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► **To cite this version:**

Oluwafunmike H. Ajayi, Gbenga S. Oladosu, Opeyemi O. Bolajoko, Juliet O. Okoruwa, Agboola A Adebowale. ASSESSMENT OF THE GLYCEMIC INDEX OF MEAL FROM UNRIPE PLANTAIN (*Musa paradisiaca*). *Journal of Institutes for Dietetics in Nigeria*, 2023, 1 (1), pp.31-41. hal-04184444

HAL Id: hal-04184444

<https://hal.science/hal-04184444v1>

Submitted on 21 Aug 2023

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ASSESSMENT OF THE GLYCEMIC INDEX OF MEAL FROM UNRIPE PLANTAIN (*Musa paradisiaca*)

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Abstract

Plantain, usually consumed as a cheap source of energy in many parts of African countries has been identified to have therapeutic importance for its low glycemic index properties. This study assessed the glycemic index of meals from unripe plantain. The unripe plantain was purchased from Osiele markets, Abeokuta. Ten (10) apparently healthy volunteers aged 21-25 years with normal BMI (18.50-24.99kg/m²) were served 350g of the meal to give 50g available carbohydrates and 50g glucose was used as the reference sample. The meal was served plain after 11-12 hours overnight fast, and blood glucose was tested at a specified time interval using a calibrated glucometer. The incremental area under the curve (IAUC) was determined using Microsoft Excel, and the GI was calculated. Statistical Package for Social Sciences was used to calculate the mean and standard deviation. The mean proximate values from the duplicate readings were moisture (68.9±0.2), crude protein (4.0±0.1g), crude fat (1.81±0.04g), total ash (1.55±0.1g), total carbohydrate (23.1±0.1g) and total dietary fiber (8.8±0.2g). The mean incremental area under the curve for the sample was 7791.9±513.3mg/dl, and glucose was 1402.2±1725.5mg/dl. The glycemic index and glycemic load values of the meal were 56.4±8.4 and 8.1±1.2, respectively. The result of this study revealed that unripe plantain has a moderately low glycemic index and load; thus, it has potential for therapeutic purposes. However, there is a need for further research on the effects of processing methods on glycemic index and load of unripe plantain.

Keywords: Glycemic Index, Unripe Plantain, Glycemic Load, Blood Glucose

INTRODUCTION

Plantain (*Musa paradisiaca*), usually consumed as a cheap source of energy in many parts of African countries (Vivienne *et al*, 2016) has been identified to have therapeutic importance for its low glycemic index properties (Oluwajuyitan & Ijarotimi, 2019). Plantains, an important plant food crop grown in more than 120 countries of the world (Bertin *et al*, 2020) is ranked third after yam and cassava, and it's an excellent source of dietary calorie staple for millions of people in Nigeria (Vivienne *et al*, 2016;

Akinjayeju *et al*, 2020). Plantain is widely cultivated in the southern parts of Nigeria and other African countries due to the favorable weather condition (Fadimu *et al*, 2018). According to Food and Agricultural Organization Statistics (FAOSTAT) (2019), Western African production of plantain stands at nearly 39 million tons in 2017, with an overall mean growth rate of 1.7% per year.

Plantain is mainly consumed in different forms (both ripe or unripe), which include; boiled, fried, roasted, or processed into flour

and accustomed to preparing local dough meal referred to as 'amala' (Famakin *et al*, 2016; Honfo *et al*, 2020). All of these forms have the advantage of all-season availability, low cost, and ease of processing (Lampthey *et al*, 2019).

Plantain is an important food and cash crop (Nwosu and Lawal, 2010) which has been found to contribute significantly to food and nutritional security through income diversification and poverty reduction (Honfo *et al*, 2020). United States Department of Agriculture (USDA) (2012) and Honfo *et al*, (2020) revealed that plantain is one of the most important horticultural crops and among the ten most important food security crops that feed the world. In the last one decade, the demand for plantain has been found to have a tremendous increment; this is because of the emergence of local processing industries that use plantain industrially in the production of bread, cakes, biscuits, among others (Ayanwale, 2016).

