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Research Article
Hypoglycemic, Hypolipidemic and Antioxidant Activities of *Musa paradisiaca*, Normalis (Plantain) Supplemented Diet on Alloxan Induced-diabetic Albino Rats

[1]Friday O. Uhegbu, [2]Chinedu Imo and [1]Chibuzo H. Onwuegbuchulam

[1]Department of Biochemistry, Faculty of Biological and Physical Sciences, Abia State University, PMB 2000, Uturu, Nigeria
[2]Department of Biochemistry, Faculty of Pure and Applied Sciences, Federal University Wukari, Taraba State, Nigeria

Abstract

Background: This study investigated the effect of unripe *Musa paradisiaca* (plantain) supplemented diet on serum blood glucose, lipid peroxidation, cholesterol and some antioxidant enzymes on alloxan induced-diabetic albino rats. **Materials and Methods:** Fifty healthy male albino rats weighing between 86-110 g and aged 6 weeks were used for the study. The rats were placed randomly into five groups of 10 animals each. Group 1 served as control and was not diabetic induced and fed on normal diet. Group 2 served as negative control, they were diabetic induced and fed on normal rat chow. Groups 3-5 were diabetic induced and fed *Musa paradisiaca* supplemented diet 10, 20 and 30%, respectively for 21 days. Induction of diabetes was by administering intraperitoneally 150 mg kg^{-1} b.wt., alloxan hydrate to the animals. After 21 days of feeding, animals were starved overnight, anaesthetized with chloroform, killed and blood collected by cardiac puncture. Serum blood glucose, lipid peroxidation, cholesterol and antioxidant enzymes: Superoxide dismutase, catalase, gluthathione-s-transferase and reduced gluthathione were assayed. Data obtained were subjected to one way analysis of variance (ANOVA) and group means were compared using Duncan's new multiple range tests. Differences were considered to be significant at ($p \leq 0.05$). **Results:** The study reveals that 30% *Musa paradisiaca* supplemented diet reduced significantly ($p \leq 0.05$) serum blood glucose, 223.42±3.65 to 98.54±2.36 mg dL^{-1}, total serum cholesterol and lipid peroxidation levels 149.97±1.35 to 133.23±0.61 mg dL^{-1} and from 8.96±0.65 to 6.87±0.86 mg dL^{-1}, respectively. Antioxidant enzymes increased significantly ($p \leq 0.05$), superoxide dismutase 25.30±3.28 to 32.72±3.68 U L^{-1}, catalase 2.76±0.05 to 3.45±0.11 U L^{-1}, reduced glutathione 2.86±0.41 to 3.86±0.62 U L^{-1} and gluthatione-s-transferase 6.86±0.86 to 9.76±1.32 U L^{-1} in the test animals. **Conclusion:** The plantain supplemented diet elicited hypoglycemic, antilipidemic and antioxidant effects on rats that were fed the diet. The plantain is rich in phytochemicals which may have caused these observed effects and could be of nutritional and clinical importance in the management of diabetes and cardiovascular disease and justices the claim of alternative medicine practitioners that plantain could be used in the management of diabetes.

Key words: Nutrition, carbohydrate metabolism, cardiovascular disease, arthrosclerosis, phytochemicals

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Corresponding Author: Friday O. Uhegbu, Department of Biochemistry, Faculty of Biological and Physical Sciences, Abia State University, PMB 2000, Uturu, Nigeria Tel: +234(0)8035426500

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Diabetes is not a single disease entity but a syndrome characterized by an absolute or relative lack of insulin leading to a persistent elevation of blood as well as alteration in lipid and fat metabolism[1,2].

Diabetes is a chronic disease; it affects the breakdown and utilization of carbohydrate, protein and fat, water and salt, resulting sometimes in very grave consequences[3]. This derangement of metabolic activities is frequently associated with permanent and irreversible functional and structural changes in the cells of the body, with those of the blood vessels being particularly susceptible[4]. Glucose usually spills over into the urine and this is associated with polyuria and loss of weight, acute complication of keto-acidosis and other ocular and vascular complications[5]. Untreated diabetes can cause many complications, which include diabetic ketoacidosis and nonketotic hyperosmolar coma[6]. It has been reported that about 382 million people have diabetes worldwide and diabetes being responsible for 1.5-5.1 million deaths per year, making it the leading cause of death[7,8].

