Comparative Analysis of the Anti-diabetic Effects of Cocoyam, Soya Bean & Bambara groundnut flour Fed differently to Streptozotocin (STZ)-induced Diabetic Rats

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ABSTRACT

Background: Diabetes mellitus (DM) with the common type, being, Type 2 Diabetes Mellitus, affects a vast population globally especially within the age range of 20 – 79 years, with the need for cure being prioritized by the World Health Organization, who champions the use of cheaper treatment strategies as a result. Food-based approach including use of medical plants have been canvassed as a preventive and Public Health remedy for the management of DM. Plants foods like Cocoyam (CYN), soya bean (SB), and Bambara groundnut (BGN) have been reported to have health benefits, and hence the need in this study to evaluate and compare the anti-diabetic effects in diabetic rats. **Methodology:** Cocoyam (CYN), soya bean (SB), and Bambara groundnut (BGN) were processed into fine flour, pelletized, oven-dried at 60°C, and stored in airtight container for future use. Insulin resistance and Type 2 Diabetes were induced with low fructose diet and intraperitoneal injection of streptozotocin respectively on fifty-eight male albino rats with weight range of 134 to 247 g. The intervention formulations were administered for 28 days, while blood samples were collected from the killed animals for random and fasting blood glucose levels. **Results and Discussion**: The reports from the study revealed a mean random blood glucose (RBG) levels that changed over the time trend ($F=13.963$, $p<0.001$) with a similar group pattern in weeks 1, 2, 3 and 4 ($F=79.106$, $p<0.01$) ($F=76.755$, $p<0.001$). The mean value of the random blood glucose in the rat group fed on Bambara groundnut (BGN) was better than that of the SB group, which was better than that of the group given CYN (BGN>SB>CYN). When the intervention groups were compared with the control group, the CYN and SB groups had better anti-diabetic outcomes. **Conclusion:** Plant foods, Bambara groundnut, Soya bean and Cocoyam possess anti-diabetic properties but the potency of the hypoglycemic effects when compared showed that Bambara groundnut was more effective in glycemic control in diabetic rats and hence can be used as an additional therapeutic adjunct in the management of Type 2 diabetes mellitus.

Keywords: Diabetic rats, anti-Hyperglycemia, Cocoyam, Bambara groundnut, Soya bean

1. INTRODUCTION

Diabetes mellitus is an autoimmune disease which affects the pancreatic beta cells and which has assumed a public health problem due to the humungous population affected and at risk globally [1]. The defective pancreatic cell damage leads to insulin production insufficiency, uncontrolled rise in blood glucose level and multiple organ damage [2]. Nigeria and other low, low-middle and high-middle income countries are at increasing risk of higher incidence, prevalence rates and daily adjusted life years, than in high-income regions [3].

With the exorbitant orthodox medical care cost, dearth of modern medical equipment and emigration of the human resource for health to advanced countries, management of diabetes mellitus and the attendant complications are in danger [4]. This is worsened by the weak health systems and increasing poverty [5], necessitating alternative management strategies to curtail the rising incidence and prevalence especially in resource-poor countries.

Various strategies advocated included improved physical activity levels and use of recommended dietary patterns and these have very impactful outcomes on the number of new cases and in the seriousness of the disease and its prognosis [6]. In terms of the recommended dietary pattern, the Diabetic Medical Nutrition Therapy, was developed [7] and have been reported to have positive impact on diabetic complications [8].

In furtherance to the recommended dietary pattern for the management of diabetes mellitus, the World Health Organization approved the use of medicinal plants and foods derived from plants [9], since such plants have been documented to possess bioactive components with biological activities *invivo*, especially with plant foods like the Bambara groundnut (*Vigna subterranean*), which has good proximate composition [10, 11] and phytochemicals [12]. The phytochemical content of Bambara groundnut include tocopherols, tocotrienols, and phytosterols which are known to possess antioxidant, antimicrobial, immune-stimulating, platelet aggregation-reducing, hormone metabolism-modulating, and enzyme detoxification properties [13, 14], while the phenolic chemicals in them have α-amylase and α-glucosidase, inhibitory effects [15]. Several studies have reported the hypoglycemic effects of Bambara groundnut in diabetic rats [16].

The roots and tubers such as cocoyam, has been credited with immunomodulatory and antihyperglycemic properties [17. 18], possibly as a result of the presence of bioactive chemicals like peptides, amino acids, flavonoids, and polyphenols, which can stimulate pancreatic β-cells and hepatic enzymes in rats, to regulate blood glucose levels [19]. Various scholars have reported the hypoglycemic and antioxidant activities of cocoyam phytochemicals [20, 21].

