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Antioxidant potentials and glycaemic indices of ripe *Musa* acuminata, ripe *Musa paradisiaca* and unripe *Musa paradisiaca*

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Abstract

Antioxidants are compounds that inhibit oxidation, a chemical reaction that can produce free radicals, leading to cell damage. The GI is a measure of how quickly a food raises blood glucose levels after consumption, with higher GI values indicating a faster release of glucose into the bloodstream. This study aims to compare the antioxidant potentials and glycaemic indices of ripe *Musa acuminata*, ripe *Musa paradisiaca*, and unripe *Musa paradisiaca*. The antioxidant potentials were examined using ferric reducing antioxidant power assay. The carbohydrate content of the samples was obtained using spectrophotometric method. The glycaemic index was calculated using albino rats' blood on a glucometer. The antioxidant potential of the standards (Butylated hydroxytoluene (BHT) and α- tocopherol) and samples exhibit the order BHT > α- tocopherol > unripe *M. paradisiaca* > Ripe *M. paradisiaca* > ripe *M. acuminata*. The carbohydrate content of the samples is ripe banana-26 g/100g, ripe plantain- 12 g/100 g and unripe plantain- 16g/ 100g. The glycaemic indices for ripe *M. acuminata*, ripe plantain and unripe plantain are 55%, 86% and 75% respectively. The unripe *M. paradisiaca* has higher antioxidant potential and moderate glycaemic indices and can be recommended for a diabetic diet.

Keywords: Antioxidant; Glycemic Index; Oxidation; Blood Glucose Level

1. Introduction

Bananas (*Musa acuminata*) and plantains (*Musa paradisiaca*), though botanically similar, are distinguished mostly by their use and starch content. Bananas are usually consumed as a fruit in their ripe state, while plantains are often cooked before consumption, particularly when they are unripe. As fruits ripen, their starches are converted into simpler sugars, affecting not only their sweetness but also their glycemic response when consumed Englyst *et al*, [1]).

M. paradisiaca (Plantain) is a staple food crop in many tropical regions around the world, renowned for their versatility and nutritional value. Nutritionally, plantains are a rich source of complex carbohydrates, dietary fiber, vitamins, and minerals Smith, [2]. Additionally, plantains contain significant levels of resistant starch, which has been associated with better glycaemic control and gut health Garcia and Martinez, [3].

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*M. acuminata (*Bananas), one of the most widely consumed fruits globally, belong to the genus *Musa* and are native to Southeast Asia. They are typically long, curved fruits with a yellow skin that encloses soft, sweet flesh Robinson and Sauco, [4] . The fruit is highly valued for its nutritional benefits, providing a rich source of vitamins, minerals, and dietary fiber. Bananas are particularly noted for their high potassium content, which plays a crucial role in maintaining heart health and regulating blood pressure Eckles *et al*, [5].

Bananas are versatile in culinary uses, commonly eaten raw or used in a variety of recipes, including smoothies, desserts, and baked goods. Their natural sweetness and smooth texture make them a popular ingredient in many dishes worldwide. The presence of antioxidants such as dopamine and catechins in bananas can help reduce oxidative stress and inflammation, which are linked to chronic diseases such as heart disease Boccellino *et al*,[6] .

Antioxidants are compounds that play a critical role in neutralizing free radicals, thereby preventing oxidative stress and its associated damage to cells and tissues. Antioxidants are the most important inhibitors of oxidation, as they prevent autoxidation Mere *et al*, [7]. These compounds can be classified into several categories based on their origin, solubility, and mechanism of action. This classification helps in understanding their role in maintaining cellular health and preventing oxidative damage, which is implicated in various chronic diseases.

Antioxidants can be classified based on their origin into two main types: endogenous and exogenous antioxidants. Endogenous antioxidants are produced within the body and include enzymes like superoxide dismutase (SOD), catalase, and glutathione peroxidase, which play a significant role in protecting cells from oxidative damage. These enzymes work by converting reactive oxygen species (ROS) into less harmful molecules Birben *et al*, [8]. On the other hand, exogenous antioxidants are obtained from external sources such as diet, and they include vitamins (e.g., vitamin C, vitamin E), minerals (e.g., selenium), and phytochemicals (e.g., flavonoids, carotenoids) that contribute to the body's defense against oxidative stress Lobo *et al*, [9].

