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Research Article

Hypoglycemic and hypolipidemic potentials of processed and non-processed *Dioscorea dumentorum* (bitter yam) and its blends with *Digitaria exiles* (acha) administered to diabetic rats

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Abstract

Introduction: Diabetes is the most common of the endocrine disorders and poses a serious challenge to health care globally. Objective of the study: To evaluate the hypoglycemic and hypolipidemic potentials of processed and non-processed bitter yam and acha flour blends on diabetic rats.

Methodology: Bitter yam (*Dioscorea dumentorum*) was blanched in hot water at 80ºC for 5 mins, dried at 50ºC and milled into flour. Un-blanched bitter yam flour served as control. Bitter yam blanched at 80ºC for 5 min and the unbalanced was blended with varying levels of acha (*Digitaria exilis*) flour. The hypoglycemic and hypolipidemic potentials of the flour blends were also evaluated using rat bioassay. Data was analyzed using ANOVA and Duncan Multiple Range Test and $p < 0.05$ is significant. Results: Diets formulated with un-blanched bitter yam/acha and blanched bitter yam/acha blends significantly ($p < 0.05$) reduced fasting blood glucose (FBG) of diabetic rats. Diabetic rats fed diet containing 50:50 blanched bitter yam/acha blends reduced FBG by 71.44% while diet containing 50:50 unbalanced bitter yam/acha blends reduced FBG by 72.65%. Diabetic rats fed normal rat chow reduced FBG by 11.22%. Rats fed 100% blanched bitter yam diet and 100% unbalanced bitter yam diet also reduced FBG by 30.39% and 18.40% respectively. The FBG of rats fed blanched bitter yam diet and unbalanced bitter yam diet differed significantly from that of rats fed normal rats chow. The lipid profile of rats fed bitter yam/acha flour blends showed that serum total cholesterol increased from 74.50 to 183.75 mg/dL, triglyceride from 21.50 to 94.00 mg/dL, high density lipoprotein from 44.25 to 56.75 mg/dL, and low density lipoprotein from 60.25 to 149.00 mg/dL.

Conclusion: The blends of bitter yam/acha showed anti diabetic and anti-hyperlipidemia activity in diabetic rats.

Keywords: Blood glucose, Lipid profile, Bitter yam, Acha, Diabetic rats, Blanching treatment

INTRODUCTION

Diabetes is the most common of the endocrine disorders and poses a serious challenge to health care globally. Diabetes mellitus (DM) is characterised by hyperglycemia and changed metabolism of carbohydrate, lipids and protein (Kishalay et al., 2012). It poses threat to health in both developing as well as developed countries. It is ranked

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seventh among the leading causes of death and considered the third cause of death when its total complication is taken into account (Vivek et al., 2010). Due to the high prevalence of this disorder in our society research light is being beamed on the development of appropriate diets that can effect glycemic control and thus can be used to manage the disorder (Nestor et al., 2009). Pertinently noted that dietary management could help reduce the risk of diabetes complication and prolong life expectancy.

Bitter yam (*Dioscorea dumentorum*) is a lesser known yam among the yam species and is underutilized. It is easily identified by its trifoliate leaf. Bitter yam tubers are eaten boiled during the time of famine or scarcity. Yams like other higher plants contain appreciable quantity of phytochemicals like alkaloids, tannins, flavonoids, glycoside, sapogenins, phenols, phytates, and oxalates among others. The most predominant phytochemicals in yams are dioscorine, an alkaloid and diosgenin a saponin. These compounds have been implicated as toxic factors. However, they have been shown to be removed by washing, boiling and cooking (Eka, 1998). Some yam species are consumed as staple, some as traditional specialty foods while some like bitter yam (*Dioscorea dumentorum*) are used for medicinal purposes. In addition, due to their high saponin content especially sapogenin noted that it is the presence of these alkaloids and saponins that confer medicinal properties to bitter yam in particular (Omoruyi, 2008).

Digitaria exilis commonly called hungry rice or “acha” is one of the Lost Crops of Africa. It is described as one of the most nutritious grains and is among the world’s best tasting cereal. Acha contains about 7.0% crude protein and the protein is high in leucine (9.8%), methionine (5.6%) and valine (5.8%). According to Philip & Itodo, (2006) its methionine content is twice as high as those of egg proteins. Thus acha has important potential not only as a survival food crop but also as a complement for standard diets. Its usage has been recommended in weaning food and food for diabetic patients (Temple & Bassa, 1991). This is because of its low glycemic index (Ayo & Nkama, 2003). Low glycemic index foods are those foods that are by virtue of their slow digestion and absorption produce gradual rise in blood sugar and have proven health benefit (Kaniz et al., 2011). They have also been shown to improve both glucose and lipid level of people with Diabetes (Type 1 and Type 2).

