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Evaluation of Anti-diabetic Synergism of Two African Plants (*Treculia africana* and *Bryophyllum pinnatum*) using STZ-diabetic Models

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ABSTRACT

Diabetics' mortality is mostly attributed to hyperglycaemia and its attendant vascular diseases and is conventionally managed with medicines functioning as hypoglycaemic agents, insulin production-modulators, and lipoprotein-lowering agents singly or in combinations. Some of these agents have adverse side effects hence alternatives are highly sought for the management of disease conditions. Bioactive compounds from plants are sought-after candidates for drug development since they provide lead structures for new or existing drug targets. *Treculia africana* and *Bryophyllum pinnatum* are ethnobotanically used in Africa for the management of diabetes. Effects of aqueous ethanol (80%) extracts of *T. africana* leaves and *B. pinnatum* plants singly and in (1:1) mixture on plasma glucose level (PGL), total triglycerides (TT), high density lipoprotein (HDL) cholesterol, low density lipoproteins (LDL) cholesterol, total cholesterol (TC), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and plasma creatinine levels (PCL) in Streptozotocin (STZ)–induced diabetic rats was checked. A 1:1 *T. africana* and *B. pinnatum* mixture lowered the postprandial blood glucose level from 101.4 ± 2.2 mg/dl to 93.5 ± 1.1 mg/dl in two hrs. Significant reduction ($P \leq 0.05$) in STZ-induced diabetic rats' blood glucose levels, TT levels, and an increase in HDL were also observed. Our results suggest a rapid synergistic hypoglycaemic effect of a combined therapy of *T. africana* and *B. pinnatum* in the management of hyperglycaemia. It provides a very promising lead for a rapid-acting oral hypoglycaemic drug.

Keywords: atherosclerosis, *Bryophyllum pinnatum*, inter and intra synergy, Streptozotocin, *Treculia africana*
Abbreviations: ALT, alanine aminotransferase; **AST**, aspartate aminotransferase; **CVD**, cardiovascular disease; **HDL**, high density lipoprotein; **LDL**, low density lipoprotein; **PCL**, plasma creatinine level; **PGL**, plasma glucose level; **STZ**, Streptozotocin; **TC**, total cholesterol; **TT**, total triglycerides; **TMP**, traditional medical practitioner

INTRODUCTION

The aim of this work was to investigate the effects of aqueous ethanolic extracts of a mixture (1: 1) of two African plants (*Treculia africana* leaves and whole plants of *Bryophyllum pinnatum*) on plasma glucose level (PGL), total triglycerides (TT), HDL cholesterol, LDL cholesterol, total cholesterol (TC), aspartate aminotransferase (AST), alanine aminotransferase (ALT) and plasma creatinine levels (PCL) in Streptozotocin (STZ)-induced diabetic albino rats, a model of type 2 diabetes to explore the possibility of synergistic interactions, potentiation or antagonism of the chemical constituents of the two test plants.

Diabetes is a major risk factor for the development of cardiovascular disease (CVD) (Chattopadhyay and Bandyopadhyay 2005). Hyperglycaemia, the hallmark metabolic abnormality associated with type 2 diabetes (Nathan *et al*. 2009) for instance, leads to an increase in the level of diacylglycerol which activates protein kinase C activity in the aorta of STZ-induced diabetic rats (Inoguchi *et al*. 1994) and dogs (Xia *et al*. 1994). Coronary atherosclerosis is a CVD, which undergoes a complex process that begins with increased numbers of LDL particles entering the sub-endothelial space, the number and size of these LDL particles directly influence the progression of atherosclerosis and the risk of coronary events (Weiss *et al*. 2009). Atherosclerotic lesions develop over many years and pass through several stages (Goff *et al*. 2005).

Interestingly, in developed countries, the people most affected with diabetes are in the lower socioeconomic groups while in developing countries the opposite is true (Mohan *et al*. 2001). Physical inactivity may induce negative effects on relatively fast-acting cellular processes in skeletal muscles or other tissues regulating risk factors like TT and HDL cholesterol. (Hamilton *et al*. 2007). Therefore, the magnitude of the healthcare problem of type 2 diabetes arises not just from the disease itself but also from its association with obesity and cardiovascular risk factors, particularly dyslipidaemia and hypertension (Zimmet *et al*. 2001; Gæde *et al*. 2008).