Nutritionally, Plantains are lauded for being a source of macronutrient, and micronutrients like minerals and vitamins (Lampthey *et al*, 2019; Oluwajuyitan & Ijarotimi, 2019; Honfo *et al*, 2020). It provides for more than 70 million people 25% and 10% of the daily intake of carbohydrates and calories respectively (Ayanwale *et al*, 2016). It is also rich dietary fiber especially hemicelluloses. It is however considered to have minimal protein and fat (Odenigbo *et al*, 2013). Unripe plantain is a good source of vitamins and minerals including iron, zinc, potassium, and Provitamin A (Oluwajuyitan and Ijarotimi, 2019). Honfo, *et al* (2007) discovered that the daily consumption of plantain foods by children provided approximately 0.88mg of iron, 0.26mg of zinc, and 24.55µg Retinol Activity Equivalent (RAE) and daily consumption of plantain derived foods provided mothers with approximately 1.80mg of iron, 0.6mg of zinc and 43.35µg Retinol Activity Equivalent (RAE).

The glycemic index is a ranking system for carbohydrates based on their immediate effect on blood glucose levels (Madu *et al*, 2018). Ekwe *et al* (2019) defined glycemic index as a ranking of carbohydrate foods

from 0 to 100 according to the ability of a food item to raise blood glucose. The nutritional quality of food is related to its glycemic index (Akinlotan *et al*, 2016). The glycemic effect of food is a measure of how fast, how high the blood glucose rises and how quickly the body responds by bringing it back to normal after food ingestion. Lower GI foods were considered beneficial relative to the low glycemic response following ingestion compared with high GI foods (Madu *et al*, 2018). The concept of glycemic index has been extended to include the effect of the total amount of carbohydrate consumed on the glycemic response. Thus, glycemic load (GL), a product of GI and quantity of carbohydrate eaten. Lampthey *et al* (2019) observed that eating a low glycemic foods including plantain provides healthy and beneficial nutrients with protective properties against metabolic diseases. Ayodele and Godwin (2010) established that consumption of carbohydrate rich foods with a high glycemic index is a risk factor not only for diabetes, but also obesity and other cardiovascular diseases. The consumption of low GI and GL diets have more recently been widely recommended for the prevention of chronic diseases including diabetes, obesity, cancer, and heart disease and in the treatment of cardiovascular risk factors, especially dyslipidaemia (Madu *et al*, 2018).

According to Faturoti *et al* (2007) and Ayanwale *et al* (2016), Plantain has been found to have outstanding and proven medical relevance. Oluwajuyitan & Ijarotimi (2019) identified plantain as important staples medically recommended for diabetic patient for its reduction effect on postprandial glucose level. Plantain is effective in lowering blood glucose because the insoluble fibers present therein create a barrier to enzymatic hydrolysis of starchy staples thereby decreasing the glycemic response (Lampthey *et al*, 2019). Fiber has also been identified by Ng *et al* (2020) as an important food component that can be used to reduce glycemic index of a food. In addition to the blood glucose lowering action of fiber in plantain, Eleazu (2016) in a study carried out using streptozotocin-induced diabetic rats confirmed that plantains rich in alkaloids, flavonoids, saponins and tannins have an anti-hyperglycemic and

hyperlipidemic properties. Oluwajuyitan & Ijarotimi (2019) also supported the claim that plant-based functional foods are getting more attention than ever before, because of their potential benefit to the society especially in the area of nutrition, medicine, and pharmacology. The nutritional values of these plant-based foods have been said to be in bioactive compounds like photochemicals and proteins (Igwe *et al*, 2012).

PROBLEM STATEMENT AND JUSTIFICATION

The increasing incidence of many generic diseases like diabetes mellitus, and heart related ailments like stroke and high blood pressure level is becoming alarming globally, both in developed and developing countries (Akinjayeju *et al*, 2020).

