Use of Vegetables to Manage Diabetes in Diabetes Induced Rats

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DOI: 10.56201/ijhpr.vol.10.no2.2025.pg66.79

Abstract

The study identified some lesser-known vegetables in plateau state through a focus group discussion. The extracts of the identified vegetables were used to manage Diabetic induced rats. The lesser known vegetables used were identified at the Botany Department's herbarium of the University of Jos. The vegetables were P. crispum, B. pilosa, L. taraxicifolia and V. doniana. The leaves were sorted, cleaned and processed into powdered samples; extracts were derived using aqueous extraction. One gram of the powdered leaves was soaked in 100ml distilled water to produce a concentration of 10mg/ml of the acqueos extract used for the experiment. Acute toxicity test LD50 was conducted on the four leaf extracts using six mice per extract. The study adopted survey and experimental methods. A total of 66 adult rats were used for the study. The rats were divided into 11 groups of 6 each for the diabetes study. The rats were induced with a single dose of 150mg/kg body weight of freshly prepared aloxan monohydrade interperetonially, except the first group used for the control. The rats were then divided into 8 groups treated with 500mg/kg body weight and 1000mg/kg body weight of the vegetable extracts. Another group was given 500mg/kg body weight of the standard drug glibenclamide while one group was induced but not treated used as another control. The diabetic study lasted for 13 days. Their blood glucose and lipid profiles were dertermined. Paired sample t-test was used to analyze the baseline and end line data on blood glucose levels and lipid profiles. Statistical analysis revealed that the four aqueous leaf extracts were of good nutrient quality and within the safe level. That all the groups except the first controls (undiabetic untreated) had post-induction elevated fasting blood glucose (above 10mmol/dl), lipid profiles, and lowered high density lipoprotein. When treated with the four aqueous leaf extracts at 500mg/kg and 100mg/kg body weight, they showed anti-diabetic properties by lowering the elevated fasting blood glucose and lipid profile levels and elevating the high density lipoprotein. All the four aqueous leaf extracts exhibited good efficacy at 500mg/kg and 1000mg/kg body weight. The four leaf extracts were safe and capable of managing and treating diabetes mellitus as reported in literature and local users. The study should be carried out on humans to confirm the results obtained in this research. Food industries should be encouraged to look into the possibility of incorporating these vegetables in food products to diversify diets.

Key Words: Diabetes, Vegetables, Lesser Known, Rats

1.0 INTRODUCTION

It is an indisputable fact that health is something to be treasured. A healthy person is a wealthy person. A healthy nation is a wealthy nation. Every nation strives to have a healthy populace. Some nations allocate much money in their annual budget to health care to produce healthy citizens. Diabetes mellitus is a chronic disease caused by the inability of the pancreas to produce insulin or use insulin properly.Normally, the pancreas produces enough insulin to accommodate the quantity of sugar produced after carbohydrate consumption, but when a diabetic's pancreas produces little or no insulin or the cells do not respond normally to the insulin, the blood sugar increases, overflows into the urine and is excreted unused(Lagat *et al.*2021).

Diabetes in clinical diagnosis usually accompanies the symptoms of hypercholesterolemia and hyperglycemia which damage blood vessels (micro-vascular disease) and increase the risk of heart attack, stroke, and kidney failure. Hyperglycemia and hypercholesterolemia are risk factors in type 2 diabetes.

According to International Diabetes Federation (IDF) (Saeed *et al.* 2019) there has been a progressive increase in the prevalence of diabetes worldwide and it is estimated to increase even further. The burden of diabetes is also growing in Africa and it is estimated that African region will have the greatest percentage increase (143%) in the burden of diabetes between 2019 and 2043 Similarly there has been a progressive increase in the prevalence rates of diabetes mellitus in Nigeria. Studies reported prevalence rates ranging between 0% - 4.4% in some rural communities in Nigeria, while the prevalence in urban areas has been reported to range between 4.6 – 7%.

Deadly and life threatening diseases are very rampant and on the increase. Diabetes mellitus which was regarded as a disease of the affluent now affects anybody no matter the status.