Type 2 diabetes, known as non-insulin dependent diabetes mellitus (NIDDM), and now recognised as one manifestation of the "metabolic syndrome", a condition characterised by insulin resistance and associated with a range of cardiovascular risk factors (Zimmet *et al*. 2001) has wide-reaching impact on the lives of people. Globally, about 25 to 30% of all diabetics are Black or Hispanic (Diabetes Statistics 1999). Asian Americans have a 60% greater risk for developing diabetes and native American Indians have also exhibited a high incidence of diabetes (Diabetes Statistics 1999). The onset of type 2 diabetes usually precedes clinical diagnosis by several years (National Diabetes Information Clearinghouse 1999) remaining undiagnosed and consequently untreated thereby exacerbating the effects. An increasing prevalence of type 2 diabetes cannot be divorced from the rising frequency of obesity and physical inactivity in society (Laakso 2001; Meigs 2006). The disease progresses when a large amount of fatty acids available to the

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liver in diabetic patients leads to excess acetyl CoA, which is converted to ketone bodies with subsequent damage to the liver (Kathiresan *et al*. 2006; Schindhelm *et al*. 2006). There is then an increment in PC as a result of kidney damage, raised TC, elevated AST and ALT, the last two being indicators of distressed liver function (Kathiresan *et al*. 2006; Schindhelm *et al*. 2006). These aforementioned authors demonstrated associations of this liver enzyme with features of the metabolic syndrome and type 2 diabetes mellitus. The increased availability of acetyl CoA from the β-oxidation of fatty acids is responsible for the subsequent hypercholesterolemia (Horton 1996).

In developing countries, type 2 diabetes is on the increase, especially due to poor diet habits and the unavailability of fruits and vegetables to complement a mostly starchy diet. The disease is assuming an increasing epidemic trend affecting about 10% of the world's population (Burke 2003). It currently also affects children due to the evident rising incidence of obesity in the young. The consequent death and economic cost associated with diabetes is enormous and its treatment can be reviewed and improved to incorporate natural herbs which have been in use from antiquity. There is perceived failure of diabetes treatment with the use of orthodox drugs and emphasis is fast shifting to use of plant products, diet management and exercise. Plant-derived bioactive compounds are attractive candidates for drug development since they represent lead structures for new or existing drug targets (Hellmann *et al*. 2010). Phytotherapy is a holistic approach whereby treatment is approached from several angles and is not much different to some forms of so-called 'conventional medicine' where several drugs are used to treat a particular disorder: cancer would be a prime example, and many types of mental illness are also treated in this way (Williamson 2002). Oriental systems such as traditional Chinese medicine and Ayurveda generally assume synergy to be taking place and it is an intrinsic part of their philosophy (Williamson 2002).

Generally, many herbal drugs are combined in the form of a multi-herbal formula to enhance their functions. The active substances in plants are mostly secondary metabolites, which are used as defence compounds against predators or parasites, for interspecies competition or as signal compounds to attract insects or other animals (Harborne 1990). Plants usually produce and store complex mixtures of compounds from different structural classes to simultaneously interfere with several targets, action which is thought to amplify their efficiency and reduce the risk of resistance development by pathogens (Waterman 1992). Drug delivery systems used in phytomedicines usually assume synergistic effects (Williamson 2002) which could be either intra-synergy i.e. among the active ingredients of a specific drug herb and inter-synergy that is among the different active ingredients of different herbal drugs administered. A herb can be used in treating several diseases, ranging from headache to heart palpitations and a mixture of different herbs can be likewise employed. This possibility of 'cure-all' of a particular herb has been a quandary calling for scientific explanation from natural product scientists.