Diabetes mellitus has become one amongst the foremost most common chronic diseases in the world, with 422 million people affected worldwide (International Diabetes Federation (IDF), 2015; WHO, 2016). Coupled with other non-communicable diseases, diabetes is an important cause of morbidity and mortality globally (Zheng *et al*, 2017; Mutashambara *et al*, 2018; Asmelash and Asmelash, 2019).

According to The International Diabetes Federation (2019), it was estimated that in 2017, there are approximately 425 million and 2 million adults (20-79 years) living with diabetes worldwide and in Nigeria respectively, 95% of all cases being type 2 diabetes mellitus (Marques *et al*, 2020). This increasing trend of diabetes mellitus has led to more emphasis on diabetes-related functional food with the view to improving blood sugar control (Oluwajuyitan & Ijarotimi, 2019). One in all approaches is by assessing the physiological effects of food by the concept of glycemic index which could be a value given to carbohydrate-rich foods based on their effect on post-prandial blood sugar (Ng *et al*, 2020).

Use of traditional diets has long been known to scale down the incidence of diet-related diseases (Onuoha *et al*, 2017) of which plantain, cultivated in many tropics and subtropical countries of the planet is the third

most important staple after yam and cassava (Famakin *et al*, 2016). In research conducted by Caydam *et al*. (2019), the findings showed that nutrition and lifestyle of individuals play an important role in the quality of life of patients with diabetes mellitus. Akinlotan *et al* (2016) revealed that consumption of high and simply digestible carbohydrate foods could increase the risk of diabetes and other nutritional diseases resulting from their higher glycemic index. Thus, careful combination of slowly digestible starchy food staples like plantain could give appreciable low glycemic index and therefore the required nutritional value.

Akinjayeju *et al* (2020) also observed that meals from unripe plantain have been recommended for diabetics due to its relatively low glycemic index. Plantain has however been identified to be nutritionally poor because it is deficient in fat and protein (Oluwajuyitan & Ijarotimi, 2019). In addition, diabetics are sometimes faced with the issue of monotony in their dietary pattern as a result of limited range of foods to consume, however, most diabetes care providers also considered plantains being rich sources of carbohydrates taboo for diabetics (Lamptey *et al*, 2019).

Madu *et al* (2018) affirmed that research work and data on the GI and GL of Nigerian local foods is scarce, many of these local foods are replaced with energy dense cereal and cereal products which are being consumed on daily basis in large quantities. Information on the GI and GL of these foods are therefore important as enablers of planning therapeutic diet by the physicians and dietitians (Madu *et al*, 2018). It is therefore important to assess the effect of unripe plantain meal on blood sugar of normo-glycemic adults so as to provide data on the potential of unripe plantain meal for therapeutic purposes especially in the management of metabolic disorders and also to promote healthy locally made food from unripe plantain meal for both therapeutic and non-therapeutic purposes. Hence, this study assessed the glycemic index of meal from unripe plantain (*Musa paradisiaca*).

METHODOLOGY

Research Design

This research was experimental and analytical in design

Sample Preparation

Bunches of Freshly harvested, mature Green unripe plantain (*Musa paradisiaca*) was purchased from Osiele markets, Abeokuta, Ogun State. Other equipment used were washed properly and rinsed well with water. The unripe plantain was peeled, and 5 kg quantity was cut into (10 mm long) and was boiled in 5L of water containing 1gm of salt for 1hour until tender and soft (Ayodele and Godwin, 2010). The water was drained, and the plantain was served to the subjects.

Proximate Analysis of the Sample

The standard method (AOAC, 2012) was used to determine the proximate compositions (moisture content, ash, crude fiber, crude fat, and crude protein) of the experimental food sample. Carbohydrate content was determined by difference i.e.