Diabetes mellitus is a significant metabolic illness that affects people all over the world. Because existing synthetic medications have various limits and negative effects, the search for novel drugs continues. Traditional botanicals have long been used to cure diabetes around the world (Israr et al. 2021).Anecdotal records attributed healing and preventive powers of some diseases to some of the lesser known indigenous vegetables.This needs to be confirmed through scientific research. Lesser known indigenous vegetables have health promoting and protective attributes which are linked to their nutritional and non-nutritional bio-active properties. Inclusion of vegetables in the diet will not only provide basic nutrient requirement for man, they will also provide protection against the incidence of chronic degenerative and age-related disorders due to the presence of phytochemicals and antioxidants. More recent report has shown that vegetables contain these non-nutrient phytochemicals that have been linked to protection against cardiovascular disorders, diabetes mellitus and other degenerative disease. Consumption of vegetables is the surest way to good health (Ushie *et al.* 2022). This work is aimed at using extracts of selected vegetables to manage diabetes mellitus in diabetes induced rats.

2.0 MATERIALS AND METHODS

A Survey was carried out to identify the different indigenous, underutilized vegetables assumed to have medicinal properties. This was done through a focus group discussion (FGD)

Identification and characterization of the vegetables used for the study

Four vegetables widely used for therapeutic purposes in the communities based on the FGD carried out in the twelve communities in the three zones of Plateau State were selected.

The vegetables selected were taken to the University of Jos Botany Department's Herbarium for characterization. The vegetables selected include: Petroselinum *crispum (*Flat leaf parsley), Bidens*pilosa (*Beggerticks), Launacea *taraxacifolia* (Wild lettuce) and Vitex *doniana (*Black plum).

Preparation of the samples

The four vegetables selected were harvested from the communities in Plateau State that were used for the FGD. These vegetables were plucked separately, sorted by removing extraneous materials and washed with safe drinking water and put in a basket to drain. The vegetables were shade dried for two days and pulverized separately using Gallenkamp mixer (Kenwood – MPR 201).The samples were stored for laboratory analysisand for the biological study with diabetes induced rats. The dried powdered plants (P. *crispum*, B. *pilosa*, L.*taraxacifolia* and V. *doniana*) were weighed and placed in air-tight containers.

Preparation and administration of extract

Extraction was carried out using cold water extraction using distilled water and made to stand for 48 hours. The mixture of each plant was initially filtered through a sieve (0.5 mm) in clean laboratory glass jars and re-filtered using a laboratory sieve (0.01mm) to obtain fine particle extracts. The filtrate was then concentrated under low heat (37 °C) until dried to constant weight. The dried filtered extracts were weighed and the percentage yield computed.

Reconstitution of the extracts was done each week of administration using distilled water in a 50 mg/ml concentration for each dose of extract (500 mg/Kg and 1,000 mg/Kg). After induction of diabetes, each rats were orally treated with the plant extracts for a duration of 7 days, using an oral cannula.

Experimental animals and site

The rats were acquired from the small animal experiment unit of the National Veterinary Research Institute (NVRI) Vom, Plateau state, Nigeria. A total of one hundred and twenty one(121) Wister male rats of about 8 weeks and average body weight of 150g ± 10.0 were used for this experiment. This study was carried out in the premises of the small animal experimental unit of NVRI Vom, Plateau state, Nigeria

Determination of Lethal Dose(LD_{50}) of P. crispum, B. pilosa, L. taraxacifolia and V. doniana extracts in rats

The mean lethal dose (LD_{50}) was determined using the limit dose test (OECD, 2001). Six animals per extract were used. Briefly, one rat was administered orally with 2,000 mg/Kg of the extracts prepared in a 150 mg/ml concentration, with rat numbers 1, 2, 3, 4, 5 and 6 given the same dose on days 2, 3, 4, 5 and 6, respectively. The LD_{50} was estimated to be ≥2,000 mg/Kg, if more than3 rats survived. However, there was no record of mortality at the end of the toxicity study.

Reconstitution and administration of extract

Reconstitution of the extracts was done each week of administration using distilled water in a 50 mg/ml concentration for each dose of extract (500 mg/Kg and 1,000 mg/Kg). After induction of diabetes, each rat was orally treated with the plant extracts for aduration of 7 days, using an oral cannula.