Formulation of appropriate diets that can be used for such diet therapy can be achieved through diversification which involves the use of commonly available cereals and legumes with required composition and functional characteristics. Compositing of flours from different plants has been an area of research for many years and has helped in ameliorating malnutrition and essential nutrients deficiencies. The high saponin content of bitter yam and the low Glycemic Index (G.I) characteristic of Acha (Hungry rice) make them good raw material for the development of products that can be used in dietary management of diabetes. The American Diabetic Association reviewed the evidence of glycemic index as a nutrition therapy intervention for diabetics and acknowledged that low glycemic index foods may reduce postprandial blood glucose level (ADA, 2007).

The plant foods that are commonly used in the dietary management of diabetes in Nigeria include breadfruit (*Treculia africana*), Plantain (*M. paradisiaca*) and beans (*Phaseolus vulgaris*). However, the need for diversity of dietary choice due to complaints of dietary monotony among diabetic consumers has prompted the search for other plants with anti diabetic potentials like acha (*Digitaria exilis*) and bitter yam (*Dioscorea dumentorum*). Bitter yam is underutilized yam specie with anti diabetic property. Besides the presence of bitter principle in bitter yam its characteristic property of hardening few days after harvest have limited its use to only scanty traditional culinary applications despite its rich content of bioactive components that needs to be exploited. Processing bitter yam into shelf-stable flour and developing a product with the flour may bring these benefits to the limelight, diversify its use, maximize exploitation of its benefits and consequently add value to the indigenous plant food. Therefore, the objective of the study was to evaluate the hypoglycemic and hypolipidemic potentials of processed and non-processed bitter yam and acha blends on alloxan-induced diabetic rats.

METHODOLOGY

Experimental study design was used to investigate the hypoglycemic and hypolipidemic potentials of *D. dumentorum* and its blends with *D. exilis* administered on diabetic rats.

Sourcing of raw materials

Freshly harvested *D. dumentorum* (yellow Bitter yam) were obtained from Ogige Market in Nsukka, Enugu State, while *D. exilis* (Acha grain) were obtained from Jos Market, Plateau State, all in Nigeria. Rats for bioassay were procured from Department of Veterinary Medicine, University of Nigeria, Nsukka. Chemical (alloxan) for diabetes induction was obtained from credible chemicals suppliers and/or dealers all in Enugu state.

SAMPLE PREPARATION

Processing of Bitter yam tuber flour

The bitter yam tubers (100kg) were peeled, washed with clean water, sliced (1 × 1 cm), and then divided into two portions the first portion was blanched at 80°C for 5 minutes in hot water and the other portion served as the control without treatment. The dried chips were oven dried at 50°C for 24 hours to a constant weight. It was then milled using hammer mill (De-Demark brand, model De-Demark super Gx 160.55) sieved through 0. 25 mm mesh sieve and then packaged in high density polyethylene bags prior for used.

Processing of Acha Grain flour

Acha (*Digitaria exilis*) grain was sorted, cleaned and washed by floatation to remove all the foreign materials, spoilt grains and debris, and then oven dried at 50°C to constant weight. The cleaned dried grains were then milled using hammer mill (De-Demark brand, model De-Demark super Gx 160.55) sieved through 0.25 mm mesh sieve and then packaged in high density polyethylene bags until used.

Formulation of composite flours blends of bitter yam and acha

Flour from blanched and un-blanched bitter yam was formulated with acha flour in varying ratios as seen in **(Table 1).**

Bioassay

One hundred and twenty-eight (128) adult Wistar albino rats, weighed between 117.0 g to 185.0 g were used for the study. Diabetes was induced by a single dose intra peritoneal injection of 1% solution of alloxan (100 mg/kg body weight) dissolved in normal saline and administered within 5 minutes of preparation. Diabetic state was confirmed after 48 hours. Animals with glucose concentration level of 160 mg/dl and above were considered diabetic and were used for the experiment. The animals (rats) were divided into sixteen (16) groups of eight (8) rats each and fed different blends of blanched and un-blanched bitter yam/acha diets for three (3) weeks.