Soya Bean (*Glycine max. (L) Merrill*) on the other hand contains varying concentrations of food nutrients [22], and phytochemicals such as isoflavones, oxalates, phytic acids, bioactive peptides and Inositols documented with antioxidant effects [23], antioxidative and immunomodulatory properties. The purpose of this study, is to further establish the hypoglycemic potentials of these plant foods and compare the anti-hyperglycemic potency of such plant foods.

2. MATERIAL AND METHODS

Collection of Plant Materials

Bambara groundnut and soya bean were sourced and soaked in water for ten minutes before washed and oven-dried at 60°C until a consistent weight was obtained, then ground into fine flour, pelletized, and stored for future use. Similarly, the roots of a *Colocasia esculenta* variety known as edeofe in South East Nigeria, was sourced locally, then cleaned, peeled, soaked in water for ten minutes, rinsed, boiled, and oven-dried at 60°C until a consistent weight was reached, before grounding into fine flour, pelletized, and stored in an air-tight container.

Experimental Animals

Fourty-two (42) male albino rats, with weight range 134 to 249 grams, were purchased, and divided into subsets of eight in each cage and with an indelible marker, each rat in the cage were numbered 1 to 8 on their tails. The experiment was conducted under a constant light-dark cycle (12 hours of light and 12 hours of darkness) at room temperature (27^0–30^0 degrees Celsius). The study adhered to ethical guidelines for the use, care, and treatment of laboratory animals as outlined in the NRC [24].

Induction of Insulin Resistance Using Low Fructose Diet

Exactly 10% fructose diet, made by dissolving 30 g of fructose in 300 mL of water, was used to induce insulin resistance in the rats that were acclimated for one week. The low fructose drink was given *ad libitum* for two weeks, at the end of which the blood glucose level was checked using *AcuChek*^{R} glucometer. All the rats were normoglycemic.

Induction of Type 2 Diabetes Mellitus using STZ

On the sixth day following low fructose diet, the normoglycemic rats were given an intraperitoneal injection of streptozotocin (STZ) using the formula for giving extracts to experimental animals [25, 26]. The STZ was dissolved in 50 mL of freshly made buffer (sodium citrate buffer, 0.1M, pH 4.5) to ensure its potency. Blood samples from the tail vein of the STZ-treated rats were taken and with the aid of blood glucometre (Acu-check active^{R}), blood glucose concentrations at 72 hours and on the 12th day post-STZ exposure were tested. Nine rats which were not administered with the STZ, were assigned to the normal control group (Group B) while eight each of the STZ-induced diabetic rats were randomly assigned to the standard control (Group A), negative control (Group B), and intervention groups (Group D). All groups received the same treatment for 28 days: Group C received oral metformin at a dosage of 200 mg/kg administered daily via an oral dispenser at 0.002 ml per kg body weight; Group D received a blend of 50% commercial rat feed and 50% cocoyam flour, as per the methodology outlined by Nnadi and colleagues [27]. Groups A and B were fed a commercial rat diet.

The groups were as follows:

- Group A: STZ-induced Diabetic rats administered with Metformin (Standard Control)
- Group B: Non-diabetic control fed on commercial rat feed (Normal Control)
- Group C: STZ-induced Diabetic rats administered with commercial rat feeds (Negative Control)
- Group D: STZ-induced diabetic rats administered with Bambara groundnut intervention feed, Cocoyam or Soya bean intervention feeds.

Estimation of Blood Glucose,

The random blood glucose level were taken on weeks 1, 2, 3 and 4 using glucometer (Acu-check active^{R}), and at the end of the 28 days intervention period.

Statistical Analysis

The statistical package for social sciences (SPSS Inc., Chicago, IL) version 20.0 was used to analyze the data, which were thus obtained and expressed as the standard error of the mean (SEM) of triplicate for eight rats in each group. Tukey's post-hoc test was used to determine whether the difference between means was statistically significant at P<0.05. The means were compared using a one-way analysis of variance (ANOVA).

