

Effect of *Solanum melongena* fruits supplemented diet on hyperglycemia, overweight, liver function and dyslipidemia in male New Zealand rabbits fed high fat and sucrose diet

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Abstract

The aim of the present study is to evaluate the effect of *Solanum melongena* Fruits supplemented diet on hyperglycemia, overweight, liver function and dyslipidemia in male New Zealand rabbits fed high fat and Sucrose solution diet. A qualitative phytochemical analysis of *Solanum melongena* fruits extract was performed using standard methods and phytochemical analysis showed presence of saponin, flavonoids, alkaloids, anthraquinones, tannins, steroids and terpenoids. A total of twenty male New Zealand rabbits with mean weights between 489.00 ± 8.0 to 493.00 ± 10.5 g were divided into five (5) groups (n=4), normal control group was fed normal rabbit chow and experimental groups were fed high fat diet and 30% sucrose solution. Body weights, blood sugar levels, key liver enzymes and lipid profile were examined, and the results demonstrated that, diet supplemented with 10% and 20% of *Solanum melongena* fruit possess a hypoglycemic ability, could aid weight reduction, restored liver function and acted as a good regulator of lipid profile levels.

Introduction

Diabetes mellitus is a metabolic disorder characterized by hyperglycemia and alterations in carbohydrate, fat, and protein metabolisms associated with absolute or relative deficiencies in insulin secretion and/or insulin action [1]. Associated with obesity, there is hyperinsulinemia, high circulating triglyceride and low HDL, and alteration in the sensitivity or reactivity of vascular smooth muscle to neurotransmitters and circulating hormones, which may cause or contribute to diabetic vessel complications [2,3]. In diabetes, the plasma cholesterol level is usually elevated and this plays a role in the accelerated development of atherosclerotic vascular disease, which is a major long-term complication of diabetes in humans [4,5]. Reported that it is clear that diets enriched in sugar and fat result in obesity and it is widely recognized that obesity is a major risk factor for several diseases including Diabetes mellitus and cardiovascular disease. Recapitulated studies in animal models have shown that exposure to diets that resemble those commonly consumed by human's leads to a marked deterioration in a range of metabolic systems [6]. Diets high in sugar and/or a range of fats including both saturated and polyunsaturated fats invariably leads to excess calorie intake and drives animals toward a positive energy balance concomitant with obesity [5].

Medicinal plants have been used since ancient times for the treatment of different diseases. Currently, medicinal plants continue to play an important role in the management of DM, especially in developing countries, where many people do not have access to conventional anti-diabetic therapies [7]. Ethno-pharmacological surveys indicate that more than 1,200 plants are used in traditional medicine systems following claims of their hypoglycemic properties [8,9].

Solanum species (eggplants) belong to the family of *Solanaceae* and the plant genus *Solanum*. *Solanum melongena* is an economically important vegetable crop that is widely cultivated in the tropical [10]. The leaves and fruits serve as vegetables and are used in traditional

medicine [11]. The extracts of *Solanum melongena* has been shown to be effective against a number of diseases, Antidiabetic [1], as an antioxidant [12], hypolipidaemic agent [13], Anti-inflammatory and Vasodilator [14]. Studies revealed that *Solanum melongena* eggplant possess key bioflavonoids, phytochemicals and vitamins alike. Flavonoids, total phenolic, alkaloids, saponins, anthraquinones, tannins, vitamin, A, B, C and E [10,12] and this constituent makes *Solanum melongena* eggplant a potent candidate in abrogating various disease conditions and oxidative imbalance. The nutraceutical power of *Solanum melongena* fruit has been extensively evaluated and rightly made it imperative to investigate its effect on hyperglycemia and dyslipidemia with focus on diet supplementation which is the predominant way of consuming eggplant rather than using the extract from various solvents as reported in existing literatures.

Materials and method

Collection and preparation of plant material

The *Solanum melongena* fruits were obtained from a farmland at Iseyin, Oyo state and were identified by a botanist in the department of botany, University of Ibadan, Oyo state, Nigeria. The samples were washed with water, sliced into pieces, dried at room temperature for three weeks, grounded into powder, then pelletized as feeds for the experimental animals and stored in an air tight container for further use.

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Phytochemical screening

Phytochemical screening of *Solanum melongena* fruits was performed by standard methods according to [15,16].

