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A Study of Blood Glucose Response Following Ingestion of Ripe Banana in Healthy and Diabetic Nigerian Adults

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ABSTRACT

Banana is composed of about 80% carbohydrate mainly as resistant starch. Carbohydrate digestion and released is influenced by many factors, thus different carbohydrates do not have the same effects on blood glucose levels. Glycaemic index ranks equal carbohydrate portions of different foods according to the extent to which they increase glucose levels. We examine the blood glucose response to four different ripe bananas in diabetic and non diabetic Nigerians. 59 subjects were recruited comprising 27 diabetics and 32 non-diabetics. Four species of banana were eaten after weighing to contain the equivalent of 50 g carbohydrate. Blood for glucose were taken at 30, 60, 90 and 120 minutes. The anthropometric data and blood pressure were measured. Diabetics subjects were significantly older 59.7 ± 11.6 vs 45.09 ± 10.36, P<0.01. IAUGC were significantly higher among the diabetes; however, there was no significant differences between the diabetics and non-diabetics glycaemic indices (84.5, 82.9, 83.1, 83.3 vs 80.2, 80.6, 88.2, 76.5). Ripe banana has a high content of simple sugar with a high glycaemic index (>70), thus not very appropriate for diabetic patients achieving good metabolic control.

Keywords: Diabetes, Non-Diabetes, Banana, Glucose Response, Glycaemic Index, Hypoglycemia.

INTRODUCTION

Green banana is usually eaten raw when ripe and it is the most popular fruit worldwide in terms of export [1]. The physico-chemical and proximate composition of plantain and banana has been widely documented [2, 3, 4, 5]. Apart from being a source of income for the farmers; it contributes to a good quality diet and also a very rich source of dietary energy. Carbohydrates play a major role in human diets, comprising some 40-75% of energy intake. Healthy, moderately active adult individuals require at least 100 g of carbohydrate per day [6] to sustain normal brain metabolism and muscle function [7], and the carbohydrate should represent at least50% of energy intake; banana is composed of about 80% carbohydrate (Our data shows that *Musa* hybrids satisfy this requirement.), mainly as resistant starch (insoluble fibre). The rate at which carbohydrate is digested and released into the bloodstream is influenced by many factors, such as the food's physical form, its fat, protein and fiber content, and the chemical structure of its carbohydrate [8]. This suggests that different carbohydrates do not have the same effects on blood glucose (sugar) levels after consumption. Consequently, the glycaemic index method was developed in order to rank equal carbohydrate portions of different foods according to the extent to which they increase glucose levels after being eaten [9]. Diabetes is increasing globally and Nigeria is not left out. IDF 2010 reported a prevalence estimate of 3.9% for Nigeria [10] and the current prevalence of 4.9% is more than double the previous national prevalence of 2.2% [11]. Globally diabetes accounts for 3.8 million deaths annually, a number similar in magnitude to the mortality attributed to HIV/AIDS [12]. In Nigeria, acute diabetic complications – ketoacidosis, hyperglycemic hyperosmolar state and hypoglycemia were the commonest causes of death in diabetic patients [13].

Epidemiological and dietary intervention studies suggest that a low-GI diet is beneficial for blood glucose control and consumption of foods with a high GI or glycemic load (GL) is hypothesized to contribute to insulin resistance, which is associated with an increased risk of DM, obesity, cardiovascular disease, and some cancers [14, 15, 16].

In this study we examine the blood glucose response to four different ripe bananas in both diabetic and non diabetic adult Nigerians.

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MATERIALS AND METHOD

Study Location

This study was conducted at the College of Medicine, Ekiti State University, and the Medical Outpatient Department, Ekiti State University Teaching Hospital both in Ado-Ekiti, Ekiti State.

Ethical Approval

Approval for the study was obtained from the Ethic and Research Committee of Ekiti State University Teaching Hospital. Written consent of each participant was also obtained.