Carbohydrate (%) = 100 - (% Moisture + % Fat + % Protein + % Ash + % Crude fibre)

Subject Selection

Ten healthy volunteers (5 Males and 5 Females) were randomly selected for the study as described by Madu *et al* (2018). The volunteers were screened based on anthropometric assessment, biochemical (Blood glucose level) and vital signs assessment and it was ensured that only healthy individuals were allowed to participate in the study.

Inclusion and Exclusion Criteria

Healthy non-diabetic individuals between the ages of 19 and 25 years, with normal BMI (18.50-24.99kg/m²) were included in this study. Smokers, individuals on prescribed medications, pregnant mothers, individuals with diagnosed disease or metabolic diseases, and who refused to consent to the study were excluded in the study (Madu *et al*, 2018).

Ethical Consideration

The study was permitted by the Department of Nutrition and Dietetics, Federal University of Agriculture, Abeokuta, and also written informed consent were obtained from the subjects after the study objectives has been explained to them.

Method of Data Collection

A semi-structured and interviewer-administered questionnaire was used to assess the socio-demographic characteristics of the respondents. Anthropometric measurement and oral glucose tolerant test (OGTT) of the respondents were assessed using standard procedure described below.

Anthropometry Assessment

Anthropometry data including body weight and height were assessed using standard procedures described by Food and Nutrition Technical Assistance III Project (FANTA) (2016). Body weight was measured (to the nearest 0.5 kg) with the subject standing erect and bare footed on a calibrated weighing scale. The weighing scale was standardized by placing a known weight of 50kg on the scale as described by Ayodele and Godwin (2010). Height was measured (to the nearest 0.1 cm) using a vertical scale of portable stadiometer with the subject standing in an erect position, legs together, heels touching the backboard and knees straight. The body mass index (BMI) of the respondents was calculated as weight in kilograms divided by squared height in meter and the nutritional status was classified using the standard recommendation (WHO, 2000).

Blood Glucose Measurement

The blood sample of each of the respondent was taken by fingertip prick using the lancet and it was used to stain the test strips and the blood glucose level was checked using a fine test calibrated glucometer (Accu-check) and the readings were recorded.

Experimental Procedure

Ten healthy adults were served boiled unripe plantain and glucose on separate occasions. This was done on a daily basis for 2 days after a 10-12 hour overnight fast. The serving size was determined by calculating the quantity of the test food that will give 50gm available carbohydrate when consumed and 50g glucose was served as the reference food. All samples were consumed with 500ml of water. Blood samples were collected before feeding (0 min) and at 30, 60, 120 and 180 minutes after the test meal was given. Subjects were requested to avoid strenuous

physical activity and alcohol on the day before the experiment. During the test, they were asked to remain seated.

Calculation of Glycemic Index

Blood sugar against time was plotted in Microsoft Excel spreadsheets using a line graph. GI was calculated by expressing the glycemic response area for the tested foods as a percentage of the mean response. The glycemic index (GI) was computed using the formula:

$$GI = \frac{IAUC(a)}{IAUC(b)} \times 100$$

Note: $IAUC(a)$ = Area under the curve for test food
 $IAUC(b)$ = Area under the curve for reference food.

The average of the two measures for each subject was taken as the GI for that test food for the subject. The GI for each food was finally calculated as the mean of the average of the GIs in ten subjects in the group (Ayodele and Godwin, 2010, Madu *et al*, 2018). The Glycemic Index of the meal was categorised as follows: Low-GI=< 55%, Medium-GI= 56-69% and High-GI =>70% (Dona *et al*, 2010; Oluwajuyitan & Ijarotimi, 2019). Data were then presented by graphs, means and standard deviation values. The incremental area under the curve (IAUC) for the test meal for each subject was calculated as the sum of the surface triangle and trapezoids of the blood glucose curve

and the horizontal baseline running in parallel to the time axis from the beginning of the curve (time 0 min) to the point at 60mins to reflect the total rise in blood glucose concentration after eating the reference food. The Incremental Area under the Curve (IAUC) for the test food (unripe plantain meal) was obtained in a similar way.