Diet formulation for bioassay

The diet was formulated from blends of the selected treatment sample and untreated sample as shown in **(Table 2).**

Housing of the experimental animals (rats)

The rats were housed in stainless steel cages for 21days at room temperature (28 ± 2°C). They were supplied with water *ad libitum* and normal rat chow (growers mash, vital feed) during the one week of acclimatization period prior to the experiment. At the end of acclimatization period, the rats were induced with diabetes by a single dose intra peritoneal injection of 1% solution of alloxan (100 mg/kg body weight). All the rats were induced apart from those in groups 7, 14, and 16 which were normal and used as controls. The diabetic groups were fed formulated diets composed of blanched and un-blanched bitter yam with acha at varying ratios, while those in groups 7, 14 and 16 were fed 100% blanched bitter yam, 100% un-blanched bitter yam and growers mash, respectively. Daily food intake of the rats was recorded. The grouping of the rats into sixteen (16) groups is displayed in **(Table 3).**

The experiment was performed according to the principles in the guide for the care and use of laboratory animals described by the National Institute of Health. The experimental protocol was made to conform to the rules for ethical conduct within the animals use and care. Ethical clearance was sorted and obtained from the Animal Care and Use Committee, Faculty of Veterinary Medicine, University of Nigeria, Nsukka, Enugu State, Nigeria.

Determination of fasting blood glucose and lipid profile of the rats

The fasting blood glucose (FBG) level of the rats was determined at 4days interval during the experiment. Blood sample was collected from the tip vein of the rat's tail and the FBG was measured using Accu-Chek active glucometer and its strips (model GC, Roche Diagnostics Mannheim, Germany). The lipid profile (total cholesterol, triglycerides, high density lipoprotein and low density lipoprotein) of the rats was done using standard method described by (Eavenson et al., 1996); (Trinder, 1969).

Statistical analysis

Data were analyzed using one-way Analysis of Variance (ANOVA). Duncan multiple range test (DMRT) was to separate the means. Statistical significance was accepted at P < 0.05, while IBM-SPSS statistical package version 22 was used for the analysis.

Table 1. Formulation of composite flours.

Samples	Bitter yam (g)	Acha (g)
Un-blanched bitter yam flour	100	0
	90	10
	80	20
	70	30
	60	40
	50	50
Blanched bitter yam flour	100	0
	90	10
	80	20
	70	30
	60	40
	50	50

Table 2. Composition of the experimental diets for bioassay (g/100g).

Diets Groups	Casein	VIT/MIN Mix	Corn Oil	BBY	UBY	Acha	Control
NF							100
BBY0	15	5	5	100			
BBY10	15	5	5	90		10	
BBY20	15	5	5	80		20	
BBY30	15	5	5	70		30	
BBY40	15	5	5	60		40	
BBY50	15	5	5	50		50	
UBY0	15	5	5		100		
UBY10	15	5	5		90	10	
UBY20	15	5	5		80	20	
UBY30	15	5	5		70	30	
UBY40	15	5	5		60	40	
UBY50	15	5	5		50	50	

***Keys**: BBY= blanched bitter yam diets, UBY= unblanched bitter yam diets, NF= normal feed/diet, BBY0= diet containing 100 % blanched bitter yam, BBY10= diet containing 90:10 blanched bitter yam: acha blends, BBY20= diet containing 80:20 blanched bitter yam:acha blends, BBY30= diet containing 70:30 blanched bitter yam: acha blends; BBY40= diet containing 60:40 blanched bitter yam:acha blends, BBY50= diet containing 50:50 blanched bitter yam:acha blends, UBY0 = diet containing 100 % Unblanched bitter yam, UBY10 =diet containing 90:10 Unblanched bitter yam: acha blends, UBY20 = diet containing 80:20 Unblanched bitter yam:acha blends, UBY30 = diet containing 70:30 Unblanched bitter yam:acha blends, UBY40 = diet containing 60:40 Unblanched bitter yam:acha blends, UBY50 = diet containing 50:50 Unblanched bitter yam:acha blends.*

Table 3. Grouping of rats based on treatment diets.

Treatment groups	Condition of animal	Codes	Diet administered
Group 1	Diabetic	$DBBY_0$	100:0 (balanced bitter yam:acha)
Group 2	Diabetic	$DBBY_{10}$	90:10 (balanced bitter yam:acha)
Group 3	Diabetic	$DBBY_{20}$	80:20 (balanced bitter yam:acha)
Group 4	Diabetic	$DBBY_{30}$	70:30 (balanced bitter yam:acha)
Group 5	Diabetic	$DBBY_{40}$	60:40 (balanced bitter yam: acha)
Group 6	Diabetic	$DBBY_{50}$	50:50 (balanced bitter yam:acha)
Group 7	Normal	$DBBY_0$	100:0 (balanced bitter yam: acha)
Group 8	Diabetic	$DUBY_0$	100:0 (unbalanced bitter yam:acha)
Group 9	Diabetic	$DUBY_{10}$	90:10 (unbalanced bitter yam:acha)
Group 10	Diabetic	$DUBY_{20}$	80:20 (unbalanced bitter yam:acha)
Group 11	Diabetic	$DUBY_{30}$	70:30 (unbalanced bitter yam:acha)
Group 12	Diabetic	$DUBY_{40}$	60:40 (unbalanced bitter yam: acha)
Group 13	Diabetic	$DUBY_{50}$	50:50 (unbalanced bitter yam:acha)
Group 14	Normal	$NUBY_0$	100:0 (unbalanced bitter yam: acha)
Group 15	Diabetic	DNF	Growers mash
Group 16	Normal	NNF	Growers mash