Some scientists proposed that different chemical compounds in the plants extract performs different functions in a biological system (Ogbonnia *et al.* 2008; Otieno *et al.* 2008) for instance; a prescription of a Nigerian TMP for gall bladder disease can include the following: wormwood (*Artemisia* sp.) as a basic remedy which is the core ingredient in the mixture and has a strong biological function, mango (*Mangifera indica*) bark as an auxiliary remedy as the name suggests; helps the core ingredient, basil (*Ocimum graticimum*) leaves as an improver; this mostly acts on the senses, perking up the medicament through taste, smell, appearance etc, bamboo *Phyllostachys* sp. leaves as a filler adds volume to the mixture, African pepper (*Capsicum frutescens*) as a preservative (Odukoya 2006, unpublished). As can be seen from the above example, each herb in the mixture has a particular function and this is how it has been from antiquity of traditional medical practice.

The relevance of studying synergistic effects lies in being able to prove that it is a reason for the traditional preference of whole extracts to isolated components due to greater efficacy and safety. This proof will then help to solve some of the mystery surrounding the success of traditional medicine that in the past was inexplicable and mysterious.

Treculia africana (Moraceae family) is commonly called breadfruit and is believed to be native to a vast area extending from New Guinea through the Indo-Malayan Archipelago to Western Micronesia (Morton 1987). It is comprised of about 53 genera and 1400 species. Two main varieties are known: *T. africana* var. *africana* (with large fruit heads) and *T. africana* var. *inversa* (with small fruit heads). *T. africana* leaves are simple, alternate, very large, about 30 (max. 50) × 14 (max. 20) cm, dark green, smooth above, tough, paler below with some hairs on the 10-18 pairs of clear veins; tip pointed; a short stalk of about 1.5 cm. Young leaves are red or yellow. They are mainly tropical or subtropical shrubs or trees containing latex. Fruit is often multiple, like *Ficus* sp., chemical constituents reported in the family are cardenolides (in five genera) and pyridine alkaloids (in two genera) (Evans 1996).

The variety used for our studies is var. *africana*. Its grains have an excellent polyvalent dietetic value; the biological value of its proteins exceeds even that of soybeans (Enibe 2006).

A decoction of the leaves is used to manage high blood pressure (Morton 1987) and is said to relieve asthma. Crushed leaves are applied on the tongue as a treatment for thrush, the leaf juice is employed as eardrops, and ashes of burned leaves are used on skin infections. A powder of roasted leaves is used as a remedy for enlarged spleen, crushed fruit is poulticed on tumours to "ripen" them while toasted flowers are rubbed on the gums around an aching tooth (Aderibigbe *et al.* 2010).

The latex is used on skin diseases and is bandaged on the spine to relieve sciatica and diluted latex is taken internally to treat diarrhoea (Morton 1987). In Nigeria, the leaf decoctions are reportedly used in treating diabetes and heart complaints (Aderibigbe *et al.* 2010). The plant is an important food item in parts of southern West Africa. The seeds may be eaten after boiling or frying; many delicacies, including porridges, are commonly produced from the seed. It is a rich source of vegetable oil (10%), protein (17%), carbohydrate (40%), as well as several minerals and vitamins, and is a possible commercial raw material for the production of vegetable oils, pharmaceuticals, soaps, perfumes and paints (Enibe 2006).

Bryophyllum pinnatum (Crassulaceae family) is part of a family of plants that has 35 genera and 1500 species, many of which are perennial xerophytes. An interesting chemical character of the family is the presence, often in large amounts, of isocitric acid; in this family there is a distinctive build-up of malic acid during the dark and the term Crassulacean acid metabolism was given to this particular adaptation of the photosynthetic cycle (Peng *et al*. 1998). *B. pinnatum* is originally a native of South Africa, Madagascar and Asia and is an erect, succulent, perennial shrub that grows about 1.5 m in height and reproduces mostly vegetatively from leaf bulbils (Ojewole 2005). The name *Bryophyllum* comes from *bruo* Greek for 'I sprout' and *jullon* Greek for 'leaf' (Ojewole 2005). The plant, grows profusely and is generally regarded as a weed, It is quite notorious for its growth potential (Gwehenbergera *et al.* 2004). It is reported as a cholesterol-lowering agent (Peng *et al*. 1998). The leaves are eaten fresh with onions to treat high blood pressure and the juice from the leaf is rubbed on limbs of children to treat convulsions (Okwu and Josiah 2006). This plant also has cyanogenetic and cardiac glycosides, tannins and rarely alkaloids (Ojewole 2005).