Feeding trial on diabetic induced rats

After diabetes was induced, the rats were fed rat chow in addition to the vegetable extracts in graded substitution. Groups 1-4 were given 500 mg/kg body weight of vegetable extract and groups 5-8 were given 1000 mg/kg body weight of the same vegetable extracts. The vegetable extracts were given orally using a syringe daily. Rats in group 9-11 were the control groups. The first control (group 9)comprised of rats that were not induced and not treated (normal control).The secondcontrol (group 10)were rats that were induced and were not treated. The last control (group 11) was rats that were induced and treated with the standard drug glibenclamide (standard control) which is one of the oral anti diabetic drugs in WHO list of essential medicines used to treat type 2 diabetes as at 2011(www.ncbi.nim.nih.gov/pubmed/18503731/).The study was carried out over a period of 13 days consisting of 3-days acclimatization, 2-days for induction of diabetes, 1-day to establish diabetes and 7-days for experimental diet.

Determination of blood glucose

Experimental animals were rearranged according to the blood glucose concentration, except the control group (not induced), before commencement of treatment. Blood glucose concentration in all experimental groups were recorded following 12-hr fasting each day, at 8:00 a.m. before feeding the rats, using a portable glucometer (On Call®Plus, Hannover, Germany) and glucose test strips.

Determination of lipid profiles for diabetic induced rats

Determination of total cholesterol

The approach used in this study was modified from that described by Abell *et al.* (1952).

Low density lipoprotein (LDL)

The following expression was adapted to calculate low density lipoprotein-cholesterol (LDL-C):
LDL-C conc (mg/dL) = total cholesterol (TC) x (HDL + triglycerides/5).

High density lipoprotein (HDL)

In the presence of divalent cations, a polysaccharide precipitates low and very low density lipoproteins (LDL and VLDL) from serum. The amount of HDL in the supernatant was then measured.

The concentration of the cholesterol in the supernatant was analyzed as elucidated by Kameswara *et al*. 1999.

Triacylglycerol

Enzymatic hydrolysis with lipases was used to evaluate triacylglycerol. Quinoneimine is an indicator produced from 4-aminophenazone, 4-chlorophenol and hydrogen peroxide under the influence of catalytic peroxidase.

Statistical analysis

Paired sampled t-test (PSTT) was used to analyse the baseline and end-line data on blood glucose levels and lipid profile of the diabetic rats, while PSTT was also used to analyze lipid profile of

the diabetic rats after treatment with the leaf extracts. The IBM-SPSS version 22 statistical tool was used for the statistical analysis. Statistical difference and/or significance were set at $P < 0.05$ and $P < 0.01$, while percentage difference was also calculated.

3.0 RESULTS AND DISCUSSION

Alloxan induces diabetes through reactive oxygen species (ROS) that leads to a rapid destruction of pancreatic beta cells causing hyperglycaemia (Stanly *et al.* 2000). Hyperglycemia in turn increases the generation of free radicals by glucose auto-oxidation (Bajaj andKhan 2012). In Table 1, it was observed that the fasting blood sugar levels of the rats significantly decreased in all the experimental groups as against an increase in the diabetic untreated and non-diabetic control groups. This observation is consistent with various findings including that of Mukhtar, Yakasai and Firdausi 2020, Yakubu *et al*. 2014, Gidado Ameh and Atawodi 2005, Olagbende-Dada et al. 2011, Okorie *et al.* 2020, Hassan et al. 2020 and Kuyooro *et al.* 2013, following the oral administration of aqueous leaf extracts of Senna *singueana*, Ficus *exasperate*, Nauclea *latifolia*, Vitex *doniana*, Graptophyllum *pictum*, *Adansonia digitate*, Parkia *biglobosa*and methanolic leaf extract of Launacea *taraxacifolia* respectively. The reduction in blood glucose level was not significantly dose-dependent which is in contrast with the work done by Adefolalu *et al*. 2019 on methanol extract of *Hibiscus sabdariffa* seeds where administration of the methanol extract showed a significant reduction in the fasting blood glucose level of all treated diabetic rats on a dose-dependent rate. P. *crispum* leaf extract in the present study had the highest blood glucose lowering effect, followed by B. *pilosa* leaf extract. In comparison with the standard drug (glibenclamide/metformin), P. *crispum* leaf extracts showed similar hypoglycaemic effect compared to standard anti-diabetic drug. Overall, the hypoglycaemic activity of the leaf extracts may be attributed to their ability to restore the functions of pancreatic tissues thereby causing increase in insulin output and/or insulin secretion just like other antidiabetic medicinal plants (Neelish et al.2010). It is also possible that the leaf extracts might have suppressed hepatic gluconeogenesis, stimulated glycolysis, inhibited or decreased intestinal absorption of glucose. Phytochemicals such as flavonoids, alkaloids and tannins have been reported to possess antioxidant activities which could be responsible for the antidiabetic properties of the leaf extracts via insulin modulation and destruction of ROS (Petchi *et al*. 2013: Mashi *et al.* 2019).Also, minerals like magnesium are known to play a role in glucose metabolism and absorption in the body, and this might have contributed to the anti-diabetic effect of the aqueous extracts studied. Thus, the higher blood glucose lowering effect ofP. *crispum* leaf extract could be attributed to the higher contents of phytochemicals such as flavonoids, alkaloids, tannins and saponins as well as magnesium.