Experimental animals

Twenty (20) male rabbits (New Zealand) with the average weight of 490g were obtained from Abayomi Farm at Ogbomosho. The animals were allowed to acclimatize for two weeks under standard laboratory condition. During this period of acclimatization, they were fed with standard rabbit chow and allowed free access to clean drinking water.

Preparation of high fat diet

High fat diet was prepared according to method of [17] some with slight modifications (Table 1).

Supplemented feed preparation

The eggplant *Solanum melongena* sample was supplemented into normal diet at two different concentrations (10% and 20%). 10% eggplant supplemented diet had 10g of the eggplant sample mixed with 90g of normal diet while 20g of the sample was mixed with 80g of the normal diet for 20% supplementation. These were thoroughly mixed and made into pellets.

Induction of diabetes and overweight

The experimental animals were fed with the formulated high fat diet and 30% sucrose solution for the period of three (3) weeks.

Study design

A total of twenty (20) rabbits were used for this study, the animals were randomly grouped into 5 groups with four (4) animals in each group.

Group A: Normal control fed with normal diet

Group B: Positive control Fed with high fat diet and 30% sucrose solution for 6 weeks and treated with 20mg/kg Simvastatin for a period of three (3) weeks

Group C: Negative Control Fed with high fat diet and 30% sucrose solution for 6 weeks and remained untreated.

Group D: Fed with high fat and 30% sucrose solution for 6 weeks and subsequently with normal diet supplemented with 10% *Solanum melongena* for 3 weeks

Group E: Fed with high fat and sucrose solution for 6 weeks and subsequently with normal diet supplemented with 20% *Solanum melongena* for 3 weeks

Blood Sugar level and Biochemical Analysis

Blood glucose level was measured using ACCU-CHEK glucometer. RANDOX kit method of enzymatic hydrolysis described by [18] was used for estimating triglyceride, total cholesterol and high density lipoprotein-cholesterol. Alanine aminotransferase (ALT) and Aspartate aminotransferase (AST) were determined using RANDOX kit a method described by [19]. Alkaline phosphatase was determined by standard method according to the recommendation of [20].

Statistical analysis

Data were treated by ANOVA (analysis of variance) and mean separation was done using Duncan multiple range test and Turkey. Paired T-test was used to establish difference in timely events. $p < 0.05$

were considered significant. Data was expressed as means±standard deviation and pictorially presented in form of charts. All statistical analysis was done using IBM SPSS Version 22 and Microsoft Excel.

Results

Qualitative Phytochemical analysis of *Solanum melongena* fruit extract (Table 2) showed positive results for seven (7) out of eight (8) phytochemical tests. Namely: Saponin, Flavonoids, Alkaloids, Anthraquinones, Tannins, Steroids and Terpenoids respectively.

Table 3 shows the hypoglycemic ability of *Solanum melongena* (eggplant) supplemented feed. Fasting blood sugar levels (FBSL) was measured prior to exposure to high fat diet (HFD) + 30% Sucrose solution represented as baseline and no significant difference $p > 0.05$ was observed between all the groups A, B, C, D and E respectively. After exposure to HFD+Sucrose for a period of 6weeks FBSL was also determined and the experimental groups (A, B, C and D) was significantly higher $p < 0.05$ relative to the normal control (Group A). Following confirmation of hyperglycemia, the FBSL was measured on weekly intervals and they was no significant difference $p > 0.05$ between the experimental group at the end of week one. However, at end of week two and three FBSL was significantly lowered in 20% *S. melongena* supplemented fed group (E) relative to the Negative control (group C)

Table 4 demonstrates the weight reduction ability of *Solanum melongena* (eggplant) supplemented feed. Baseline body weight was determined and no significant difference $p > 0.05$ was observed between all groups A, B, C, D and E respectively. After HFD + sucrose exposure, the body weight of experimental groups significantly increased $p < 0.05$ relative to the normal control (Group A). Treatment followed for a period of three weeks and at the end of week one, they were no significant $p > 0.05$ weight reduction observed however, at the end of week two and three the body weight was significantly reduced in the group fed 20% *S. melongena* (group E) and the positive control (group B) respectively relative to the negative control (group C).