There are findings which link obesity, infections, trauma, emotional stress and over-nutrition with the emergence and severity of diabetes as seen clinically[9]. There are basically two groups of diabetes mellitus. The type I-Insulin Dependent Diabetes Mellitus (IDDM) which often involves ketosis and usually referred to as juvenile onset diabetes mellitus and type II-Non Insulin Dependent Diabetes Mellitus (NIDDM) which is referred to as adult onset diabetes mellitus and does not involve ketosis[10,6].

Diabetes is also regarded as a disorder of carbohydrate and fat metabolism that is complicated by elevated artherosclerosis and other abnormalities of the blood vessel and it is argued that serous control of the disease with insulin and diet delayed or even prevented these vascular complications[11]. In the management of diabetes mellitus, dietary control is central to successful treatment of the disease but is also accompanied when necessary by insulin or oral hypoglycemic drugs[12].

Musa paradisiaca (plantain) belongs to the Musaceae family which is evergreen tropical giant herbs. The fruits can be consumed either as ripe or unripe; either cooked roasted, steamed, baked or grilled[13]. Unripe plantain meal is usually consumed by Nigerian diabetics to reduce postprandial glucose[10]. Proximate composition of unripe plantain shows it contain, moisture 0.46%, protein 8.10%, fat 1.10%, fiber 1.50% and ash 1.10%. It also contain carbohydrate 83.40%, pulp 63.35%. It is also a major carbohydrate source and rich in vitamin K and provitamin A and vitamin C. It contains significant quantities of saponins, flavonoids, alkaloids and tannins[14-16]. It has been reported that plantains are good source of vitamin B complex, vitamin C, A and E, high potassium and low sodium[17,18].

Alternative medicine practitioners prescribe unripe plantain *Musa paradisiaca* diet for diabetic patients and claim it lowers blood glucose level. It is also used for treatment of ulcer and wound healing due to its hypoglycemic, anti-ulcerogenic and analgesic properties[19]. The plantain sap is used for the treatment of diarrhea, dysentery, hysteria and epilepsy, while a cold infusion of the plantain plant root is used to treat veneral diseases. The plantain fruit is used as antiscorbutic, aphrodisiac, anemia and diuretic[20].

The present study is therefore designed to investigate this claim vis-à-vis its effect on serum glucose level, cholesterol levels and some serum antioxidant enzymes in alloxan-induced diabetic albino rats.

MATERIALS AND METHODS

***Musa paradisiaca* (Plantain):** Healthy *Musa paradisiaca* (unripe) plantain was bought as sold from Eke Okigwe market and was identified at the Department of Plant Science and Biotechnology Abia State University, Uturu.

Processing of *Musa paradisiaca*: The unripe *Musa paradisiaca* was washed clean with tap water. The plantain was then depulped, cut into pieces and sun dried to a constant weight. The dried pulp was then milled into a fine powder (flour) and used to formulate the diet for the investigation (Table 1).

Animals: Fifty apparently healthy male albino rats weighing between 86-110 g and aged 6 weeks were used for this study. The rats were placed randomly into 5 groups of ten animals each. Group 1 served as control (non diabetic). Group 2 served

Table 1: Dietary composition of *Musa paradisiaca* supplemented diet

	Control diet	*Musa paradisiaca* supplemented diet (g)		
Diet composition	Control (g)	10%	20%	30%
Corn	69.0	59.0	49.0	39.0
Fish meal	5.0	5.0	5.0	5.0
Ground nut	10.0	10.0	10.0	10.0
Bone meal	5.0	5.0	5.0	5.0
Palm oil	5.0	5.0	5.0	5.0
Unripe plantain	-	10.0	20.0	30.0
Vitamin premix	1.0	1.0	1.0	1.0
Corn starch	5.0	5.0	5.0	5.0
Total	100.0	100.0	100.0	100.0

as diabetic (negative control), groups 3-5 were diabetic and fed the supplemented diet 10, 20 and 30%, respectively.