Table 1: Effect of the aqueous extracts of the leaves on the blood glucose level of treated alloxan-induced diabetic rats

Groups	Baseline	End-line	MD	T	%D
P. crispum$_{500}$	312.40 ± 80.96	96.50 ± 70.18	215.90 ± 0.37	54.03**	69.11
B. pilosa$_{500}$	278.60 ± 30.90	99.60 ± 10.20	179.00 ± 0.54	68.63**	64.25

L. taraxa$_{500}$	270.00 ± 68.24	123.48 ± 23.60	146.52 ± 0.48	69.10**	54.27
V. doniana$_{500}$	260.20 ± 40.67	108.30 ± 12.00	151.90 ± 0.33	93.19**	58.38
P. crispum$_{1000}$	310.20 ± 60.70	95.70 ± 2.90	214.50 ± 0.24	51.40**	69.15
B. pilosa$_{1000}$	273.55 ± 20.92	95.70 ± 50.10	177.85 ± 0.18	92.17**	65.02
L. taraxa$_{1000}$	280.45 ± 70.86	130.60 ± 65.40	149.85 ± 0.43	73.15**	53.43
V. doniana$_{1000}$	290.60 ± 28.60	125.80 ± 50.86	164.80 ± 0.14	23.62**	56.71
UN	80.46 ± 22.08	102.47 ± 56.80	-22.01 ± 0.50	-87.66**	27.36
DU	314.30 ± 51.28	328.80 ± 66.25	-14.50 ± 0.41	-71.04**	4.61
DT	300.40 ± 20.00	90.40 ± 70.28	209.90 ± 0.21	94.29**	69.87

MD = mean difference; Std error = standard error; df = degree of freedom; t = t-test value; %D = percentage difference; * = ($P < 0.05$); ** = ($P < 0.01$); baseline = after induction; end-line = after treatment; *L. taraxacifolia*; UN = untreated non-diabetic; DU = diabetic untreated; DT = diabetic treated with standard drug

Effect of the aqueous leaf extracts on the lipid profile of diabetic rats

After induction of alloxan in the present study, abnormalities in the lipid profile (increase in total cholesterol levels, triglyceride levels and LDL levels and a decrease in the HDL levels) of the rats were observed in Table 2. Diabetes-induced hyperlipidemia occurs as a result of excess mobilization of fat from the adipose tissue due to the underutilization of glucose.The elevation of lipids might also be due to an increased action of hormone sensitive enzyme, lipase, which promotes lipolysis, and hence increases the level of free fatty acids in the plasma that is readily catabolized to acetyl CoA. The resultant acetyl CoA is channeled to cholesterol synthesis, thereby increasing blood cholesterol level (Muhammad 2015).

After treatment with the aqueous leaf extracts, the total cholesterol levels of the experimental rat groups were decreased as against the increase in the total cholesterol levels of the diabetic untreated rats. A similar result was obtained by Obasi *et al.* 2013, Nwogor 2016, and Kuyooro *et al*. 2013, following the administration of aqueous leaf extracts of *Vitex doniana*, *Ocimum gratissimum*, *Momordica charantia* and methanolic leaf extract of *Launaea taraxacifolia*, respectively on diabetic rats.In Table 2, a dose-dependent effect on total blood cholesterol was observed of which *B. pilosa* leaf extracts showed higher ameliorating effect on total cholesterol at higher dose of 500mg/kg body weight. In comparison with the standard drug, the aqueous leaf extracts *B. pilosa* showed significantly more reductive effect on total cholesterol level of the diabetic rats. Generally, the significant decreases in the total cholesterol level of the test group is indicative of the hypocholestrolaemic activity of aqueous leaf extracts at a dose dependent ratio and this could be attributed to the content of saponins, flavonoids and steroids. All these components are known to reduce serum lipid level in animals (Ezekwe and Obidoa 2001). Studies

have demonstrated that saponins isolated from different plants produce significant anti-hyperlipidemic effects mainly by suppression of cholesterol luminal absorption and also by increasing cholesterol secretion through biliary excretion (Francis et al. 2002: Ma et al. 2002).