Table 1. Feed composition of normal and high fat diet

Composition	Normal diet (%)	High Fat diet (%)
Maize	20	18
Soya bean meal	10	9
Wheat Offal	30	27
Corn bran	15	-
Palm Kernel cake	20	18
Bone meal	3	3
Limestone	2	2
Salt	-	0.3
Grower premix	-	0.3
Rice bran	-	12.4
Pork Lard	-	10

Table 2. Phytochemical screening of *Solanum melongena* fruit extract

Phytochemical	<i>Solanum melongena</i>
Saponin	+
Flavonoids	+++
Alkaloids	+++
Anthraquinones	++
Cardiac glycosides	-
Tannins	+
Steroids	+
Terpenoids	+

(+) indicates presence in trace amount, (++) indicates presence in moderate amount, (+++) indicates presence in strong amount, and (-) indicates not detected.

Table 3. Effect of *Solanum melongena* (eggplant) supplemented feed on the mean fasting blood glucose level of male New Zealand Rabbits

Groups	Baseline (mg/dl)	HFD+Sucrose (mg/dl)	Feed supplementation duration		
			Week 1 (mg/dl)	Week 2 (mg/dl)	Week 3 (mg/dl)
A	68.75±3.4 ^a	72.75±2.9 ^a	72.50±1.9 ^a	72.75±4.5 ^a	71.75±2.9 ^a
B	65.50±9.0 ^a	195.00±4.8 ^b	191.25±4.6 ^{bc}	172.75±7.4 ^{bc}	161.75±5.9 ^c
C	66.25±6.3 ^a	194.75±4.8 ^b	207.75±7.1 ^c	204.73±6.6 ^d	205.50±9.7 ^d
D	71.50±2.5 ^a	193.25±8.7 ^b	191.00±10.8 ^{bc}	181.25±11.2 ^c	157.75±13.1 ^c
E	68.50±6.6 ^a	196.75±11.5 ^b	188.50±11.1 ^b	153.00±12.9 ^b	112.75±8.5 ^b

Data are expressed as means ± SD: Means with different alphabet as superscript within each column variable are considered significantly (p<0.05). The abbreviations denote HFD: high fat diet, A: Normal control, B: Positive control, C: Negative control, D: 10% *S. melongena*, E: 20% *S. melongena*

Table 4. Effect of *Solanum melongena* (eggplant) supplemented feed on body weights of male New Zealand Rabbits

Groups	Baseline (g)	HFD+Sucrose (g)	Feed supplementation duration		
			Week 1 (g)	Week 2 (g)	Week 3 (g)
A	489.00±8 ^a	804.50±10.2 ^a	819.50±10.3 ^a	843.75±15.2 ^a	864.75±5.7 ^a
B	489.25±15.2 ^a	1332.5±46.7 ^b	1351.25±57.8 ^b	1220.50±53.4 ^b	1196.75±61.5 ^b
C	492.25±15.6 ^a	1349.5±42.6 ^b	1376.00±45.3 ^b	1489.5±39.9 ^c	1508.00±39.6 ^d
D	486.75±10.5 ^a	1369.75±46.4 ^b	1385.00±47.1 ^b	1447.00±82.8 ^c	1346.75±49.6 ^c
E	493.00±10.5 ^a	1389.00±9.6 ^b	1400.25±12.5 ^b	1254.75±11.3 ^b	1247.75±10.1 ^b

Data are expressed as means ± SD: Means with different alphabet as superscript within each column variable are considered significantly (p<0.05). The abbreviations denote HFD: high fat diet, A: Normal control, B: Positive control, C: Negative control, D: 10% *S. melongena*, E: 20% *S. melongena*

Liver enzyme

Figure 1 shows effect of *S. melongena* on liver function. At the end of week three of supplemented diet feeding, serum levels of liver enzymes AST, ALT and ALP was respectively was assayed for and they negative control that remained untreated had a significant increase p<0.05 in all the enzyme levels relative to the normal control. for AST, 10% and 20% *S. melongena* supplemented diet fed groups and the positive control significantly showed a decrease levels of AST relative to the negative control (group B). however, 20% *S. melongena* supplemented diet fed group significantly reduced p<0.05 levels of ALT and ALP respectively when compared to the 10% *S. melongena* supplemented diet fed group which was significantly lower than the negative control.

Lipid profile

Figures 2, 3 and 4 respectively shows the effect of *Solanum melongena* (eggplant) supplemented diet on lipid profile levels. Baseline serum levels of Cholesterol (CHOL), Triglyceride (TRIG) and High Density Lipoprotein (HDL) was determined and they was no significant difference p>0.05 between all groups and after exposure to HFD+30% Sucrose for 6 weeks, the experimental groups showed a significant change p<0.05 in lipid profile levels relative to the baseline. Treatment followed for another 3 weeks, 20% and 10% *S. melongena* supplemented diet fed groups and the positive control significantly lowered p<0.05 levels of CHOL and TRIG relative to after HFD+30% Sucrose. However, HDL levels were significantly increased p<0.05 in the treated groups.