It functions as an anti-inflammatory, hypoglycaemic, anti diabetic and anticancer agent (Gill 1992). Other studies have shown the following *in vitro* effects in rodent tissue: positive inotropism i.e. increasing the force of contraction

of the heart (Pal *et al.* 1999; Gwehenbergera *et al.* 2004), sedation, H1 antagonism (ileum, bronchial muscle, peripheral vasculature), and antimicrobial activity (Aibinu *et al.* 2007). Decoctions also reportedly help contraction of the uterine wall at childbirth (Gwehenbergera *et al.* 2004).

MATERIALS AND METHODS

Collection and preparation of test plants

The leaves of *T. africana* were collected from Atani 6°1′N 6°45′E in Anambra state of Eastern Nigeria and whole plants of *B. pinnatum* was collected from the same location. They were identified at the Forest Research Institute of Nigeria (FRIN) and assigned herbarium specimen number FHI 107, 720 and FHI 107, 762, respectively. The collected plant specimens were dried using an electric oven at 50°C. The dried leaves and plant parts were then milled with Lab mill (Christy and Norris Ltd. England) to fine particle size that was used for the extraction.

Chemicals

Acetic acid, acetic anhydride, acid alcohol, AST and ALT quantitative *in vitro* determination reagents (Randox, Montpellier, France), BIOLABO triglyceride reagents (France), chloroform, citrate buffer, citric acid, concentrated sulphuric acid, DIALAB glucose enzymatic reagent (Neudorf, Austria), dilute ammonia solution, dilute hydrochloric acid, Dragendorff's reagent (potassium bismuth iodide solution), ethanol, ferric acid in glacial acetic acid, ferric chloride solution 60%, Human cholesterol liquicolor Test Kit (Human, Germany), Jaffé-Reaction (Creatinine Colorimetric test, Human, Austria), Mayer's reagent (potassium mercuric iodide solution), phosphate buffer, sodium citrate, Streptozotocin urea (Sigma, St Louis, MO) and Tween 60. All chemicals were of analytical grade and gotten from BDH Chemical Laboratory (Yorkshire, UK) unless stated otherwise.

Extraction from *T. africana*

T. africana dried leaves weighing 100 g and labelled A was extracted in a Soxhlet extractor in 1.5 L of 80% ethanol for 48 hrs. The extracts slurry was then dried further in an oven (Rostfrei Memmet W. Germany) at 40°C until constant weight was obtained.

Extraction from *B. pinnatum*

B. pinnatum whole plant weighing 100 g and labelled B was extracted using a Soxhlet extractor with 80% ethanol for 24 hrs. The extracts were then concentrated in a rotary extractor (E1M5 UK.) before being transferred to the oven at 40°C until constant weight was obtained.

Extraction from *T. africana* leaf and *B. pinnatum* whole plant

Both plants weighing 100 g (i.e. 50 g each) and labelled C was extracted with a Soxhlet extractor and 1.5 L of 80% ethanol used for 48 hrs. The extracts slurry was then dried further in an oven (Rostfrei Memmet W. Germany) at 40°C until constant weight was obtained.

Phytochemical tests

Alkaloid, anthraquinone, saponin, tannin, Keller Kilani, Kedde, Liebermann's, Salkowski's tests were all carried out according to Harborne (1998).

Diabetes-inducing experiment

The study was carried out with the approval of the University of Lagos Animal Ethical Committee. Healthy, male and female albino rats of about eight weeks old and weighing between 180 ± 5 g were purchased from the animal house of the College of Medicine University of Lagos, Idi Araba Nigeria. The animals were housed in clean metallic cages and kept in a well-ventilated room. Their cages were cleaned regularly. They had free access to water and standard rat diet (Pfizer PLC). They were distributed randomly into five groups of four animals each.

The animals were fed standard laboratory diet, and given water *ad libitum*. After randomisation into various groups, the animals were acclimatized for a period of 6-7 days before the initiation of experiment. Animals described as fasted were deprived of food for at least 12 hrs, but had free access to water.