The Glycemic Index (GI) is a system that ranks carbohydrates based on their effect on blood glucose levels. The blood glucose responses of carbohydrate foods can be categorized by the GI Mere, [10]. The concept of the GI was developed by Jenkins *et al*.[11] to provide insight into how quickly different carbohydrate-containing foods raise blood sugar levels post-ingestion.

The GI can be divided into three categories: low (55 or less), medium (56-69), and high (70 and above). Low-GI foods, such as lentils and many vegetables, cause a slower, more gradual rise in blood sugar levels. In contrast, high-GI foods, like white bread and many processed snacks, cause a rapid spike in glucose levels. This distinction is particularly important for individuals with diabetes or those at risk of developing the condition, as managing postprandial blood glucose levels is critical for long-term health Augustin *et al*, [12].

Aim of the study

The aim of the study was to assess the antioxidant potentials and glycaemic indices of ripe M. *acuminata*, ripe *M. paradisiaca* and unripe *M. paradisiaca*.

Objectives

- Specific objectives of the study were to determine
- Antioxidant potentials of ripe *M. acuminata*, ripe *M. paradisiaca* and unripe M. *paradisiaca*.
- The carbohydrate content of ripe *M. acuminata*, ripe *M. paradisiaca* and unripe M. *paradisiaca*.
- The serving size of ripe *M. acuminata*, ripe *M. paradisiaca* and unripe M. *paradisiaca*.
- Glycaemic indices of ripe *M. acuminata*, ripe *M. paradisiaca* and unripe M. *paradisiaca*.

2. Materials and methods

2.1. Materials

All chemicals used were in analytical grade and were either Sigma-Aldrich GmbH, Sterhnheim, Germany or Merck. The Ripe and unripe *M. paradisiaca* and ripe *M. acuminata* used in this study were purchased from Afo Egbu market in Egbuoma, Oru East Local Government Area, Imo State, Nigeria

2.2. Methods

2.2.1. Antioxidant Status Determination

Extraction of Sample

Four grams of ground sample was mixed with 25 ml of 1 M acetic acid and homogenized using an orbital Rocker Shaker. The homogenate was centrifuged at 3000 rpm for 20 minutes using centrifuge (model 1412-1). The supernatant was gently recovered with a pasteur pipette, and assayed with ferric ion reducing antioxidant power assay. Ripe and unripe *M. paradisiaca* and ripped *M. acuminata* were used as samples.

The Ferric Ions (Fe^{3+}) Reducing Antioxidant Power Assay (FRAP)

The reducing power of Ripe and unripe *M. paradisiaca* and ripe *M. acuminata* and standard (BHT and α-tocopherol) were determined by the method of Oyaizu [13] as modified by Gulcin, [14]. Three concentrations of 15 µl, 30 µl and 45 µl of extract and standard were treated differently

Exactly 15 µl of each extract was added with 1 ml of distilled water mixed with 2.5 ml of 0.2M sodium phosphate buffer pH 6.6, 2.5 ml of 1 % potassium ferricyanide [$K_3Fe(CN)_6$]. The mixture was incubated at 50 ˚C for 20 minutes. Aliquots 2.5 ml of 10 % trichloroacetic acid were added to the mixture. The upper layer of solution (2.5 ml) was mixed with distilled water (2.5 ml) and $FeCl_3$ (0.5 ml, 0.1 %), and the absorbance was read at 700 nm in 722N Shanghai visible spectrophotometer. Absorbance of different concentration of the extracts (15, 30 and 45 µl/ml) were compared. Increased in absorbance of the reaction mixture indicates an increase of reduction capability Buyukokuroglu *et al*, [15]; Gulcin *et al*, [16]. The solutions without sample extract or standards were used as blank. Reducing antioxidant power determination was performed in triplicates.

2.2.2. Glycemic Index

The phenol-sulphuric acid method for the estimation of carbohydrate quantitatively was used. Sucrose was used as standard carbohydrate to prepare a calibration curve. 10 mg of sucrose was weighed and dissolved with 100 ml of distilled water. Six test tubes were labeled one to six and carbohydrate standard (10 mg/100ml sucrose) was put in serial dilution. Distilled water was added to make it up to 0.5 ml. 0.5 ml of 5 % phenol solution was then added with thorough mixing. 2.5 ml of concentrated sulphuric acid was added to the mixture and the test tube was shaken thoroughly. It was allowed to stand for 20 minutes and read in a spectrophotometer at 420 nm.