Study Participants/Sampling

The study was conducted between December 2015 and May 2016. A total of 59 subjects were recruited for the study. The participants were 27 patients with T2DM (12 male, 15 female), as defined by World Health Organization (WHO) criteria [17], attending the Endocrine clinic of Ekiti State University Teaching Hospital. The controls were 32 non-diabetic subjects (13 male, 19 female). Diabetic subjects recruited were maintained with diet alone or diet and oral hypoglycaemic agents (OHAs), had good glycemic control (FPG at recruitment 4.0- 6.7 mmol/L). Diabetic subjects on OHAs did not take treatment on the morning of the test meal consumption.

Food preparation and test procedure

The four different species of banana were eaten raw after peeling. Using proximate analysis, weighted amounts of each banana specie to contain the equivalent of 50 g carbohydrate were determined. Timing for sample collection was commenced with the initiation of consumption.

Test Procedure

With the aid of a pre-tested structured interview questionnaire, demographic parameters such as age, gender, marital status, were obtained from the participants. Relevant medical history was also obtained.

Anthropometric and Blood Pressure Measurements

The height, weight, waist and hip circumferences were measured by standard protocols. The body mass index (BMI) was taken as the ratio of weight to the square of the height, while the waist-to-hip ratio (WHR) was calculated from the values of waist and hip circumferences. The blood pressure was determined with mercury sphygmomanometer. The first and fifth Korotkoff sounds were taken as the systolic and diastolic blood pressures respectively.

Blood Sampling

After an overnight, fasting venous blood samples were drawn into appropriate bottles for plasma glucose determination using aseptic techniques. Thereafter, a 50g of anhydrous glucose in 200ml of water was administered per oral and samples for blood glucose were taken at 30, 60, 90 and 120 minutes. This was repeated daily for 50g caloric equivalent of each variety of bananas.

Laboratory analysis

The samples for glucose were centrifuged at 3000rpm for 5minutes and analysed using glucose oxidase method within three (3) hours of collection.

RESULTS

Table 1 below shows the characteristics of the population studied. The non diabetics were significantly older than the diabetics subjects; although the diabetics had a higher BMI and Waist Circumference (WC), it was the WC that was significantly higher. The Fasting Plasma Glucose (FPG) was significantly higher in the diabetics. The FPG 8.159mmol/l was higher than the expected level for adequate glycemic control of 7mmol/l; this suggests that this group of diabetic patients had a poor control of their diabetes.

Table 1: Characteristics of subjects

Characteristics	Diabetics (27)	Non-Diabetics (32)	P
Age (yrs)	59.7 ± 11.6	45.09 ± 10.36	<0.01
Weight (kg)	77.0 ± 12.4	75.16 ± 13.76	0.59
Height (m)	1.61 ± 0.07	1.64 ± 0.05	0.22
BMI (kg/m^2)	29.7 ± 5.0	28.18 ± 5.60	0.29
WC (cm)	101.30 ± 8.50	92.49 ± 13.81	<0.01
HC (cm)	100.24 ± 9.20	100.52 ± 13.38	0.93
WHR	1.01 ± 0.06	0.92 ± 0.07	<0.01
SBP (mmHg)	138.2 ± 25.0	126.39 ± 21.02	0.06
DBP (mmHg)	85.0 ± 14.0	80.77 ± 11.33	0.22
FPG (mmol/l)	8.16 ± 3.17	5.0 ± 0.71	<0.01
TC (mmol/l)	5.4± (1.7)	4.4± (1.4)	0.021
TG (mmol/l)	1.3±0.7	1.5± 0.6	0.421
HDL (mmol/l)	1.5± 0.7	1.2± 0.6	0.158
LDL (mmol/l)	3.4± 1.9	2.6± 1.2	0.07

Table 2 below shows the response of the study population to 50gram of glucose load. The responses of the diabetics were all significantly higher during the 2hour period of blood sampling.