Table 2: Effect of the aqueous extracts of the leaves on the total cholesterol (mg/dL) level of alloxan-induced diabetic rats

Groups	Baseline	End-line	MD	T	%D
P. crispum$_{500}$	120.25 ± 5.93	90.70 ± 6.40	29.55 ± 0.19	315.9**	24.57
B. pilosa$_{500}$	128.15 ± 6.66	71.60 ± 7.40	56.55 ± 0.40	281.29**	44.13
L. taraxa$_{500}$	126.00 ± 3.50	78.80 ± 2.47	47.20 ± 0.24	385.39**	37.46
V. doniana$_{500}$	128.12 ± 5.00	102.40 ± 5.60	25.72 ± 0.22	232.70**	20.07
P. crispum$_{1000}$	134.60 ± 4.80	86.50 ± 5.20	48.10 ± 0.22	445.32**	35.74
B. pilosa$_{1000}$	120.80 ± 9.00	76.40 ± 8.50	44.40 ± 0.37	237.33**	36.75
L. taraxa$_{1000}$	132.40 ± 2.00	95.86 ± 6.50	36.54 ± 0.05	364.93**	27.60
V. doniana$_{1000}$	125.60 ± 1.20	90.20 ± 6.43	35.40 ± 0.24	289.04**	28.18
UN	90.50 ± 4.83	89.40 ± 2.05	1.10 ± 0.42	5.18*	1.22
DU	130.50 ± 5.05	150.20 ± 6.80	-19.70 ± 0.43	-91.19**	15.10
DT	129.50 ± 6.08	120.40 ± 2.90	9.10 ± 0.49	36.65**	7.03

MD = mean difference; Std error = standard error; df = degree of freedom; t = t-test value; %D = percentage difference; * = (P < 0.05); ** = (P < 0.01); baseline = after induction; end-line = after treatment; *L. taraxacifolia*; UN = untreated non-diabetic; DU = diabetic untreated; DT = diabetic treated with standard drug.

Triglycerides (TG) are fatty acid esters of glycerol and represents the main lipid component of dietary fat and fat depots of animals (Cox and Garcia-Palmieri 2000). Its elevation may play a role in heart disease risk (Wedro 2018). In Table 3, the triglyceride levels of all the rats in the treatment group showed significant decreases in triglyceride levels with the dose of 500mg/kg body weight of the aqueous leaf extracts showing higher decrease in triglyceride levels compared to the 1000 mg/kg body weight of the samples. This result is consistent with the results by Obasi *et al.* 2013, Nwogor 2016, Sani et al. 2015 and Kuyooro *et al.* 2013, following the administration of aqueous leaf extracts of *Vitex doniana*, *Ocimum gratissimum*, *Momordica charantia* and methanolic leaf extract of *Launaea taraxacifolia*, respectively on diabetic rats.However, the result is in contrast with the report of Umar *et al.* 2012 who reported an increase in the TG level of alloxan-induced diabetic rats following the administration of aqueous leaf extract of *Ocimum suave*. Be that as it may, the significant decrease in TG level of the test group treated with the aqueous leaf extract in the present study (in Table 3) as against the increase in the control (diabetic untreated) rat group signifies the triglyceride lowering effect of the test samples. At 500 mg/kg body weights of the

aqueous leaf extracts *P. crispum* and *L. taraxacifolia*, the triglyceride lowering effect of the samples was comparable to that of the standard antidiabetic drug.

Table 3: Effect of the aqueous extracts of the leaves on the triglycerides (mg/dL) level of alloxan-induced diabetic rats