Ripe and unripe *Musa paradisiaca* and ripe *Musa acuminate* were used as samples. The samples were ground differently to fine suspension using mortar and pestle. 10mg of each ground sample was weighed and dissolved in 100 ml of distilled water.

Exactly 0.5 ml of 10mg/100ml of sample was pipetted into test tubes and treated with 0.5 ml of 5 % phenol solution and 2.5 ml of concentrated H_2SO_4. This was done in triplicates. The mixtures were allowed to stand for 20 minutes and absorbance read at 420 nm. The absorbance of each of the triplicates for the samples were extrapolated from the calibration curve for the concentrations. Mean concentration (X) from the triplicates of the test samples were taken.

The estimated carbohydrate concentration of each sample was used to determine the serving size of the test foods that is the quality of test foods that contain 1-gram carbohydrate.

2.3. Determination of Blood Glucose

Albino rats were used for the experiment. The experimental animals were fasted overnight. Their fasting Blood sugar was taken at 0 hour. Then they were fed with calculated quantity of sample that contains 1 g carbohydrate. Animals that finished eating the sample between 5 to 10 minutes were used for the experiment. The blood was taken and checked for glucose level after 30 minutes of feeding and consequently for 3 hours. Blood was taken from the tail of the animals.

In estimating the rate of blood glucose after feeding with the samples, three (3) animals were used for each sample. Each blood sample was placed on a test trip which was inserted in a calibrated glucometer (prestige) which gave direct readings after 45 seconds based on glucose oxidase assay method. The determination of blood glucose level was done at intervals i.e. 0 hour (fasting level), 30 minutes, 60 minutes, 90 minutes, 120 minutes and 180 minutes.

2.4. Glycemic Index Calculation and Statistics

Changes in blood glucose concentration were calculated separately for each post meal period by using the blood concentration before meal (0 hour) as a baseline. Postprandial responses were compared for maximum increase and incremental area under the glucose curve for each food. The integrated area under the postprandial glucose curve was calculated by trapezoidal method. Area increment under the curves for a given food were determined for the 3-hour period after the meal. The relative glycemic index of each food was calculated as percent of the mean of areas under the glucose response area was analyzed statistically using one way ANOVA Mere, [10] .

3. Results

3.1. Antioxidant Potentials in the different samples using Ferric Reducing Antioxidant Powder Assay

Table 1 Antioxidant Potentials in the different samples using Ferric Reducing Antioxidant Powder Assay with Absorbance at 700 nm.

Conc. (µg/ml)	BHT	α-TP	Ripe Banana	Ripe Plantain	Unripe Plantain
15	0.69± 0.03#	0.76± 0.02	0.47± 0.03*#	0.55± 0.00*#	0.38± 0.03*#
30	0.89± 0.05	0.77± 0.14*	0.52± 0.01*	0.56± 0.00*#	0.63± 0.06*#
45	0.90± 0.15#	0.84± 0.11	0.63± 0.02#	0.64± 0.00#*	0.72± 0.04*#

The results presented in Table 4.1 provide valuable insights into the antioxidant potentials of ripe *M. acuminata* and *M. paradisiaca* (both ripe and unripe) with well-known antioxidants, Butylated Hydroxytoluene (BHT) and α-Tocopherol (α-TP). These findings are critical as they offer a comparative understanding of how natural food sources stack up against synthetic antioxidants in terms of their capacity to reduce ferric ions, which is a measure of their antioxidant potential as assessed by the Ferric Reducing Antioxidant Power (FRAP) assay, with absorbance measured at 700 nm.

3.2. The Carbohydrate Content in the Different Samples

Table 2 Carbohydrate Content in the Different Samples (Carbohydrate Content/100 grams)

Food Samples	Carbohydrate Content (/ 100 g)
Ripe *M. acuminata*	26.00±0.15
Ripe *M. paradisiaca*	12.00±0.23
Unripe *M. paradisiaca*	16.70±0.21

The carbohydrate content of various food samples, as presented in Table 4.2, indicates that a ripe banana contains 26.00±0.15 grams of carbohydrates per 100 grams, which is significantly higher than both ripe and unripe plantains.