Table 2: Blood Glucose Response To 50g Glucose Load

Time	Diabetics	Non-Diabetics	P
0	8.16 ± 3.17	5.0 ± 0.71	<0.01
30	12.09 ± 3.66	6.95 ± 1.35	<0.01
60	13.81 ± 3.17	6.99 ± 1.74	<0.01
90	13.27± 3.15	6.32 ± 1.71	<0.01
120	11.75 ± 3.75	4.94 ± 1.36	<0.01

Table 3: Blood Glucose Response to Different Banana

Time (minutes)	0		30		60		90		120	
	Diabetics	Non diabetics	Diabetics	Non diabetics	Diabetic	Non diabetics	Diabetics	Non diabetics	Diabetics	Non diabetics
Banana Type					MEAN±SD					
Banana 1	8.38±3.6	4.65±0.9	11.27±5.6	5.40±1.1	11.96 ±4.5	5.20±1.2	10.24±3.6	4.66 ±0.9	9.19 ±3.5	4.43 ±0.8
Banana 2	8.26±3.5	4.95±1.0	10.86±3.4	5.47±1.4	11.05±2.9	5.08±1.0	10.19±3.3	4.43±0.8	8.96±3.7	4.35±0.7
Banana 3	8.77±3.3	5.27±0.9	10.55±3.3	6.07±1.2	11.11±3.7	5.55±1.0	9.94±3.4	5.08±1.0	8.87±3.2	4.63±1.1
Banana 4	8.4±2.9	4.47±0.7	10.08±2.7	4.99±1.0	11.25±2.7	4.77±1.0	10.63±3.1	4.56±0.8	9.22±2.8	4.50±0.7

The diabetic subjects had higher blood glucose level at each time of sampling

Table 4: Incremental Area Under the Glucose Curve (IAUGC) for the studied population

	Mean ± SD		P value
	Diabetics (27)	Non diabetics (32)	
GLUCOSE	1473.8± (346.3)	756.8± (140.3)	<0.001
BANANA 1	1267.5± (474.8)	594.0 ± (87.3)	<0.001
BANANA 2	1221.4± (376.0)	588.9± (89.8)	<0.001
BANANA 3	1212.8± (381.7)	649.6± (114.2)	<0.001
BANANA 4	1223.1± (325.8)	564.2 ± (73.2)	<0.001

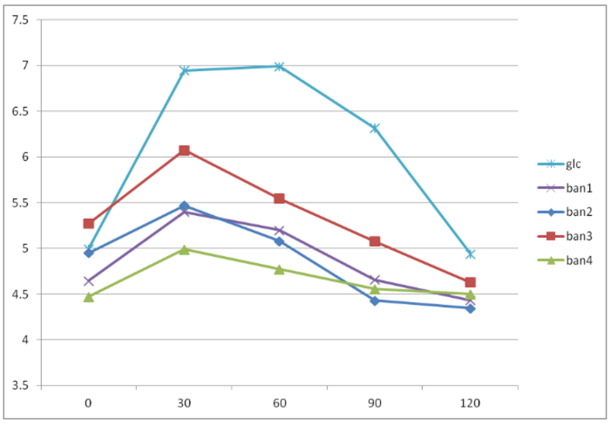

Figure 1: shows the incremental area under the glucose curve for the non diabetic subjects

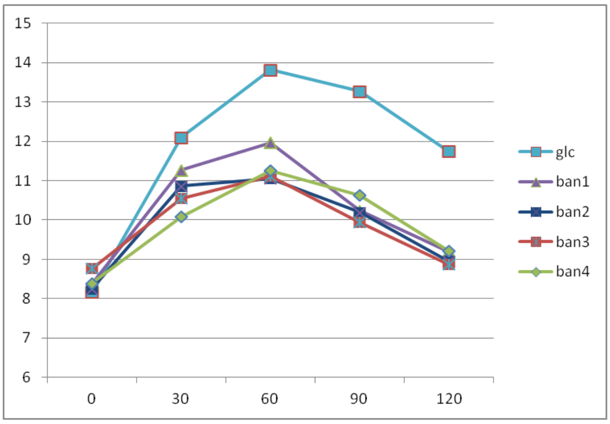

Figure 2: shows the incremental area under the glucose curve for the diabetic subjects

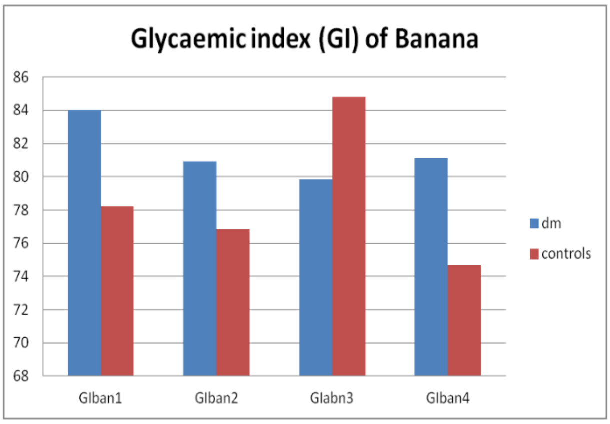

Figure 3: shows the glycemic index of the four banana species in both the diabetics and the non diabetics subjects. Banana 3 has a higher glycemic index in the non diabetic.