Discussion

The present study tried to established hyperglycemia and overweight by feeding male New Zealand rabbits with a formulated high fat diet and 30% sucrose solution a model previously shown to be effective in rabbits and other experimental animals a well [5,21,22]. The result of this study table 3 showed that the formulated high fat diet with 30% sucrose solution (HFD+Sucrose) caused a frank hyperglycemia as they was a significant increase p<0.05 in fasting blood sugar levels (FBSL) in the experimental group relative to the normal control and this indicates that high-fat-/high-sucrose-induced diabetes could have arisen from conjunct effect of lipotoxicity and glucotoxicity [21,23]. *S. melongena* fruits have been shown to be a promising nutraceutical and a

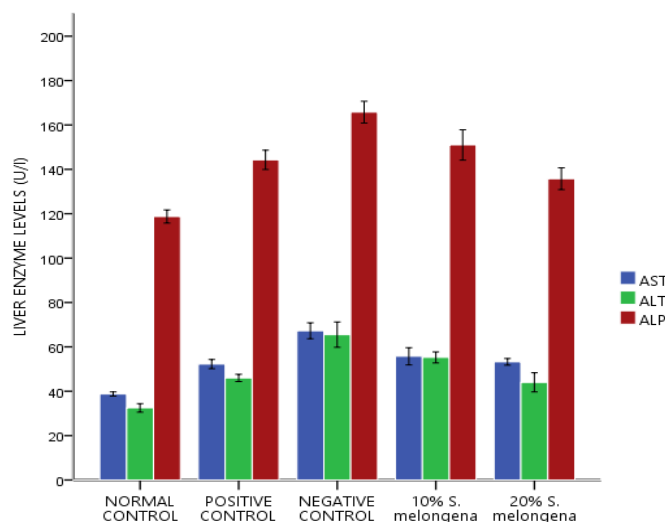


Figure 1. Effect of *Solanum melongena* (eggplant) supplemented feed on liver enzymes of male New Zealand Rabbits

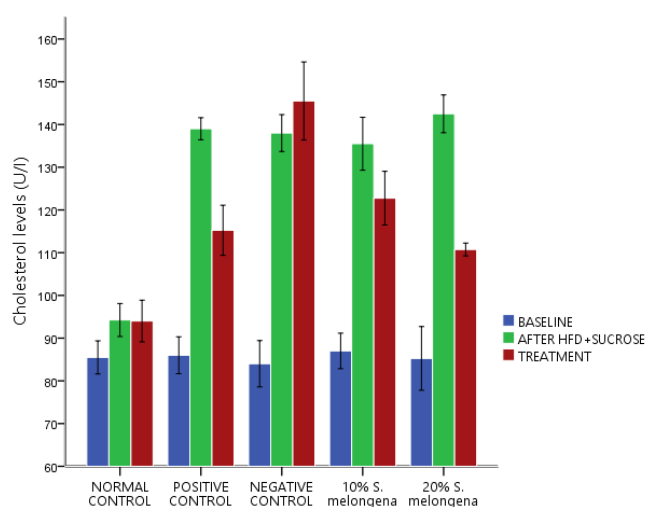


Figure 2. Effect of *Solanum melongena* (eggplant) supplemented feed on cholesterol levels of male New Zealand Rabbits

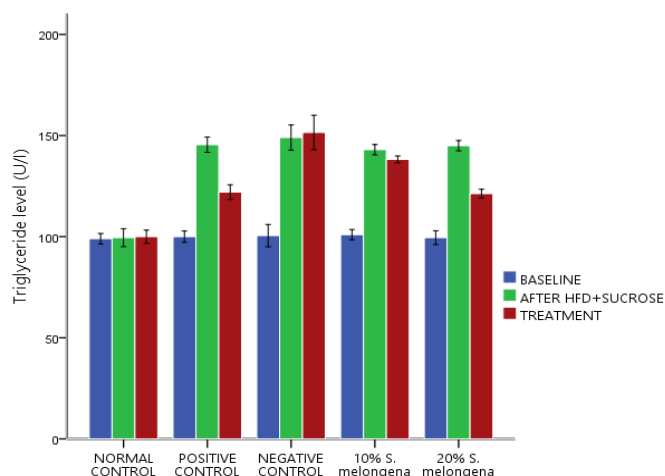


Figure 3. Effect of *Solanum melongena* (eggplant) supplemented feed on Triglyceride level of male New Zealand Rabbits