Statistical Analysis

Excel version 2016 was used for coding of questionnaire and figure presentation such as line graph (was used for representing change in blood sugar level of respondents for experimental food), for calculating the incremental areas under the curve (IAUC) using the trapezoidal rule for the food samples. Statistical package for social science (SPSS) version 25.0 was further used for data presentation like Frequency count, Percentage, Mean, and Standard deviation.

Results

Socio-Demographic Characteristic of the Respondents

Table 1 below shows the socio-demographic characteristics of the respondents. The mean age was 21.0±2.0years. Half (50.0%) of the respondents were of the age range 18-21years, most (80.0%) were from a monogamous family, the majority (70.0%) were Christians and there was equal distribution of males and females.

Table 1: Socio-Demographic Characteristic of the Respondents (n=10)

Variables	Frequency	Percentage
Age (years)		
18-21	5	50.0
22-25	5	50.0
Mean age		21.0±2.0years
Gender		
Male	5	50.0
Female	5	50.0
Family Type		
Monogamous	8	80.0
Polygamous	2	20.0
Religion		
Christianity	7	70.0
Islam	3	30.0

Anthropometric Characteristics of the Respondents

Table 2 revealed the anthropometric characteristics of the respondents. The mean BMI, waist circumference and hip circumference for male was $21.82 \pm 0.93 \text{ kg/m}^2$, $74.90 \pm 1.88 \text{ cm}$ and $91.10 \pm 1.43 \text{ cm}$, respectively while the mean BMI, waist circumference and hip circumference for female was $21.16 \pm 1.25 \text{ kg/m}^2$, $66.20 \pm 7.69 \text{ cm}$ and $90.80 \pm 7.98 \text{ cm}$, respectively.

Table 2: Anthropometric Characteristics of the Respondents (n=10)

Variable	Male		Female	
	Mean	SD	Mean	SD
Height (m)	1.76	0.02	1.63	0.09
Weight (kg)	67.80	3.35	56.60	7.80
BMI (kg/m^2)	21.82	0.93	21.16	1.25
Waist Circumference (cm)	74.90	1.88	66.20	7.69
Hip Circumference (cm)	91.10	1.43	90.80	7.98
Waist/Hip Ratio	0.82	0.02	0.73	0.03

Proximate Analysis of Boiled Unripe Plantain

Table 3 depicted the proximate analysis of boiled unripe plantain. The mean proximate values from the duplicate readings for moisture, crude protein, crude fat, crude fiber, total ash, total carbohydrate, and total dietary fiber were $68.99 \pm 0.17\%$, $4.00 \pm 0.09\%$, $1.81 \pm 0.04\%$, $0.57 \pm 0.02\%$, $1.55 \pm 0.06\%$, $23.11 \pm 0.13\%$ and $8.79 \pm 0.18\%$ respectively.

Table 3: Proximate Analysis of Boiled Unripe Plantain per 100g

Parameters	Mean	SD
Moisture (%)	68.99	0.17
Crude Protein (%)	4.00	0.09
Crude Fat (%)	1.81	0.04
Crude Fiber (%)	0.57	0.02
Total Ash (%)	1.55	0.06
Total Carbohydrate (%)	23.11	0.13
Total Dietary Fiber (%)	8.79	0.18

Mean Value of Blood Glucose at Different Time Interval

Mean value of blood glucose at different time interval is shown on table 4 below. The mean value for the test meal was 56.4 ± 7.4 , 67.4 ± 7.4 , 67.5 ± 7.7 , 70.0 ± 6.7 , and 53.4 ± 7.5 at 0mins, 30mins, 60mins, 90mins and 120mins respectively compared to the reference sample with 85.5 ± 22.55 , 113.7 ± 33.5 , 118.9 ± 14.0 , 127.3 ± 12.8 , and 129.5 ± 10.4 mean value at 0mins, 30mins, 60mins, 90mins and 120mins, respectively. The changes in blood glucose level at different time interval is represented in figure 1 below.

