug. Percentage reductions in LDL ranged from 63.19-74.05% in all the treatment groups. The rats that were not treated experienced increased serum lipoprotein by 1.95%. Other researchers have reported similar effects of ethanol extract of monkey cola seed in reducing cholesterol, triglycerides and low lipoproteins in diabetic albino rats (Ekweogu, Nwankpa, Egwurugwu, Etteh, Ugwuezumba & Chukwuemeka, 2018). They attributed this to the presence of saponins in the seeds. Monkey cola fruits are also sources of dietary fibre, saponins and phytochemicals such as flavonoids. This decrease in LDL cholesterol could be an indication that monkey cola fruits may possess hypolipidemic effects since the reduction in LDL enhanced decreases in lipid deposits in the blood vessels, total cholesterol and increment in HDL, high-density lipoprotein levels thereby enabling cardiovascular health in animals that are diabetic. Oladiran *et al*., (2016) observed that intake of sufficient amounts of dietary fibre is linked with lower level of serum cholesterol, occurence of heart disease, diabetes, hypertension as well as certain cancers.

Triglycerides are the main ingredients in animal fats and vegetable oils and are the type of fats regularly digested by humans (Nordestgaar, Benn, Schnohr & Tybjaerg-Hansen, 2007). The elevated triglyceride levels observed in this study prior to treatment are some of the diabetic indicators. High levels of triglycerides levels are implicated in diseases such as atherosclerosis and peripheral artery disease. Levels of triglycerides significantly ($p < 0.05$) decreased by 12.99-31.08% in all treatment groups except for the untreated group who experienced significant ($p > 0.05$) increase in levels of triglycerides by 14.72%.This decrease in high blood triglycerides indicated the potentials of *Cola pachycarpa* and *Cola lepidota* fruit juices to reduce plasma levels of triglycerides similar to the diabetic drug. These reductions will be profitable in preventing metabolic degenerations associated with diabetes and improving lipid metabolism. Irondi, Oboh and Akindahunsi, (2016) reported that diabetic rats treated using different foods whose plasma triglycerides, cholesterol, low density lipoproteins decreased with an accompanying increase in the high density lipoprotein levels may have experienced improvement in secretion of insulin from the pancreas. This suggests in this case that these fruit juices might have the capacity to protect the liver and pancreas from damage due to oxidation.

Conclusion

Cola pachycarpa and *Cola lepidota* fruit juices demonstrated efficacy in decreasing cholesterol, low density lipoproteins and effecting increase in food intake, body weight and high density lipoproteins in diabetic induced albino rats similar to the standard diabetic drug. These bioactive potentials reviewed are however clearly understudied. There is

need to encourage consumption of Monkey *Cola* fruits and fruit juice, undertake further research into its anti-hyperlipidaemic properties in diabetes management which will enhance national health. Findings from this study will contribute to nutritional database of bioactive potentials of monkey cola fruit varieties on diabetes-induced rats.

Conflict of Interest: There is no conflict of interest in this study.

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