***Keys:** DNF= Diabetic rats fed diets normal feed/diet, NNF= Normal rats normal feed/diet, : BBY0= Diabetic rats fed diets containing 100 % blanched bitter yam, BBY10= Diabetic rats fed diets diet containing 90 % blanched bitter yam: 10 % acha BBY20= Diabetic rats fed diets diet containing 80 % blanched bitter yam: 20 % acha, BBY30= Diabetic rats fed diets diet containing 70 % blanched bitter yam: 30 % acha, BBY40 = Diabetic rats fed diets diet containing 60 % blanched bitter yam: 40 % acha, BBY50= Diabetic rats fed diets diet containing 50 % blanched bitter yam: 50 % acha, UBY0 = Diabetic rats fed diets diet containing 100 % Unblanched bitter yam: 0 % Acha blends, UBY0= Diabetic rats fed diets diets conataining 100 % unblanched bitter yam, UBY10 = Diabetic rats fed diets diet containing 90 % Unblanched bitter yam: 10 % Acha blends, UBY20 = Diabetic rats fed diets diet containing 80 % Unblanched bitter yam: 20 % Acha blends, UBY30 = Diabetic rats fed diets diet containing 70 % Unblanched bitter yam: 30 % Acha blends, UBY40 = Diabetic rats fed diets diet containing 60 % Unblanched bitter yam: 40 % Acha blends, UBY50 = Diabetic rats fed diets diet containing 50 % Unblanched bitter yam: 50 % Acha blends.*

RESULTS

Blood glucose level of treated alloxan-induced diabetic rats

Blood glucose did not change significantly ($p > 0.05$) in the control diabetic rats group fed normal diet (DNF) all through the 21 days of the experiment whereas the experimental diets containing blanched and un blanched bitter yam: acha flour blends at all levels of blending produced significant changes in the blood glucose level of the rats especially after the 4th day of the experiment. The diabetic rats group fed normal rat chow (DNF) showed increased blood sugar concentration

(> 200 mg/dL) up to the end of the 21st day while other diabetic rats groups that were fed the experimental diets showed reduced blood glucose concentration (< 200 mg/dL). There were significant ($p < 0.05$) differences between the blood glucose level of rats fed unblended un blanched diet ($DUBY_0$) and those fed blanched unblended bitter yam ($DBBY_0$) when compared with the glucose level of the diabetic rats fed normal rat chow (NF). Significant ($p < 0.05$) decreases observed in the blood glucose level of diabetic rats that were fed experimental diets formulated with blanched and un blanched bitter yam: acha blend show that the diets exhibited hypoglycemic effect Table 4.

Lipid profile level of treated alloxan-induced diabetic rats

Table 5. shows the lipid profile of rats that were fed blanched and un blanched bitter yam acha flour blend diets. There were significant differences ($p < 0.05$) in the total cholesterol (Tchol) level of the diabetic rats and non-diabetic rats fed the experimental diets. Diabetic (control) rats fed the normal rat diet (DNF), blanched bitter yam diet ($DBBY_0$) and un blanched bitter yam diet ($DUBY_0$) showed initial marginal ($p < 0.05$) differences in their total cholesterol (120.75 mg/dL, 86.00 mg/dL and 74.50 mg/dL respectively). Diabetic rats fed diet $DUBY_0$ had the highest Tchol value of 183.75 mg/dL which differed significantly ($p < 0.05$) from that of those diet containing blanched bitter yam ($DUBY_0$) (114.25 mg/dL) reflecting the effects of the blanching treatment. Diabetic group fed diet DBBY50 had the lowest final Tchol value of 99.00 mg/dL. There were significant differences ($p < 0.05$) in high density lipoprotein (HDL) level among the diabetic rats and control rat groups fed the experimental diets. Diabetic control group fed $DUBY_0$ had the highest HDL value of 94.50 mg/dL which differed significantly ($p < 0.05$) from the HDL value of the diabetic rat groups fed ($DUBY_0$) and DNF while the group fed diet $DBBY_{50}$ had the lowest HDL value of 48.50 mg/dL. The level of low density lipoprotein (LDL) known as the bad cholesterol differed significantly ($p < 0.05$) among the experimental groups that were fed diets from blanched and unbalanced bitter yam andtheir blends with acha. There was an obvious increase in theLDL value of all the experimental rats fed the blanched and unbalanced bitter yam and their blends with acha flour diet, showing that the diet did not reduce the LDL of the rats. The diabetic (control) rats (DNF) showed lower LDL value of 47.00 mg/dl while the diabetic rats fed the experimental diets showed LDL values ranging from 50.75 mg/dL to 84.50 mg/dL. The LDL value (48.75 mg/dL) for diabetic rats fed UBY_0 was lower than the LDL value (76.00 mg/dL) of rats fed BBY_0Triglyceridelevel of the diabetic and normal rats was within the normal range of below 150 mg/dL at both the initial and final stages. Rats fed 100% Un blanched bitter yam (UBY_0) diet exhibited ahigher triglyceride level of 149.0 mg/dL than the rats fed other treatment diets (**Tables 4 and 5).**