3.3. Serving Size of the Test Food Samples

Table 3 The Serving Size of the Test Food Samples

Food Samples	Serving Size (Quantity/ 1 g of Carbohydrate)
Ripe *M. acuminata*	3.85±0.06
Ripe *M. paradisiaca*	8.33±0.31
Unripe *M. paradisiaca*	5.99±0.23

The data presented in Table 4.3 shows the serving sizes of the food samples required to obtain 1 gram of carbohydrate. The results indicate that ripe banana requires the smallest serving size, with an average of 3.85 ± 0.06 grams per gram of carbohydrate.

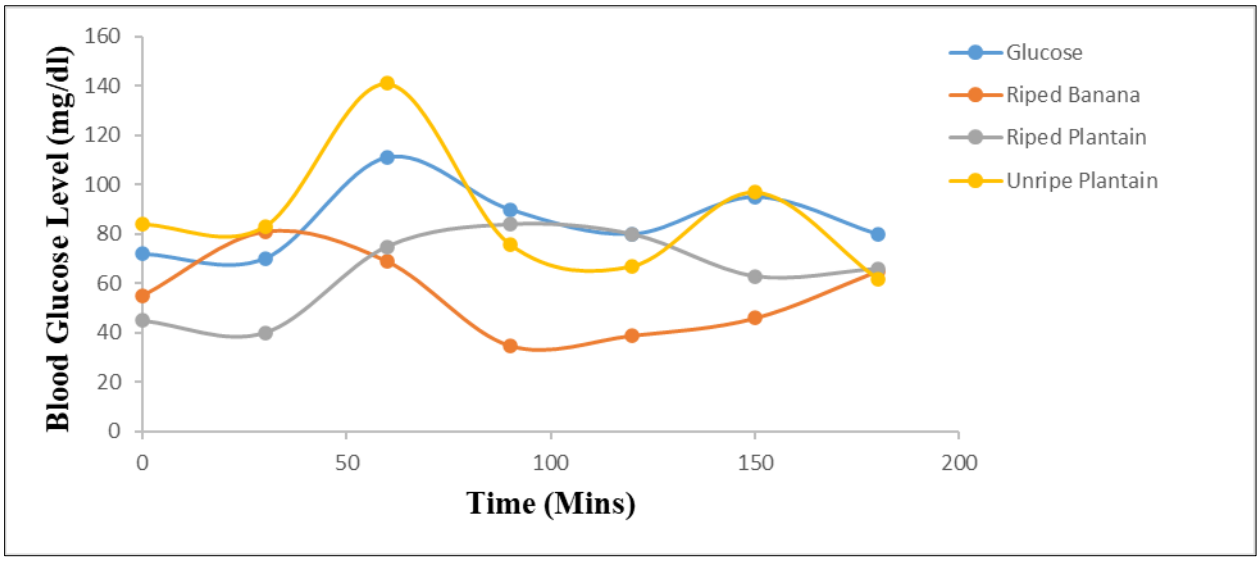

Figure 1 Blood Glucose Level in the Different Test Foods with Time

The graph in Figure 6.1 illustrates the blood glucose levels over time for different test foods: glucose, ripe banana, ripe plantain, and unripe plantain. Each food item demonstrates a distinct pattern of blood glucose response, reflecting its biochemical impact on glucose metabolism. As expected, the glucose curve shows a rapid increase in blood glucose levels, peaking sharply around 60 minutes before gradually declining. Figure 6.2 show the rate at which blood glucose level increase or decrease with respect to 0 min of the study.