Induction of diabetes: The groups 2-5 animals were fasted overnight prior to the induction of diabetes. They were administered intra-peritoneally 150 mg kg^{-1} b.wt., alloxan hydrate (Sigma-Aldrich, USA) using 10% physiological saline as vehicle. After 96 h of alloxan administration, blood was collected from the tails of the animals for blood glucose estimation to establish elevated blood glucose level using the fine test glucometer. Rats that had fasting blood glucose level of 200 mg dL^{-1} and above were considered diabetic.

Animal feeding: The group 3-5 animals were placed on the *M. paradisiaca* supplemented diet; 10, 20 and 30%, respectively, while groups 1 and 2 animals were placed on standard rat chow for 21 days. All the animals were allowed feed and water *ad libitum.* Animal weight was recorded every 7 days. All processes involved in the handling of animals and the experiment was carried out according to the standard protocols approved by the Animal Ethics Committee of the Faculty of Biological and Physical Sciences, Abia State University, Uturu, Nigeria.

Collection of blood sample and serum preparation: At the 22nd day of the experiment, the animals were starved overnight, anesthetized with chloroform and killed. Incisions were made into their thoracic cavity. Blood samples were collected by heart aorta puncture using a 10 mL hypodermic syringe and allowed to clot in sample vials. The samples were centrifuged at 3000 rpm for 5 min.

Biochemical sample analysis

Blood glucose determination: Blood glucose was assayed using the glucose enzymatic-colorimetric test kit, produced by Cypress diagnostics (Belgium). The test principle is based on the oxidation of glucose by glucose oxidase to gluconic acid and hydrogen peroxide. The hydrogen peroxide forms a red violet color with a chromogenic oxygen acceptor, phenolaminophenazone in the presence of peroxidase. The color intensity is proportional to glucose concentration in the sample.

Determination of cholesterol and lipid peroxidation: Total cholesterol was determined as described by Richmond[21]. The method is the Ilea's method which is based on the Lieberman-Buchard reaction. The principle involves the reaction of 2.1 mL of Ilea's reagent with 0.1 mL of cholesterol to produce a blue-green colored complex which is measured using a spectrophotometer at a wavelength of 570 nm. Lipid peroxidation was determined according to the method as described by Wallin *et al.*[22]. The method also known as the Thiobarbituric acid reactive substances (TBARS) method. The assay is based on the reaction of a chromogenic reagent, N-methyl-2-phenylindole (R1), with malondialdehyde (MDA) a product of lipid peroxidation at 45°C. One molecule of MDA reacts with 2 molecules of reagent R1 to yield a stable chromophore which is measured using a spectrophotometer at 586 nm.

Assay of antioxidant enzymes: The SOD, catalase, gluthathione-s-transferase (GST) and reduced gluthathione (GSH) was assayed according to the method described by Weydert and Cullen[23], using test kits produced by Biosystem (Spain).

Statistical analysis: Values were represented as Mean±SD. Data obtained were subjected to one way analysis of variance (ANOVA) and group means were compared using Duncan's new multiple range tests. Differences were considered to be significant at ($p \leq 0.05$).

RESULTS

The results of various parameters studied are presented in the Table 2-4.

Table 2 shows the effect of plantain supplemented diet on weight of the experimental animals. The group 2 animals lost weight compared to control group 1. The group 2 animals were diabetic and were fed normal rat chow. The group of animals fed on 10, 20 and 30% plantain supplemented diet respectively had significant ($p<0.05$) increase in body weight compared to group 2 animals (negative control). The increase in weight is percentage plantain supplemented diet dependent as seen in animals fed 30% plantain supplemented diet which gained weight similar to those of the control group. The plantain supplemented diet could have been responsible for the weight increase.