3. RESULTS AND DISCUSSION

1.0 Effect on Blood Glucose

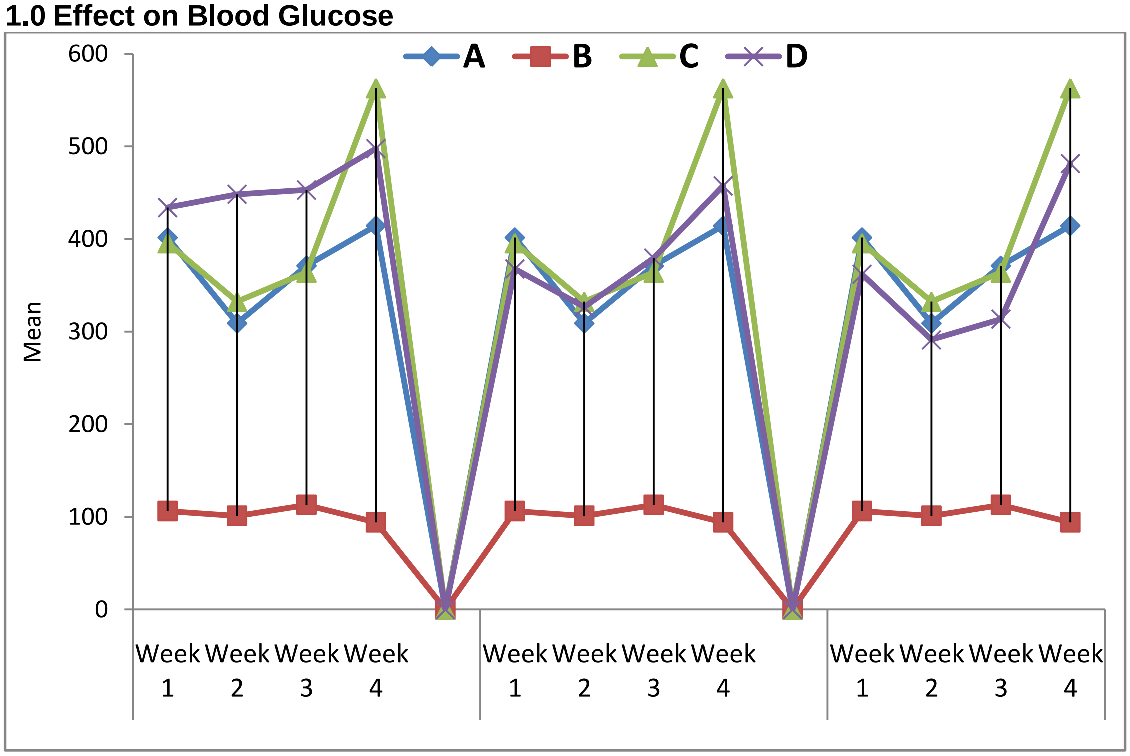

Figure 1: Blood glucose concentrations (Weeks 1-4) for cocoyam, soybean, and Bambara groundnut among the different groups of STZ-induced diabetic and non-diabetic rats. Standard control was represented by A, Normal control by B, Negative control by C and Intervention feed (Cocoyam, Soybean, or Bambara groundnut) by D.

Figure 1 highlighted that in weeks 1-4, the random blood glucose (RBG) was lowest in the normal control group (B). The rats given Bambara groundnuts had better RBG management than the group-fed on soybeans, which was better than the group-fed on cocoyam. In the cocoyam-fed group, the standard control group outperformed the soybean and Bambara groundnut groups in terms of RBG control.

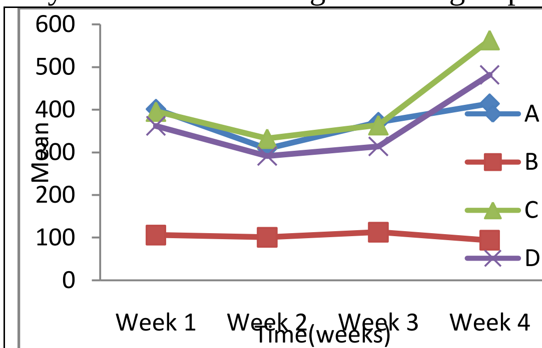

Figure 2: RBG of Bambara groundnut (BGN)-fed Diabetic Rats compared to the control groups

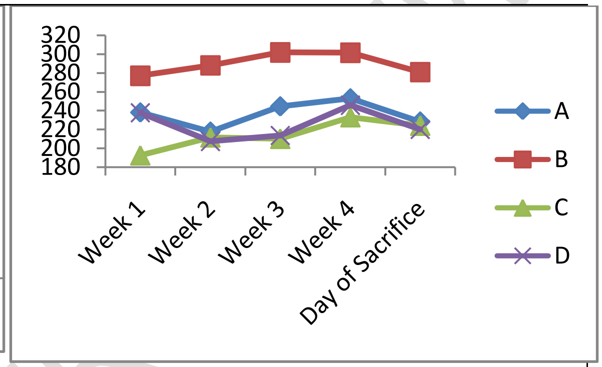

Figure 3: Body weight of Diabetic rats fed on Bambara groundnut (BGN) Flour compared to the control groups

Figures 2 & 3 Shows the Random Blood Glucose (RBG) of the Diabetic Rat group fed on Bambara groundnut flour compared to the control groups and that of their Body weight of the rats over the period Week 1 to week 4.