Table 4: Mean Value of Blood Glucose at Different Time Interval

Time (minutes)	Type of Food	Mean of Blood Glucose ± SD
0 Minutes	Glucose	85.5±22.6
	Boiled Unripe Plantain	56.4±7.4
30 Minutes	Glucose	113.7±33.5
	Boiled Unripe Plantain	67.4±7.4
60 Minutes	Glucose	118.9±14.0
	Boiled Unripe Plantain	67.5±7.7
90 Minutes	Glucose	127.3±12.8
	Boiled Unripe Plantain	70.0±6.7
120 Minutes	Glucose	129.5±10.4
	Boiled Unripe Plantain	53.4±7.5

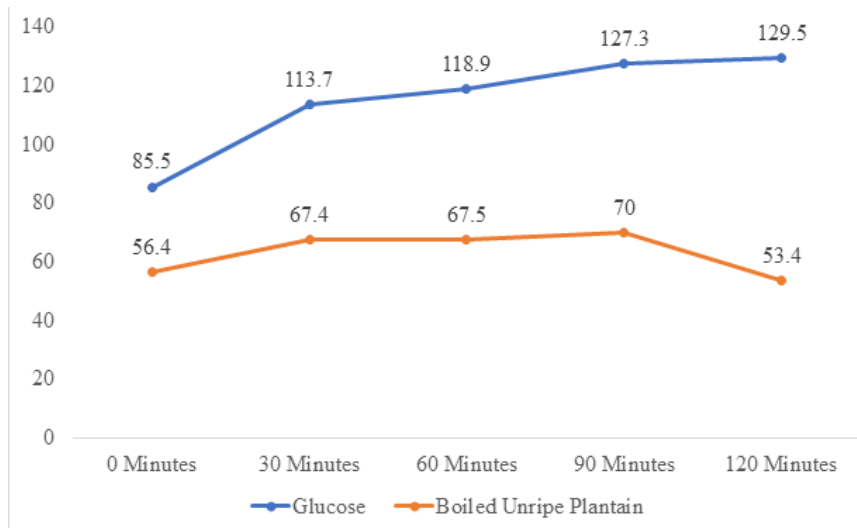


Figure 1: Change in blood glucose level of subjects on test glucose and unripe plantain meal

Mean Glycemic Index and Incremental Area under the Curve for Test Foods

The mean Glycemic Index and Incremental Area under the Curve for Test Foods is shown on table 5 below. The mean glycemic index was 56.36±8.4, the mean Incremental Area Under Curve (IUAC) for the test food was 7791.85±513.3 and the glycemic load was 8.07±1.20.

Table 5: Mean Glycemic Index and Incremental Area under the Curve for Test Foods

Variables	Values
Available Carbohydrate per 100g	14.32g
Serving Size	350.0g
Incremental Area Under Curve (IUAC)	7791.85±513.3
IUAC for Glucose	14022±1725.5
Glycemic Index (GI)	56.36±8.4
GI Ranking	Medium
Glycemic Load	8.07±1.20

Discussion

The knowledge of glycemic index of foods is important in the management of metabolic diseases and the consumption of low GI and GL diets is gaining attention in prevention and management of chronic diseases including diabetes, obesity, cancer, and heart disease (Madu *et al*, 2018; Lamptey *et al*, 2019). It is important to know the glycemic index of commonly consumed local foods and to classify them based on their glycemic properties (Dereje *et al*, 2019). This study therefore determined the glycemic index of meal from boiled unripe plantain (*Musa paradisiaca*).