Table 3 shows the effect of the diet on blood glucose level. Group 2 animals are diabetic and placed on normal rat chow, hence the blood glucose level continued to rise compared to group 1 animals (control). The animals placed on

Table 2: Weight of experimental animals (g) after 21 days of treatment

		Plantain supplemented diet (g)		
Group 1 (control)	Group 2 (negative control)	Group 3 (10%)	Group 4 (20%)	Group 5 (30%)
96.74±0.97	83.35±1.54*	91.82±0.87*	94.42±1.86*	96.76±1.12*

Values are Mean±SD of group determinations (n = 10), *Statistically significant ($p<0.05$)

Table 3: Blood glucose, total cholesterol and lipid peroxidation level of animals (mg dL^{-1})

			Plantain supplemented diet		
Parameters	Group 1 (control)	Group 2 (negative control)	Group 3 (10%)	Group 4 (20%)	Group 5 (30%)
Blood glucose	92.68±2.25	223.42±3.65*	174.65±4.54*	137.87±3.55*	98.54±2.36*
Total cholesterol	126.45±0.97	149.97±1.35*	142.68±1.57*	138.46±1.86*	133.23±0.61*
Lipid peroxidation	6.58±0.54	8.96±0.65*	8.54±0.96	7.96±0.75*	6.87±0.86*

Values are Mean±SD of group determinations (n = 10), *Statistically significant ($p<0.05$)

Table 4: Antioxidant enzymes level of animals (U L^{-1})

			Plantain supplemented diet		
Enzyme	Group 1 (control)	Group 2 (negative control)	Group 3 (10%)	Group 4 (20%)	Group 5 (30%)
SOD	30.48±1.49	25.30±3.28*	30.46±3.12*	31.24±2.67*	32.72±3.68*
GST	8.45±1.26	6.86±0.86*	8.57±1.58	9.12±1.47*	9.76±1.32*
GSH	3.48±0.36	2.86±0.41*	2.98±0.03	3.51±0.04*	3.86±0.62*
CAT	3.35±0.75	2.76±0.05*	3.07±0.08	3.26±0.06*	3.45±0.11*

Values are Mean±SD of group determinations (n=10), *Statistically significant ($p<0.05$), SOD: Superoxide dismutase, GST: Gutathione-s-transferase, GSH: Glutathione, CAT: Catalase

the plantain supplemented diet showed significantly ($p<0.05$) reduced blood glucose level compared with group 2 (diabetic group fed on normal rat chow). Animals fed 30% plantain supplemented diet had the blood glucose level reduced to a level comparable with the normal control group 1 (control). The ability to reduce significantly blood glucose level shows the diet has hypoglycemic properties.

Total cholesterol (Table 3) shows the plantain supplemented diet significantly ($p<0.05$) reduced total cholesterol in the animals compared with group 2 (negative control) animals fed normal rat chow. The group fed 30% plantain supplemented diet showed significantly ($p<0.05$) reduced cholesterol level which compares favorably with the group 1 (normal control) animals. The diet may have the ability to cause reduction in cholesterol level and so have hypocholerosterolmic properties.

Lipid peroxidation significantly ($p<0.05$) reduced in the animals fed supplemented diet compared with group 2 (negative control) fed normal rat chow (Table 3). The animals fed 30% plantain diet had the lipid peroxidation level reduced to a level close to those of the normal control group which confirms the hypolipidemic activity of plantain.

The assayed antioxidants (Table 4) shows all the antioxidants significantly ($p<0.05$) increased in the animals fed the plantain supplemented diet compared to the diabetic group 2 which were fed normal rat chow. The plantain diet may have triggered the increased activity of these antioxidants. The diet could be said to have antioxidant activities and could be used to boast antioxidant status of patients who consume plantain.

DISCUSSION

The experimental animals gained weight significantly ($p\leq0.05$) compared to the group 2 animals (negative control) which were fed normal rat chow (Table 2). The negative control group had reduced weight compared to the normal control group. The loss of weight may be due to onset of diabetes which is associated with weight loss[5]. The increase in weight of the diabetic rats fed *M. paradisiaca* supplememnted diet compared to diabetic rats fed normal rat chow from 83.35±1.54 to 96.76±1.12 g may be due to the high protein content of the plantain supplemented meal[15,16], which may have improved the nutritional status of the animals.

The serum blood glucose level of the experimental animals showed significant reduction ($p\leq0.05$) compared with the negative control group from 223.42±3.65 to 98.54±2.36 mg dL^{-1} (Table 3). The plantain is rich in fiber, ash and pulp[15,16]. Glucose absorption in the small intestine of the animals may have been substantially reduced by the fiber and ash[24]. Elevated serum glucose level has been implicated in the etiology of diabetes, ocular and vascular complications[6,25,26].