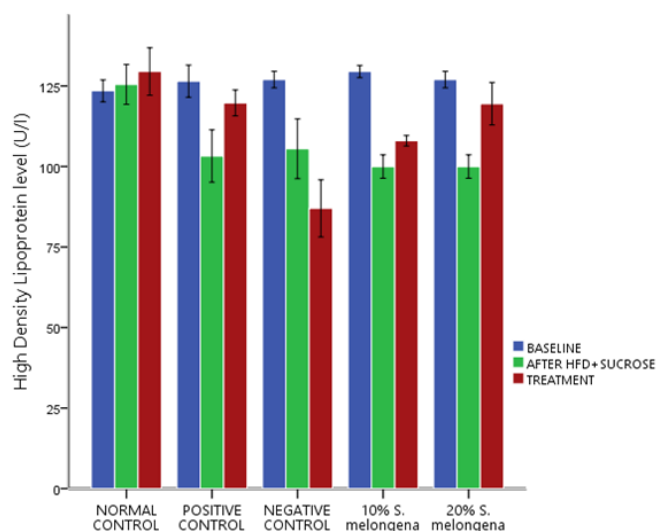


Figure 4. Effect of *Solanum melongena* (eggplant) supplemented feed on High density lipoprotein levels of male New Zealand Rabbits

potent hypoglycemic agent [1,24]. In corroboration, our result revealed that supplementing diet with *S. melongena* fruit is an effecting tool in management of hyperglycemia which characterize diabetes mellitus in that they groups fed both 10 and 20% *S. melongena* supplemented diet significantly reduced FBSL particularly at week two and three and this may be attributed to the presence of key phytochemicals and bioflavonoids.

The epidemic of overweight spreading throughout the world represents one of the major challenges for future human health and diets high in sugar and/or a range of fats including both saturated and polyunsaturated fats invariably leads to excess calorie intake and drives animals toward a positive energy balance concomitant with obesity [5] thus our result table 4 demonstrated that formulated high fat diet (Table 1) with 30% sucrose solution resulted to obvious weight gain an indicator of overweight as they was a significant increase $p < 0.05$ in the body weight of the rabbits in the experimental groups after 6 weeks of feeding relative to the normal control. However, following supplementation of the diet with 10% and 20% of *S. melongena* the body weight was significantly reduced similar to the positive control

treated with 20mg/kg Simvastatin and perhaps reduce the chance of diabetes and other related diseases.

Enzyme activities in the tissues are often used as ‘marker’ to ascertain early toxic effects of administered foreign compounds to experimental animals [25]. ALP is a membrane bound enzyme while ALT and AST are cytosolic enzymes and high levels of ALP, ALT and AST respectively in the serum are indicators of cell membrane permeability and consequent degree of damage to the liver [26]. The observed significant $p < 0.05$ increase in the serum levels of liver enzymes (ALP, ALT, AST) figure 1 in the negative control relative to the normal control indicates that HFD+30% sucrose solution may also be a key player of hepatocellular damage. However, diet supplementation with 10% and 20% of *S. melongena* was able to lower the levels of liver enzymes in male New Zealand Rabbits.

Feeding a carbohydrate- and fat-rich dietary components have been used in animals to induce the signs and symptoms of human metabolic syndrome [27,28] and high serum triglycerides and low High-Density Lipoprotein (HDL) levels are listed among the clustering medical conditions related to metabolic syndrome [29]. Thus, our findings figures 2,3 and 4 respectively demonstrated an alteration in the levels of CHOL, TRIG and HDL after high fat diet and 30% sucrose solution feeding for 6 weeks. However, following supplementation of the diet with 10% and 20% of *S. melongena*, CHOL and TRIG levels were significantly reduced, and HDL levels was significantly increased similar to the positive control treated with 20mg/kg Simvastatin and our result is in consistent with the report of [13,14].

Conclusion

Our result demonstrates that diet supplemented with 10% and 20% of *S. melongena* fruit possess a hypoglycemic ability, aid weight reduction, restores the function of the liver and acts a good regulator of lipid profile levels in male New Zealand Rabbits. However, further studies are still needed to characterize and isolate the potent compound responsible for its positive effect.

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