Table 4. Influence of the experimental diet of the blood glucose level of treated diabetic rats (mg/dL).

Treatment	0 day	4th day	8th day	12th day	16th day	21st day
DBBY0	305.0^{a} ± 25.98	278.80^{c} ± 18.74	236.0^{c} ± 21.79	208.20^{c} ± 17.34	178.40^{b} ± 27.65	148.80^{b} ± 18.24
DBBY10	306.25^{a} ± 29.83	276.50^{c} ± 20.8	236.25^{c} ± 24.96	210.50^{c} ± 19.12	185.50^{b} ± 26.13	127.75^{c} ± 7.18
DBBY20	283.25^{a} ± 17.46	277.75^{c} ± 15.82	242.0^{c} ± 5.42	204.75^{c} ± 10.18	184.00^{b} ± 7.07	118.25^{c}±6.70
DBBY30	321.75^{a} ± 46.68	284.25^{bc} ± 20.47	253.75^{bc} ± 32.38	212.25^{c} ± 21.91	190.25^{b} ± 20.11	109.00^{cd} ± 6.98
DBBY40	316.0^{a} ± 10.98	287.0^{bc} ± 14.85	259.0^{bc} ± 16.23	211.25^{c} ± 32.37	184.75^{b} ± 26.48	103.50^{d} ± 23.22
DBBY50	302.50^{a} ± 14.18	291.25^{b} ± 5.91	258.75^{bc} ± 7.80	226.75^{bc} ± 11.00	176.50^{b} ± 12.48	91.75^{d} ± 13.20
NBBY0	101.0^{b} ± 16.45	99.00^{d} ± 15.53	91.50^{d} ± 9.98	92.50^{d} ± 09.00	099.25^{c} ± 02.06	70.00^{f} ± 07.26^{e}
DUBY0	290.00^{a} ± 18.69	264.75^{c} ± 16.07	215.0^{c} ± 16.07	188.75^{c} ± 25.04	165.25^{b} ± 21.08	122.00^{c} ± 8.12
DUBY10	305.50^{a} ± 9.98	284.0^{bc} ± 19.51	248.50^{c} ± 29.51^{b}	208.25^{c} ± 25.04	181.00.^{b} ± 17.98	120.25^{c} ± 14.27
DUBY20	306.50^{a} ± 36.24	281.50^{bc} ± 29.42	242.75^{c} ± 32.71	212.75^{c} ± 24.30	165.25^{c}±18.39	118.75^{c} ± 13.14
DUBY30	297.0^{a} ± 41.68	275.25^{c} ± 48.82	245.75^{c} ± 32.71	214,25^{c} ± 43.90	170.50^{c} ± 04.92	115.00^{cd} ± 14.66
DUBY40	332.75^{a} ± 52.18	301.75^{b} ± 33.23	268.50^{b} ± 23.95^{b}	230.25^{b} ± 24.50^{b}	196.25^{b} ± 4.92	113.00^{cd} ± 5.67
DUBY50	333.75^{a} ± 52.18	320.25^{a} ± 50.76	270.75^{b} ± 23.0	235.00^{b} ± 31.10	187.50^{b} ± 09.15	91.25^{d} ± 12.33
NUBY0	115.25^{b} ± 7.54	108.50^{d} ± 12.56	97.25^{d} ± 8.29	77.75^{d} ± 7.04	081.50^{e}±06.19	82.00^{e} ± 6.16
DNF	325.25^{a} ± 53.76	328.75^{a} ± 53.24	308.25^{a} ± 35.72	290.0^{a} ± 31.36	284.75^{a}±13.60	288.75^{a} ± 16.52
NNF	100.50$^{\mathbf{b}}$ ± 1.91	101.25^{d} ± 2.99	100.0^{d} ± 1.63	100.25^{d} ± 10.81	109.75^{d} ± 04.27	111.25^{cd} ± 9.43

Values are means of 4 determinations ± SD. Means in the same column with different superscripts are significantlydifferent (p < 0.05).