Table 5: The Glycemic Index (GI) for the Banana studied

	Mean ± SD		P value
	Diabetics (27)	Non-Diabetics (32)	
GI BAN1	84.5±15.8	80.6±16.1	0.354
GI BAN2	82.9±15.9	80.2±19.4	0.566
GI BAN3	83.1±19.7	88.2±20.0	0.325
GI BAN4	83.3±13.0	76.5±14.9	0.071

DISCUSSION

The aim of this study was to determine the glycaemic index of four varieties of *Musa spp* in our environment. These species are *Musa sapientum* (BAN1), Diploid *Musa acuminate "*Cavendish subgroup (BAN2)*", Musa paradisiacal* (BAN3)., and *Musa acuminata "*Red Dacca" (BAN4). Banana fruit is one of the economically most important fruits produced and consumed in the world. It also has a high energetic value, in the range of 90-100kcal/100g; with a fruit composition that depends on the cultivation [18, 19]. The green banana is made up of a complex of carbohydrate (mainly resistant starch), minerals, vitamins, fiber and total phenolics. The presence of these functional components makes regular consumption of green banana flour beneficial to the human health. It might be used for the purpose of preventing or reducing high cholesterol, constipation, diabetes (rich in indigestibale carbohydrates that cooperate with adequate glycaemic response), and colon cancer. The type of carbohydrate found in bananas usually depends on the degree of ripeness. Unripe banana contains about 80-90% starch which transforms to free sugar as the banana ripens. Yellow or ripe bananas contain less resistant starch than green bananas and more sugar, which is more quickly absorbed than starch; thus, GI of a ripe yellow banana is expected to be higher than that of unripe green banana.

Among healthy volunteers the glycaemic indices of BAN1, BAN2, BAN3, and BAN4 are 80.2, 80.6, 88.2, and 76.5 respectively, whereas among patients with diabetes, the glycaemic indices are 84.5, 82.9, 83.1, and 83.3 respectively. Even though the values are generally higher among patients with diabetes, statistically there are no differences between the glycaemic indices among healthy volunteers and patients with diabetes. This may be due to similar weight, BMI and blood pressure among the two groups. These variables which are associated with insulin resistance may modify the expected differences in the GI between the two groups. Studies on glycaemic indices generally yielded higher values among patients with diabetes compared to healthy volunteers [20, 21].

In this study the GI of all the ripe banana species eaten were in the high glycaemic index range of above 70 for all study group. This finding is similar to that of Hermarsen *et al.*, [22] which study the influence of ripeness of banana to glucose response in type 2 diabetics; where the glucose response to ripe banana was higher to the unripe one. Edo *et al.*, [23] also found a GI above 70 among diabetics subject who ate ripe banana in Benin, Nigeria. Previous works in Nigeria by Oli *et al.*, [24] and Ohwovoriole *et al.*, [25] also revealed that unripe and fried plantain had high glycaemic indices. Some non-Nigerian authors found that three varieties of banana had moderate GI of between of 61-69% [26]. In contrast to the above, Kouamé, *et al.*, [27] researched on Glycemic Responses, Glycemic Index, and Glycemic Load Values of Some Street Foods Prepared from Plantain (*Musa spp.*, AAB Genome) in Côte d'Ivoire, and found low GI values for three varieties of *Musa paradisiaca normalis*. However, a high glycaemic index of 89 was reported for the fourth specie. Wolever *et al.* [28] found a higher glycaemic response to ripe banana compared to unripe ones. However, a study by Ercan *et al.*, [29] found little variation in the glycaemic response to varying degree of ripeness of banana.