Factors that enhance the pathogenesis of chronic diabetes include enhanced oxidative stress and changes in antioxidant capacity of the patient[14]. Hyperglycemic levels also contribute to an increased oxidative stress because of the production of several reducing sugars[14]. Reducing sugars easily react with lipids and proteins (a non-enzymatic glycation reaction) which aids the production of Reactive Oxygen Species (ROS)[27]. Therefore the early treatment of diabetes mellitus and reduction of chronic vascular complication lies in the control of postprandial plasma glucose level. The plantain supplemented diet may achieve the purpose of its usage by lowering the glucose level of the experimental animals[25,26].

The serum total cholesterol were significantly reduced ($p\leq0.05$) compared to the negative control group (Table 3). The high fiber content of *M. pardiasica* could have played a role in the reduction of cholesterol absorption from the small

intestine of the experimental animals[24]. The fiber content of the *M. paradiasica* supplemented diet may have contributed to the hypolipidemic properties of the diet. It is also reported that fiber significantly binds to cholesterol hence aid to its excretion[28]. The combined activity of saponins and fiber content of the plantain brings about the reduction in plasma concentration of cholesterol and the lipids. Cardiovascular diseases have been linked to the level of HDL-cholesterol in the body. Several dietary fiber sources have been reported to lower blood cholesterol levels, mostly the fraction transported by Low Density Lipoproteins (LDL). Elevated serum cholesterol and LDL-cholesterol constitute risk factors in the development of cardiovascular diseases[29]. Cholesterol level reduction has positive impacts on cardiovascular disease, especially atherosclerosis which is due to the deposition of cholesteryl esters during their transport in the blood vessels leading to hardening and narrowing of the vessels[30].

Lipid peroxidation (Table 3) reduced significantly ($p \leq 0.05$) in the experimental animals compared with the negative control from 8.96 ± 0.65 to 6.87 ± 0.86 mg dL^{-1}. The plantain is rich in vitamin C and polyphenols which have antioxidant activities. These antioxidants may have protected the cells from lipid peroxidation hence the significant reduction of lipid peroxidation in the experimental animals. Lipid peroxidation is caused by the oxidation of lipids especially the polyunsaturated lipids to generate peroxides and aldehydes which have been implicated in the development of diseases[31].

The antioxidant statuses of experimental animals were accessed by measuring the antioxidant enzymes (Table 4). All the antioxidant enzymes significantly increased ($p \leq 0.05$) in the experimental animals compared with negative control group. The nutritional composition of plantain shows it is rich in phytochemicals; flavonoids, alkaloids and tannins which are phenolic compounds and vitamin C. Antioxidant activity in higher plants have been associated with phenolic compounds[32-34]. The high antioxidant levels of the experimental animals may be due to the high phenolic compounds content of the plantain. Antioxidant activities of plant foods correlate with the phenolic content[35,36]. Vitamin C has also been reported to contribute to the antioxidant activity of plant foods.

The SOD is a spread enzyme that protects cells from ROS attack especially the superoxide radical[37]. The catalase works closely with SOD to prevent free radical damage in the body. The SOD functions by converting the dangerous superoxide radical to hydrogen peroxide, which the catalase converts to harmless water and oxygen[38]. The significant increase ($p \leq 0.05$) of glutathione-s-transferase (GST) and glutathione peroxidase (GSH) is beneficial to the animals. The increase in the activity of GST translates to increased capacity to conjugate and excrete toxic intermediates that can cause diseases like diabetes[39]. The GSH is involved in the reduction of lipid and hydrogen peroxide to eliminate oxidative stress[40].

CONCLUSION

The study revealed that the plantain supplemented diet can be used to reduce blood glucose and blood cholesterol levels. The supplemented diet reduced lipid peroxidation. The diet is also capable of inducing detoxification enzymes through up-regulation of their genes by interacting with antioxidant response elements, hence can increase antioxidant status of the consumer. The study has shown the diet has hypoglycemic, hypolipidemic and antioxidant activities and could be useful in the management of diabetes mellitus, atherosclerosis and oxidative stress.

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