***Keys:** DNF: Diabetic rats fed normal feed/diet, NNF:Normal rats normal feed/diet, NBBYO= Normal rats fed containing 100 % blanched bitter yam, NUBY0= Normal rats fed containing 100 % unblanched bitter yam, BBY0: Diabetic rats fed containing 100 % blanched bitter yam, BBY10: Diabetic rats fed diet containing 90 % blanched bitter yam: 10 % acha BBY20: Diabetic rats fed diet containing 80 % blanched bitter yam: 20 % acha, BBY30: Diabetic rats fed diet containing 70 % blanched bitter yam: 30 % acha, BBY40 : Diabetic rats fed diet containing 60 % blanched bitter yam: 40 % acha, BBY50: Diabetic rats fed diet containing 50 % blanched bitter yam: 50 % acha, UBY0: Diabetic rats fed diet Containing 100 % unblanched bitter yam: 0 % Acha blends, UBY0: Diabetic rats fed conataining 100 % unblanched bitter yam, UBY10: Diabetic rats fed diet containing 90 % unblanched bitter yam: 10 % Acha blends, UBY20: Diabetic rats fed diet containing 80 % unblanched bitter yam: 20 % Acha blends, UBY30: Diabetic rats fed diet containing 70 % unblanched bitter yam: 30 % Acha blends, UBY40: Diabetic rats fed diet containing 60 % unblanched bitter yam: 40 % Acha blends, UBY50: Diabetic rats fed diet containing 50 % unblanched bitter yam: 50 % Acha blends.*

Table 5. Influence of experimental diets on the lipid profile of treated diabetic rats (mg/dL).