Diabetes was induced by intraperitoneal injection of Streptozotocin (Sigma, St Louis, MO) IUPAC 1-methyl-1-nitroso-3-(2,4,5-trihydroxy-6-(hydroxymethyl)oxan-3-yl)-urea C8H15N3O7, MW 265.221 g/mol (50 mg/kg body weight) dissolved in 0.01 M citrate buffer (pH 4.5). 72 hrs after STZ injection, diabetes was confirmed in animals showing blood sugar level 200 ± 10 mg/dl. Streptozotocin is a naturally occurring chemical that is particularly toxic to the insulin-producing β-cells of the pancreas in mammals. It is used in medicine for treating certain cancers of the Islets of Langerhans and used in medical research to produce an animal model for diabetes.

Postprandial experiment

This is a blood test which measures the body's ability to metabolize carbohydrates and produce insulin. This test is administered two hours following a meal. Laboratory animals were fasted for 18 hrs with access to water only (Egwim 2005). Blood was taken from the lateral veins of the tail and the blood sugar levels were initially monitored with a glucometer (ACCU-CHEK, Roche Diagnostics).

Treatment and assessment of changes in serum lipid profile

Group A: STZ-induced diabetic + *T. africana* extract; Group B: STZ-induced diabetic + *B. pinnatum* extract; Group C: STZ-induced diabetic + *T. africana* and *B. pinnatum* extract; negative (–ve) control group: STZ-induced diabetic untreated animals; Positive (+ve) control group (non-diabetic) normal animals.

Dosage

T. africana ethanolic leaves extract at a fixed dose (500 mg/kg) was fed to stable hyperglycaemic Group A rats, *B. pinnatum* ethanolic whole plant extract at a fixed dose (500 mg/kg), was fed to stable hyperglycaemic Group B rats, *T. africana* and *B. pinnatum* extract mixture at a fixed dose (500 mg/kg), was fed to stable hyperglycaemic Group C rats, all for a week consecutively. The +ve and –ve control groups received a similar volume of 2% Tween 60. Two weeks after the start of the experiment, test animals were sacrificed, and blood collected for determination of biochemical parameters.

Evaluation of glycaemia and lipidaemic effects of plant drugs

Total cholesterol (TC) concentrations were determined using enzymatic endpoint method (diagnostic kit, Randox, UK). Normal range 50-250 mg/dl. The assay principle is based on the determination of cholesterol after enzymatic hydrolysis and oxidation. The indicator quinoneimine is formed from hydrogen peroxide and 4-amninoantipyrine in the presence of phenol and peroxidase (Trinder 1969).

Statistical analysis of data

Data is reported as mean ± SEM. Statistical comparisons were determined by analysis of variance (ANOVA) and means were separated using Duncan's multiple range test ($P \leq 0.05$) using SAS system analysis version 8.1.

RESULTS AND DISCUSSION

Phytochemical screening of test plants

T. africana percentage yield was 38.6%, *B. pinnatum* per-

Table 1 Phytochemical tests results from *Bryophyllum pinnatum* ethanolic extracts.

Test	Observation
Alkaloids	-
Anthraquinones	-
Cardiac glycosides	+
Saponins	+
Tannins	-

- Absent; + Present

Table 2 Phytochemical tests results from *Treculia africana* ethanolic extracts.

Test	Observation
Alkaloids	-
Anthraquinones	+
Cardiac glycosides	+
Saponins	+
Tannins	+

- Absent; + Present

centage yield was 10.3% and *T. africana* leaf and *B. pinnatum* whole plant had percentage yield of 17.2%. The phytochemical tests (**Table 2**) indicated the presence of steroidal saponins, anthraquinones and polyphenols in *T. africana* and presence of cardiac glycosides, tannins and small amounts of saponins in *B. pinnatum* (**Table 1**) as previously discussed in Ogbonnia *et al*. (2008) and confirmed by Ojewole (2005).

Saponins are amphiphilic compounds that can interact with biomembranes, lyse cells or can form complexes with cholesterol Hellmann *et al*. (2010). Many steroid-containing drugs have been found to lower blood cholesterol and lipids levels in animals and they decrease LDL and very low density lipoproteins (VLDL) cholesterol and increases HDL/TC ratio. Polyphenols, especially such as flavonoids and tannins, have been shown to have numerous health protective benefits Hellmann *et al*. (2010), including the lowering of blood lipids. Furthermore, recent reports have suggested that several plant sterols reduce serum cholesterol by the inhibition of intestinal cholesterol absorption. Also, Vats (2003) reported that fenugreek which contains steroidal saponins, anthraquinones and polyphenols also decreases blood glucose levels.