International Table of Glycaemic indices show that the GI of banana range between 30-89 depending on source and degree of ripeness of the banana as well as the reference food (glucose or white bread) [30]. Using glucose as the reference food in the table, (as was done in our study), the GI of banana ranged between 30-70. Thus, banana was adjudged to have low to moderate glycaemic index, unlike our findings and that of others. However, most of the studies in the table of GI were conducted among Caucasians.

Many factors may be responsible for the varying degree of glucose response to banana. Carbohydrate foods have been reported to produce different glycaemic values depending on their chemical structure, particle size, amount and type of dietary fibre, fats, proteins, antinutrients and food processing among carbohydrate foods. Jenkins *et al.* [31]. Food processing has been reported to have an effect on glycaemic response, Omoregie *et al.* [32]. Alteration of physical properties of carbohydrate through gelatinization and retrogradation thereby increasing starch availability to amylase enzyme by boiling, cooking and heating has an effect on the glycaemic response to various preparation of white yam, Jimoh *et al.*, [33].

Other factors responsible for varying GI of same food include ethnicity, acidity, insulin response, methodology, and sampling method (venous or capillary) [30, 34, 35]. It has been observed that ethnic and genetic variability exist in glycaemic response to food. For example, for similar carbohydrate load, post-prandial glucose values are more than double in South-Asians compared to Caucasians [36-38]. The study by Venn *et al*., [37] also revealed a significantly higher GI of 77 in Asians versus 61 in Caucasians. In a study that compared glycaemic response to sucrose and isomaltose, Tan *et al*., [39] also reported that the Malays exhibited greater response than the Caucasians. Similar disparities were reported between the Chinese and Europeans [40]. Finally, in a review of the effect of ethnicity on glycaemic index, Woelve *et al*., [41] reported higher GI among Caucasians than non-Caucasians for rice but not for other food. The authors however recommended high-quality studies to confirm their findings. High glycaemic index found by us and some Nigerian authors for banana may be due to genetics, but this need to be confirmed by future studies involving Caucasians and Nigerians. Also, as at the time of recruitment for this study, the diabetic patients were in good metabolic control. However, in the morning of the test procedure the patient did not take their medications; this could also contribute to the relatively higher glycaemic response to the test food and banana.

The IAUGC was significantly higher for the diabetic subjects. This is not surprising since patients with insulin resistance such as found in diabetes mellitus usually exhibit higher glycaemic response than healthy volunteers [20, 42]. Low insulin response in patients with long duration of type 2 DM also contribute impaired glucose clearance disposal resulting in higher postprandial values when compared with non-diabetic patients. Edo *et al.* [23] also found that banana elicited a higher IAUGC than orange. In an earlier study Jenkins *et al.* [43] also shows an elevated IAUGC for banana compared to other fruits. However, none of the banana studied had a higher IAUGC as that of the test food (Glucose). Fruits are generally richer in fibres and fructose which produces lower glycaemic response than glucose [44, 45]; this may account for the lower IAUGC of the bananas compared to glucose test food.

Hypoglycemia is one of the complications of a poorly managed DM; ingestion of ripen banana may be an alternative to refined simple sugars in acute episode of hypoglycemia. Ripe banana swash can also be a source of energy for athletics who may be in urgent need and not necessarily raising the blood glucose as refined sugar does. Unlike refined sugar products like candies and cake, the carbohydrates in fruit such as bananas come with fiber, antioxidants, vitamins and minerals. A study by Nieman *et al*., showed that banana and carbohydrate drink ingested during 75-km cycling resulted in similar performance, blood glucose, inflammation, oxidative stress, and innate immune levels [46].

CONCLUSION

Ripe banana has a high content of simple sugar with reduced resistance starch compare to unripe (Green) banana; fibre, vitamins and other important minerals. It has a high glycemic index (>70), thus not very appropriate for diabetic patients achieving good metabolic control. However, in view of its high GI being close to that of glucose, it can be use in cases of acute hypoglycemic episodes that would not lead to too high-level blood glucose. It can also be a good source of energy and vitamins for athletics who wants to control their glucose level.

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Conflict of Interest: None

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