Sample	**TOTAL CHOLESTEROL HDL LDL TRIGLYCERIDE**							
	Initial	**Final**	**Initial**	**Final**	**Initial**	**Final**	**Initial**	**Final**
DBBY0	$86.00^{cd} \pm 10.80$	$114.25^{e} \pm 7.23$	$35.75^{ab} \pm 18.45$	$62.25^{cd} \pm 8.12$	$45.75^{ef} \pm 14.41$	$76.00^{ab} \pm 9.45$	$73.00^{b} \pm 8.68$	$114.06^{c} \pm 6.26$
DBBY10	$65.75^{de} \pm 13.23$	$129.75^{de} \pm 2.43$	$35.50^{ab} \pm 7.42$	$61.25^{cd} \pm 1.06$	$28.25^{g} \pm 9.84$	$64.25^{c} \pm 1.53$	$57.00^{cd} \pm 0.30$	$88.75^{d} \pm 12.26$
DBBY20	$71.50^{de} \pm 15.26$	$106.25^{b} \pm 6.86$	$40.75^{a} \pm 0.24$	$59.78^{d} \pm 8.18$	$55.00^{c} \pm 1.40$	$50.75^{d} \pm 14.31$	$58.00^{cd} \pm 1.02$	$131.50^{b} \pm 6.38$
DBBY30	$106.00^{bc} \pm 4.45$	$127.75^{de} \pm 4.13$	$47.75^{a} \pm 4.41$	$67.50^{cd} \pm 2.88$	$53.75^{c} \pm 6.68$	$60.25^{c} \pm 4.57$	$76.00^{b} \pm 9.58$	$112.25^{c} \pm 2.28$
DBBY40	$72.25^{de} \pm 11.41$	$145.75^{c} \pm 7.89$	$31.50^{ab} \pm 1.70$	$65.50^{cd} \pm 1.27$	$45.00^{ef} \pm 9.59$	$74.25^{b} \pm 4.92$	$62.75^{c} \pm 0.90$	$130.25^{b} \pm 3.28$
DBBY50	$64.50^{de} \pm 9.71$	$99.00^{f} \pm 8.83$	$21.50^{b} \pm 6.86$	$48.50^{e} \pm 8.38$	$44.25^{ef} \pm 6.70$	$56.75^{d} \pm 6.50$	$60.25^{c} \pm 3.72$	$118.25^{c} \pm 2.72$
NBBY0	$112.25^{ab} \pm 18.87$	$140.25^{c} \pm 15.97$	$47.50^{a} \pm 6.45$	$89.00^{ab} \pm 15.87$	$79.00^{a} \pm 7.16$	$84.25^{a} \pm 9.03$	$91.00^{a} \pm 6.83$	$61.25^{e} \pm 6.08$
DUBY0	$74.50^{de} \pm 4.73$	$183.75^{a} \pm 24.78$	$42.25^{a} \pm 4.57$	$94.50^{a} \pm 12.66$	$36.25^{f} \pm 4.27$	$48.75^{e} \pm 2.53$	$54.00^{c} \pm 7.12$	$149.00^{a} \pm 34.89$
DUBY10	$90.75^{bc} \pm 9.88$	$129.50^{de} \pm 7.14$	$34.75^{ab} \pm 8.18$	$68.00^{cd} \pm 15.75$	$52.25^{cd} \pm 9.32$	$64.50^{c} \pm 7.33$	$72.00^{b} \pm 8.76$	$141.25^{a} \pm 29.92$
DUBY20	$79.75^{de} \pm 5.86$	$123.75^{e} \pm 22.10$	$41.50^{a} \pm 7.00$	$55.00^{e} \pm 14.47$	$40.50^{f} \pm 8.58$	$71.50^{b} \pm 7.29$	$86.00^{ab} \pm 10.23$	$116.75^{c} \pm 15.95$
DUBY30	$58.00^{e} \pm 11.22$	$144.50^{c} \pm 15.80$	$31.25^{ab} \pm 0.66$	$59.50^{de} \pm 10.50$	$31.00^{f} \pm 12.99$	$84.50^{a} \pm 3.28$	$56.25^{cd} \pm 17.13$	$140.75^{a} \pm 33.44$
DUBY40	$112.50^{ab} \pm .33$	$157.75^{b} \pm 24.14$	$46.00^{a} \pm 6.68$	$86.50^{ab} \pm 14.27$	$69.00^{b} \pm 8.76$	$69.25^{bc} \pm 14.41$	$99.25^{a} \pm 28.45$	$128.25^{b} \pm 47.44$
DUBY50	$80.75^{d} \pm 17.86$	$147.25^{c} \pm 24.21$	$32.75^{ab} \pm 1.84$	$71.50^{c} \pm 15.29$	$49.25^{e} \pm 10.63$	$81.25^{a} \pm 1.09$	$76.50^{b} \pm 27.73$	$111.50^{c} \pm 19.21$
NDUBY0	$125.00^{a} \pm 9.10$	$135.75^{d} \pm 12.45$	$47.00^{a} \pm 6.16$	$78.50^{c} \pm 8.70$	$66.00^{b} \pm 21.15$	$61.00^{c} \pm 9.87$	$79.50^{b} \pm 15.93$	$87.00^{d} \pm 5.72$
NNF	$109.50^{b} \pm 8.87$	$126.25^{de} \pm 26.46$	$45.00^{a} \pm 8.29$	$56.25^{de} \pm 14.93$	$58.75^{c} \pm 12.95$	$62.50^{c} \pm 5.29$	$99.00^{a} \pm 34.74$	$118.50^{c} \pm 18.86$
DNF	$120.75^{ab} \pm 6.95$	$133.25^{d} \pm 16.40$	$34.00^{ab} \pm 2.52$	$77.50^{bc} \pm 12.58$	$81.25^{a} \pm 10.53$	$47.00^{e} \pm 2.19$	$75.75^{b} \pm 14.93$	$73.50^{e} \pm 9.43$

Values are means of=4 determinations ± SD. Means in the same column with different superscripts are significantly different ($p < 0.05$).

***Keys**: DNF= diabetic rats fed normal feed/diet, NNF= normal rats fed normal feed/diets, NBBY0= non-diabetic rats fed blanched bitter yam, NUBY0= non-diabetic rats fed diet containing 100 % unblanched bitter yam, DBBY0= diabetic rats fed diet containing 100 % blanched bitter yam, DBBY10= diabetic rats fed diet containing 90:10 blanched bitter yam: acha blends, DBBY20= diabetic rats fed diet containing 80:20 blanched bitter yam:acha blends, DBBY30= diabetic rats fed diet containing 70:30 blanched bitter yam: acha blends; DBBY40= diabetic rats fed diet containing 60:40 blanched bitter yam:acha blends, DBBY50= diabetic rats fed diet containing 50:50 blanched bitter yam:acha blends, DUBY0 = diabetic rats fed diet containing 100 % Unblanched bitter yam, DUBY10 = diabetic rats fed diet containing 90:10 Unblanched bitter yam: acha blends, DUBY20 = diabetic rats fed diet containing 80:20 Unblanched bitter yam:acha blends, DUBY30 = diabetic rats fed diet containing 70:30 Unblanched bitter yam:acha blends, DUBY40 = diabetic rats fed diet containing 60:40 Unblanched bitter yam:acha blends, DUBY50 = diabetic rats fed diet containing 50:50 Unblanched bitter yam:acha blends.*