Groups	Baseline	End-line	MD	T	%D
P. crispum$_{500}$	112.40 ± 3.81	69.83 ± 5.06	42.57 ± 0.26	322.26**	37.87
B. pilosa$_{500}$	136.80 ± 15.30	89.00 ± 5.40	47.80 ± 0.45	210.29**	34.94
L. taraxa$_{500}$	140.60 ± 4.88	90.00 ± 11.68	50.62 ± 2.34	43.20**	36.00
V. doniana$_{500}$	124.60 ± 4.23	86.38 ± 6.63	38.22 ± 0.29	267.27**	30.67
P. crispum$_{1000}$	148.60 ± 24.84	96.41 ± 14.30	52.19 ± 0.33	319.30**	35.12
B. pilosa$_{1000}$	150.12 ± 22.88	120.50 ± 12.03	29.62 ± 0.37	159.20**	19.73
L. taraxa$_{1000}$	120.96 ± 20.26	93.85 ± 4.54	27.11 ± 0.15	358.56**	22.41
V. doniana$_{1000}$	119.80 ± 12.9	83.70 ± 5.35	36.10 ± 0.14	510.53**	30.13
UN	78.60 ± 3.15	77.80 ± 2.80	0.80 ± 0.51	3.14**	1.02
DU	130.45 ± 11.31	145.00 ± 4.00	-14.55 ± 0.32	-91.26**	11.15
DT	150.40 ± 3.55	99.73 ± 10.95	50.67 ± 0.41	249.89**	33.69

MD = mean difference; Std error = standard error; df = degree of freedom; t = t-test value; %D = percentage difference; * = (P < 0.05); ** = (P < 0.01); baseline = after induction; end-line = after treatment; *L. taraxacifolia*; UN = untreated non-diabetic; DU = diabetic untreated; DT = diabetic treated with standard drug

Low density lipoprotein cholesterol (LDL-C) is the predominant cholesterol-carrying lipoprotein, and is considered to be the main atherogenic lipoprotein (Motala et al. 2009), hence the name "bad" cholesterol.The result I Table 4 showed that after treatment with the aqueous leaf extracts, the LDL levels of all the rats in the treatment group showed significant decreases. This is contrary to the control (diabetic untreated) groups which had significant increase in LDL-cholesterol. This result is consistent with that reported by several studies on the aqueous and methanolic extracts of leafy vegetables (Ajiboye et al. 2014; Sani et al. 2015; Nwogor, 2016; Kuyooro *et al*. 2013). In the present study, it was also observed that the diabetic rat groups fed 1000mg/kg bodyweight of the aqueous leaf extracts had the higher decrease in LDL levels than the group fed 500 mg/kg bodyweight of the test sample; the LDL ameliorating effect from 1000 mg/kg body weight of the test samples compared favourably with that of the standard drug. Thus, the significant reductions in LDL-cholesterol on treatment with the various aqueous leaf extracts would be beneficial in improving lipid metabolism in diabetic state. Biochemically, the leaf extracts might be inducing rapid catabolism of low-density lipoprotein cholesterol through hepatic receptors for final elimination in the form of bile acids as reported by Chattopadhyay and Bandyopdhyay 2005.

Table 4: Effect of the aqueous extracts of the leaves on the low density lipoprotein (LDL) level of treated alloxan-induced diabetic rats

Groups	Baseline	End-line	MD	T	%D
P. crispum$_{500}$	73.80 ± 3.45	16.98 ± 3.40	56.82 ± 0.19	584.50**	76.99
B. pilosa$_{500}$	80.60 ± 10.50	19.02 ± 4.88	61.58 ± 0.33	375.69**	76.40
L. taraxa$_{500}$	85.40 ± 5.40	16.24 ± 7.40	69.16 ± 0.24	575.00**	80.98
V. doniana$_{500}$	86.70 ± 4.55	26.71 ± 4.31	59.99 ± 0.01	483.87**	69.19
P. crispum$_{1000}$	90.40 ± 7.68	18.80 ± 2.41	71.60 ± 0.43	331.44**	79.20
B. pilosa$_{1000}$	94.80 ± 3.25	16.40 ± 4.48	78.40 ± 0.24	640.13**	82.70
V. doniana$_{1000}$	88.90 ± 6.85	22.51 ± 5.50	66.39 ± 0.31	422.29**	74.68
UN	21.00 ± 3.86	21.20 ± 7.14	-0.20 ± 0.24	-1.63**	0.95
DU	80.61 ± 5.40	90.60 ± 3.60	-9.99 ± 0.38	-52.98**	9.91
DT	69.40 ± 15.42	20.60 ± 5.80	48.80 ± 0.08	195.35**	70.32

MD = mean difference; Std error = standard error; df = degree of freedom; t = t-test value; %D = percentage difference; * = ($P < 0.05$); ** = ($P < 0.01$); baseline = after induction; end-line = after treatment; *L. taraxacifolia*; UN = untreated non-diabetic; DU = diabetic untreated; DT = diabetic treated with standard drug