Postprandial experiment

Postprandial experiment data shows that the three plants extracts (A, B, C) elicited hypoglycaemia compared with the control. Extract C showed better PG-reducing effects after 2 hrs (**Fig. 1**) than A and B. Any herbal extract that can reduce the serum glucose concentration is potentially hypoglycaemic and the results here are consonant with the studies on hypoglycaemic potencies of ethanolic extracts of cashew roots and unripe pawpaw fruits in Guinea pigs and rats as reported by Egwim (2005).

Glycaemia and lipidaemic screening of test plant extracts

There were increases in the levels of PG following the administration of STZ. These were significantly higher ($P \leq 0.05$) than values obtained from +ve control animals (**Table 3**). The levels of PG and TT were lower in groups A, B and C. The PG values from treated animals were almost similar to those of +ve control animals. The HDL cholesterol values for groups A, B, C and the +ve control were significantly higher ($P \leq 0.05$) than values from the –ve control. The observed abnormalities of TT and HDL metabolism are in accordance with reports on early manifestation of insulin resistance, the precursor to diabetes (Zimmet *et al*. 2001; Hamilton *et al*. 2007). Low HDL and high LDL, VLDL cholesterol, and high total and VLDL triglycerides are powerful risk indicators for coronary heart disease events in patients with type 2 diabetes mellitus according to Mohamed and Rashid (2004) and Nathan *et al*. (2009).

An increment in HDL and a reduction in LDL and TC should be considered beneficial in the long-term prognosis of patients as noted by Gæde *et al*. (2008). Group A, B and C animals showed a significant increase in the levels of HDL cholesterol compared to the –ve control group. They had 16.25 ± 2.93, 13.00 ± 0.71 and 10.00 ± 1.15, respectively compared to the –ve control animals with 7.67 ± 1.20. In fact, group A animals had HDL values closest to that of the +ve control animals of 17.67 ± 2.40 (**Table 3**). The LDL values of the diabetic animals was inexplicably low (**Table 3**) compared to the other groups though the low values obtained from Groups A, B, C compared to the +ve control groups show a general reduction of harmful lipoproteins in treated animals. PG concentrations in excess of 190 mg/dl confirmed the diabetic state of the animals as reported by several authors (Henry *et al*. 1974; Ellenberg and Rifkin 1983; Nimenibo–Uadia 2003) when used before treatment with the plant extracts. The +ve control animals did not show any significant change in PG, TC, HDL and LDL levels. The PG of the –ve control animals shows clearly that hyperglycaemia has taken place (**Table 3**). The liver and kidney function results were not significant (data not shown) probably due to the short duration of the experiment.

CONCLUDING REMARKS

The aqueous ethanolic extracts mixture of the two plants, extract C, shows great promise as a fast-acting oral hypoglycaemic and its performance could be attributed to potentiating action of the constituents of the herbal extracts through additive synergistic interactions when compared to the performance of the single extracts. The mixture could be a cheaper alternative for use in diabetes therapy.

When the extract was used for some days though, it performed just as the single extracts. It will be fascinating to find out the specific compounds that interact in the extracts with further studies. The test extracts functioned as oral hypoglycaemic and as statins so further studies will be required on these plants and on their chemical constituents especially with focus on long term effects in order to pinpoint their mode of action and specific active principles for use in the management of diabetes mellitus and CVDs.

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Table 3 Effect of *T. Africana* and *B. pinnatum* extracts and their mixture (1:1) on glucose and serum levels in normal and STZ-induced diabetic rats.