DISCUSSION

To affect this decrease, the experimental diets may have mimicked some of the actions of insulin on glucose metabolism to have significantly reduced the glucose level in the rat system (Luka et al., 2012). According to (Eleazu & Okafor, 2012). Inhibition of the glycolytic activity of brush border enzymes by polyphenol compounds seems to be one of the factors that stimulate hypoglycemic action in some medicinal plants. In addition, flavonoids, as antioxidants may prevent the progressive impairment of pancreatic beta cell function due to oxidative stress, thereby reducing hyperglycemia. Flavonoids like myricetin a polyhydroxylated flavonol stimulate lipogenesis and glucose transport in the adipocytes, thus lowering blood sugar (Elliot et al., 2000).

The alkaloid 1- ephedrine has been associated with promoting the regeneration of islets of the pancreas following destruction of the beta cells, thus restoring the secretion of insulin and thereby correcting hyperglycemia Tannins inhibit the activities of digestive enzymes such as trypsin and amylase. Tannin like epigallo-catechin-3-gallate has been associated with anti-hyperglycemia (Broadhurst et al., 2000). The diabetic rats that were fed diets containing blends of equal weight of blanched and unbalanced bitter yam and acha ($DBBY_{50 \text{ and }} DUBY_{50}$) had comparable low blood glucose levels (91.25 mg/dl and 91.75 mg/dL) with rats fed other diet blends. This observed effect could be attributed to the equal level of flavonoid in the blends.

Flavonoids have been associated with the ability to regenerate beta cells of pancreas and stimulate insulin secretion (Hoa et al., 2007). This observation also shows that blanching did not completely alter the hypoglycemic activity of the diets formulated with blanched samples. Phytochemicals like sapogenin, alkaloid, tannin and flavonoids have been reported to exhibit anti-diabetic properties (Miura et al., 2005). The types and levels of phytochemicals found in the samples used in formulating the experimental diets differed significantly ($p < 0.05$) yet the diets had positive effect on the blood glucose level of the diabetic rats. This also confirms the report that plants with hypoglycemic potentials contain one or more classes of phytochemicals (Luka & Ihezuo 2010).

The appreciable reduction of the Tchol level in rats fed $DBBY_{50}$ shows that the diet had positive impact on lipid metabolism of the diabetic rats. Rats fed diets containing blanched sample had lower Tchol value than those fed diets containing unbalanced sample made similar observations in the total cholesterol level of diabetic rats administered extract of *Dioscoreadumenturum*. The observed Tchol levels were all within the optimal range of less than 200 mg/dL. The decreased HDL may be due to excessive catabolism of protein and amino acids that are released and used for gluconeogenesis. There was no obvious effect of blending level on the HDL value of the rat groups. The HDL value of all the groups increased after the study and was above the normal HDL level (40 mg/dL) (Bravo et al., 2010). Noted that an HDL value of 60 mg/dL and above protects against heart disease while a value of 40 mg/dL and below is a sure risk of coronary heart disease.

HDL is known as good cholesterol and has a protective effect against cardiovascular diseases as it removes excess cholesterol from circulation and carries it back to the liver where it is degraded and eliminated out of the body (Imafidon, 2010). The LDL level of all the experimental rats was within the acceptable normal range (60 to 130 mg/dL). This observation may be attributed to the higher total fat content of the unbalanced bitter yam. The abnormal high concentration of serum lipid in the diabetic rats may be attributed to increase in the mobilization of free fatty acids from the peripheral fat depots. Hypercholesterolaemia and hyperlipidemia observed in this study with diabetic rats are normal conditions associated with alloxan induced diabetes and the values are within the accepted limit. Since alteration inserum lipid profiles are known to occur in diabetics, it increases the risk of coronary heart disease (Laakso, 1996). A reduction inserum lipids particularly LDL, VLDL fractions and triglycerides levels should be considered beneficial (Massing et al., 2001).

CONCLUSION

Generally, blends of 60:40 and 50:50 bitter yam/acha diet showed beneficial effects in lowering raised blood glucose and lipid profile level of alloxan-induced diabetic rats ($p < 0.05$) when compared to other blends. Therefore, utilization of unbalanced and blanched bitter yam/acha flour blends can be recommended in formulation of diabetic diets.

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