The mean age and body mass index of the respondent in this study were 21.0±2.0 years and 21.5±1.1kg/m², respectively. This result is similar to the study carried out in Edo State, Nigeria (Ayodele and Godwin, 2010) where the mean age of the study was 22.0±0.9years and the mean BMI was recorded as 21±0.7kg/m². The similarity could be related to the respondents of the studies being undergraduate students of tertiary institution in Nigeria.

Different nutritional and physiological factors have been identified to influence glycemic response and the GI value of meals. Included among these factors is the cooking methods, starch digestibility, the interactions of starch absorption with the amount of fiber, fat and protein present, and the proportion nutrient constituent (Omaga and Omaga, 2018). Plantain has been reported as a good source of Energy, Carbohydrates, and Dietary fiber (Lamptey *et al*, 2019; Oluwajuyitan & Ijarotimi, 2019; Honfo *et al*, 2020). The

proximate value for total carbohydrate was 23.11g. This result is dissimilar to the carbohydrate content of boiled unripe plantain reported by Ayodele and Godwin (2010) with a value of 36.28g but was however similar to the carbohydrate content of unripe plantain flour (23g) reported by Ndayambaje *et al* (2019). Lamptey *et al* (2019) also reported the nutritional value of Plantains solid composition as 32% carbohydrates. The crude fiber of 0.57g was reported in the study, this is similar to the crude fiber of 0.81g for boiled unripe plantain reported by Ayodele and Godwin (2010) and dissimilar to the crude fiber of unripe raw plantain reported by Madu *et al* (2018) with a value of 12.03g. The variation can be attributed to the processing method. Generally, plantain has been said to be of low protein and fat (Odenigbo *et al*, 2013; Oluwajuyitan and Ijarotimi, 2019), The result of this study also supported the previous research as protein and fat content as indicated by proximate analysis were 4g and 1.81g, respectively. The result is similar to the crude protein value (3.13g) and fat (1.35g) of unripe plantain (*Musa paradisiaca*) reported by Ayodele and Godwin (2010).

A serving size of 350g of boiled unripe plantain was fed to the study participants to provide an equivalence of 50g available carbohydrate with the 50g of Glucose as the reference sample. The pre-prandial and postprandial blood glucose tests were done and recorded for 0, 30, 60, 90, 120 minutes accordingly. These same procedures have been used and reported in previous studies (Eleazu, 2016; Kouamé *et al*, 2017; Omaga

and Omege, 2018; Onuoha et al, 2017 and Oyesanya et al, 2022).

The glycemic index obtained from this study was 56.36 ± 8.4 , which ranked medium. Ayodele and Godwin (2010) in their study reported the glycemic of boiled unripe plantain as 64.94, which also ranked medium. However, Madu et al (2018) research findings revealed that the glycemic index of boiled unripe plantain (*Musa paradisiaca*) was 96.5, which was ranked high. In addition, Madu et al (2018) concluded that boiled unripe plantain has more promising control effect on blood glucose level and could be better used in the management of metabolic disorder such as diabetes mellitus. Oluwajuyitan and Ijarotimi (2019) found the glycemic index of unripe plantain flour dough to be low (42.95). In the study of Akinlotan et al (2016), the experiment result revealed the glycemic index of plantain blend was lower than that of cocoyam blend. In addition, Madu et al (2018) experimental result showed that the glycemic index of boiled unripe plantain (96.5) was lower than that of boiled cocoyam (97.3). This shows that plantain can be effective in the management of glycemic control.

Conclusion and Recommendation

The glycemic index of meal from unripe plantain is ranked medium and could make it a diet that will be moderately effective in the management of diabetes. Meal from unripe plantain should be promoted for both therapeutic and non-therapeutic purposes. In addition, Further research should assess the effect of processing methods on glycemic index of meal from unripe plantain and also, improving the protein and fat content of meal from unripe plantain to make it suitable in making complementary foods for infants.

Acknowledgement

We sincerely appreciate all the volunteers who participated in this study and staffs of Nutrition and Dietetics Department, Federal University of Agriculture, Abeokuta for their effort towards the success of the research.

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