Treatment	HDL	LDL	TC	PGL	TT
A	16.25 ± 2.93 ab	52.25 ± 8.80 ab	78.5 ± 9.44 ab	65.75 ± 3.88 b	49.75 ± 5.71 ab
B	13.00 ± 0.71 abc	42.00 ± 7.38 ab	65.75 ± 7.28 ab	68.25 ± 4.63 b	52.50 ± 3.77 ab
C	10.00 ± 1.15 bc	47.67 ± 5.24 ab	68.67 ± 4.06 ab	85.00 ± 6.66 b	55.00 ± 10.58 ab
Negative control	7.67 ± 1.20 c	35.00 ± 5.51 b	55.67 ± 7.22 b	145.67 ± 34.53 a	67.33 ± 5.78 a
Positive control	17.67 ± 2.40 a	60.33 ± 11.46 a	86.33 ± 13.17 a	70.33 ± 5.21 b	40.00 ± 7.00 b

Values are mean of four observations ± Standard Error of Mean
Means with the same letter in same column are not significantly different using Duncan's multiple range test ($P \leq 0.05$)

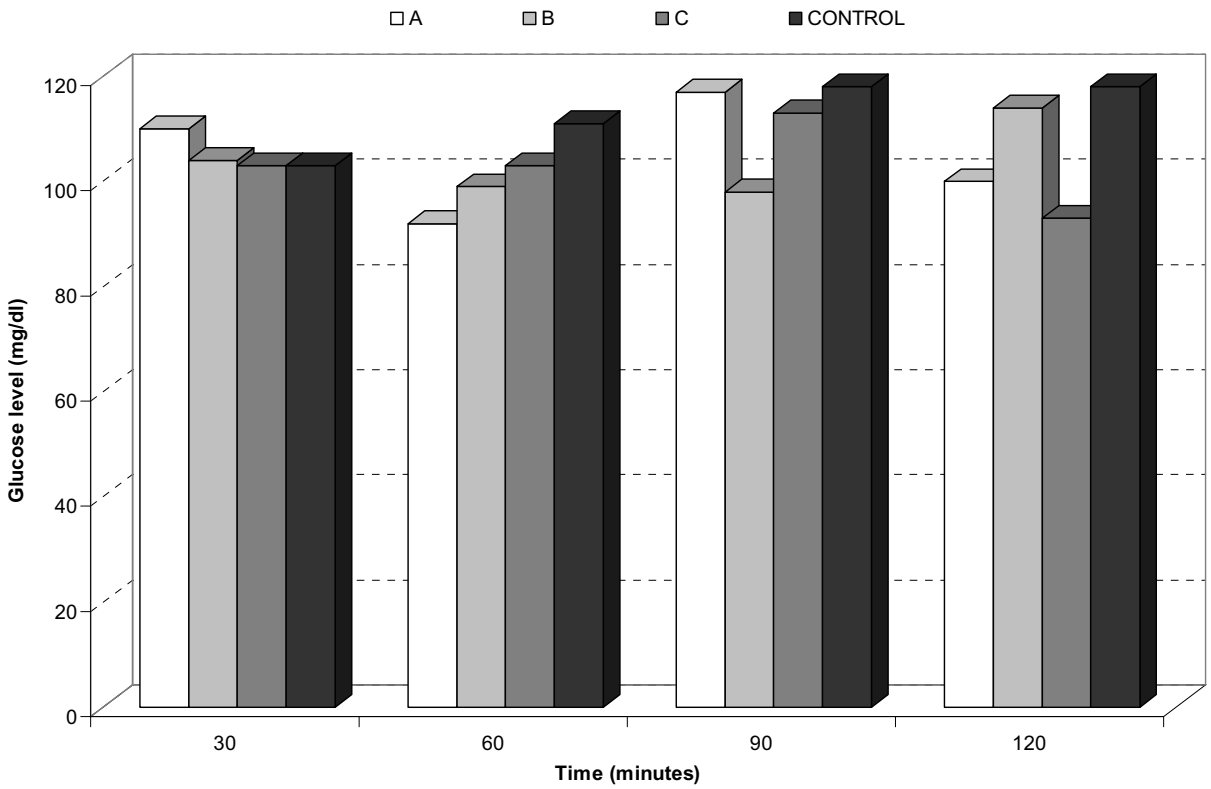

Fig. 1 Post prandial effect of ethanolic extracts of *T. africana* and *B. pinnatum* on glucose levels of normal albino rats. Group **A** = *T. africana* extract; Group **B** = *B. pinnatum*; Group **C** = *T. africana* and *B. pinnatum* (mixture; 1: 1); Group **D** = no treatment (control).

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