DISCUSSION

1.0 Effect on Blood Glucose

The investigation's findings revealed that there were significant differences in each group's mean random blood glucose (RBG) readings over time ($F= 13.963$, $p<0.001$), with a consistent pattern of changes from week 1 to week 4. This pattern showed a discernible upward trend from week 1 to week 4 ($F=76.755$, $p<0.001$) and was judged to be significantly parallel ($F=79.106$, $p<0.01$). During weeks 1-3, rats fed on Bambara groundnut outperformed the group-fed with soya beans, which in turn outperformed the group-fed with cocoyam in terms of blood glucose control (Figure 1). The random blood glucose level in the control group was lower than in the cocoyam-fed group, but groups fed with soybean and Bambara groundnut flour had lower RBG mean value than the normal control (Figure 1), implying that that the intervention formulations, would have helped lower hyperglycemia in the STZ-induced diabetic rats. Very importantly from the graph in Figure 1, the decrease in blood glucose level was not linear. There were mean blood glucose variations over the time trend, in resemblance to the usually initial erratic blood glucose control values in diabetic patients on anti-diabetic medication, which had always resulted in the use of combinations of two or more anti-diabetic drugs to attain the best possible glycemic control [28, 29]. There are possibilities that the bioactive compounds in these plant foods might be responsible for these anti-diabetic effects. Soya bean for instance contains phenolic chemicals, monoterpenoids, and naphthalene derivatives. Monoterpenoid derivatives exhibit antidiabetic characteristics due to their capacity to suppress the activities of α-amylase and α-glucosidase [30]. It has also been shown that naphthalene derivatives, such as naphthalene-1-sulfonamide, selectively and potently block Fatty Acid Binding Protein 4 (FABP4), a regulator of inflammatory and metabolic processes and by increasing insulin sensitivity, lowering serum lipid levels and fasting blood glucose, and decreasing hepatic steatosis in obese diabetic mice (db/db), this action helps control immune-metabolic illnesses such as diabetes mellitus [31]. Furthermore, there is significant agonistic activity of naphthalene derivatives on peroxisome proliferator-activated receptors gamma (PPARγ), which lowers blood glucose levels [32].

The potential benefits of cocoyam flour may be explained by the presence of bioactive substances such as artemisinin and phenolics, which are known to have antidiabetic effects [33, 34]. However, the high concentration of cocoyam used in this study might explain why studies by Eleazu and colleagues using lower cocoyam concentrations achieved more significant reductions in blood glucose levels in STZ-induced diabetic rats over a 3 –4 week period [21, 34].

The hypoglycemic effects observed in the Bambara groundnut-fed group could potentially be attributed to the presence of phenolic compounds in the formulations. These bioactive compounds are known to have anti-diabetic properties, which include stimulating glucose ingestion by skeletal muscle cells through the activation of the 5' adenosine monophosphate-activated protein kinase (AMPK) pathway, enhancing glucose metabolism through the inhibition of gluconeogenesis and improvement of glycogenesis in tumour necrosis factor-α (TNFα)-treated insulin-resistant mouse hepatocytes, and elevating the α-amylase and α-glucosidase inhibitory activity in streptozotocin-induced diabetic rats [34]. The presence of phenolics has been linked in some different studies to a decrease in blood glucose levels while fasting [34, 36].

2.0 Relationship of Blood Glucose Control and Rat Body Weight in Bambara Groundnut Fed-Group

Figures 2 and 3 depicted the relationship between the blood glucose control and body weight gain in the diabetic rat group fed on Bambara groundnut, when compared to the standard, negative and normal controls. The normal control had the best blood glucose control followed by the group fed on Bambara groundnut (Figure 2). This clearly showed that the Bambara ground nut-fed group fared better than the group on standard anti-diabetic drug. In terms of the body weight gain, Figure 3 clearly revealed that groups with better glycemic control, gained more weight when compared with persistently poorly controlled hyperglycemic groups. Hence group C, normal control gained the highest weight followed by the standard control and then the group on Bambara groundnut. The negative control had the least weight gain. This finding is in tandem with earlier studies which posited a relationship between blood glucose control and bodyweight gain in diabetic rats [37, 38]. The weight loss in diabetic rats have been linked to various factors including the effect of the streptozotocin and development of necrotic lesions in the tissues [39, 40].

4. CONCLUSION

Streptozotocin-induced diabetes exhibit hypoglycemic responses when administered with Soybean, Bambara groundnut, and cocoyam flour. Among these plant foods, Bambara groundnut flour exhibited better anti-hyperglycemicproperties than cocoyam, soybeans, and the anti-diabetic drug, metformin, implying that consumption of these plant food extracts can be very beneficial to individuals with Type 2 diabetes mellitus. It is also derived from this study that control of blood glucose level in diabetic rats can lead to gain in body weight of the animals. However more research is needed to establish the specific roles played by each of the constituent bioactive compounds in these plant foods.

ETHICAL APPROVAL

Ethical approval was obtained from the Faculty of Basic Medical Sciences, College of Medical Sciences, Rivers State University, Port Harcourt, Nigeria.

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