Table 5 shows that HDL levels of the experimental groups increased after treatment with the aqueous leaf extract against the decrease in HDL in the diabetic untreated control group. The group fed 1000mg/kg bodyweight of the aqueous leaf extracts of B. *pilosa*, L. *taraxacifolia* and *V. doniana* had higher increase in HDL levels thanthe group treated with standard antidiabetic drug to the group. A similar observation was reported by Ajiboye *et al*. 2014, Sani *et al*. 2015 and Adefolalu *et al.* 2019 where administration of the methanol/aqueous extracts of Ocimum *gratissimum*, Senecio *biafrae*, Momordica *charantia*leaves and methanolic extract of Hibiscus *sabdariffa* seed, respectively showed a significant increase in the HDL level of all treated diabetic rats on a dose-dependent rate. The significant increase observed in HDL levels across the experimental/treated groups in the present study could be as a result of the reduction in LDL cholesterol level. HDL particles remove fats and bad cholesterol from cells, including atheroma (a fatty substance that forms plaque in the arteries), and transports it back to the liver for excretion or re-utilization. Hence, the higher native HDL levels are correlated with better cardiovascular health.

Table 5: Effect of the aqueous extracts of the leaves on the high density lipoprotein (HDL) level of treated alloxan-induced diabetic rats

Groups	Baseline	End-line	MD	T	%D
P. crispum$_{500}$	38.99 ± 28.10	52.40 ± 3.55	-13.41 ± 0.25	-105.96**	34.39
B. pilosa$_{500}$	33.50 ± 4.85	58.52 ± 3.75	-25.02 ± 0.22	-230.16**	74.69
L. taraxa$_{500}$	44.16 ± 4.76	60.32 ± 1.15	-16.16 ± 0.09	-325.38**	36.59
V. doniana$_{500}$	38.60 ± 2.60	45.20 ± 1.85	-6.60 ± 0.48	-27.69**	17.10
P. crispum$_{1000}$	36.50 ± 4.98	58.00 ± 1.20	-21.50 ± 0.53	-80.31**	58.90
B. pilosa$_{1000}$	32.70 ± 5.90	60.20 ± 5.84	-27.50 ± 0.49	-112.27**	84.10
L. taraxa$_{1000}$	30.58 ± 31.38	56.24 ± 2.85	-25.66 ± 0.06	-791.89**	83.91
V. doniana$_{1000}$	34.71 ± 31.10	62.34 ± 2.25	-27.63 ± 0.32	-170.97**	79.60
UN	48.35 ± 4.60	50.20 ± 7.20	-1.85 ± 0.25	-14.88**	3.83
DU	32.38 ± 41.01	20.84 ± 4.01	11.54 ± 0.18	128.89**	35.64
DT	36.81 ± 31.70	41.90 ± 5.1	-5.09 ± 0.08	-130.70**	13.83

MD = mean difference; Std error = standard error; df = degree of freedom; t = t-test value; %D = percentage difference; * = ($P < 0.05$); ** = ($P < 0.01$); baseline = after induction; end-line = after treatment; *L. taraxacifolia*; UN = untreated non-diabetic; DU = diabetic untreated; DT = diabetic treated with standard drug.

4.0 Conclusion

The study showed that aqueous leaf extracts of *P. crispum*, *B. pilosa*, *L. taraxacifolia* and *V. doniana* offer benefits such as ameliorating diabetes mellitus on a dose-dependent rate. The use of aqueous leaf extracts as a therapeutic agent in the treatment of diabetes mellitus was observed to produce improved anti-dyslipidaemic and greater ameliorative effectswith *B. pilosa* and *L. taraxacifolia* most likely to produce more improved effect at a dose-dependent rate.

5.0 Recommendations

Further investigation in human subject is recommended to confirm the observed results.Further studies should also be carried out to investigate the ameliorative effect of the use of *P. crispum*, *B. pilosa*, *L. taraxacifolia* and *V. doniana*leaf extracts on haematological parameters of induced diabetic and rats.Food industries should be encouraged to incorporate *P. crispum*, *B. pilosa*, *L. taraxacifolia* and *V. doniana* leaves in food products in the right proportion in a bid to diversify diets and promote its therapeutic function on diabetic conditions.




Petroselinum *Crispum* **Biden *Pilosa*Launacea *taraxacifolia*** **Vitex *doniana***

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