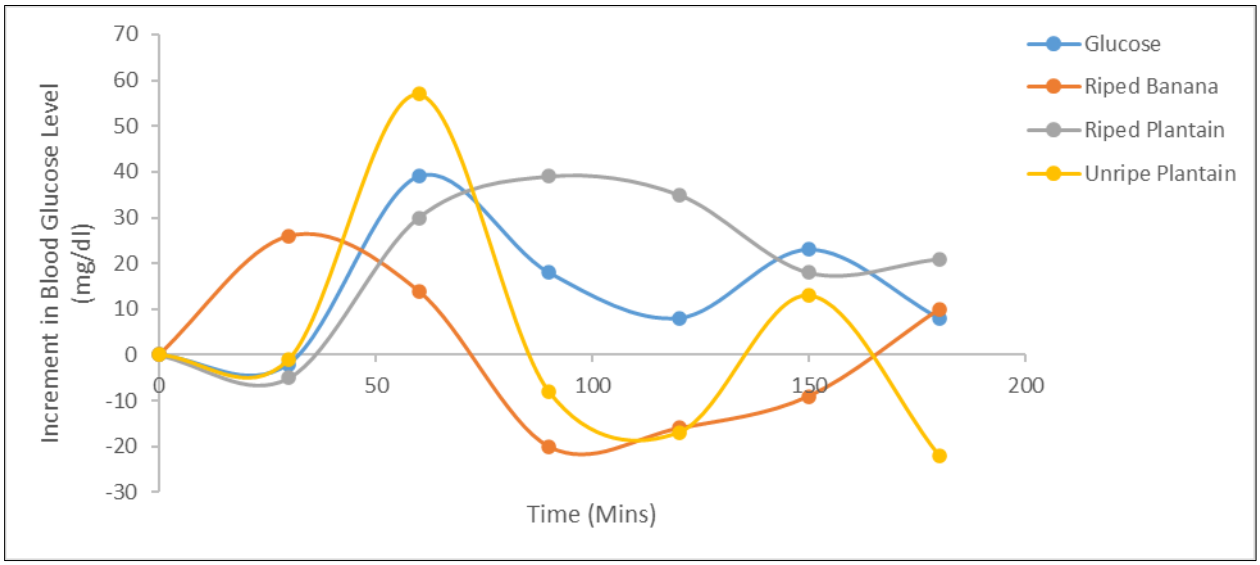

Figure 2 Increment in Blood Glucose Level in the Different Test Foods with Time

Table 4 The Glycaemic Indices of the Test Food Samples

Test samples	Glycaemic indexes (%)
Ripe *M. acuminata*	55
Ripe *M. paradisiaca*	86
Unripe *M. paradisiaca*	75

The results depicted in table 6.4 provide valuable insights into the glycaemic responses elicited by different food samples, specifically a ripe banana, ripe plantain, and unripe plantain. The glycemic index for the ripe banana is observed to be lower than that of both the ripe and unripe plantain, indicating that bananas cause a slower rise in blood sugar levels.

4. Discussion

The antioxidant content in *M. acuminata* and *M. paradisiaca* varies with ripeness, with some studies suggesting that unripe fruits may possess higher antioxidant levels due to the presence of certain bioactive compounds Someya *et al*, [17].

The results presented in Table 6.1 indicated the antioxidant potentials of the different samples, measured using the Ferric Reducing Antioxidant Power (FRAP) assay, with absorbance at 700 nm. At a concentration of 15 µg/ml, α-TP exhibited the highest antioxidant activity (0.76±0.02), which was statistically significant compared to the ripe and unripe *M. paradisiaca* (0.55±0.00 and 0.38±0.03, respectively) and the ripe *M. acuminata* (0.47±0.03), all of which showed significantly lower activity compared to BHT and α-TP ($P<0.005$). As the concentration increased to 30 µg/ml, BHT demonstrated superior antioxidant activity (0.89 ± 0.05) compared to α-TP (0.77 ± 0.14), with the unripe *M. paradisiaca* showing a marked increase in activity (0.63 ± 0.06), though still lower than BHT and α-TP. At the highest concentration tested (45 µg/ml), both BHT and α-TP displayed similar antioxidant potentials (0.90 ± 0.15 and 0.84 ± 0.11, respectively), with the ripe *M. acuminata*, ripe *M. paradisiaca*, and unripe *M. paradisiaca* exhibiting moderate antioxidant activity (0.63±0.02, 0.64 ± 0.00, and 0.72 ± 0.04, respectively), with the unripe *M. paradisiaca* showing the closest activity to the synthetic antioxidants Smith *et al*., [18]. These results imply that while natural food sources like bananas and *M. paradisiaca* possess significant antioxidant potential, they are generally less potent than synthetic antioxidants like BHT and α-TP, especially at lower concentrations. However, as the concentration increases, some natural samples, particularly unripe *M. paradisiaca*, exhibit a notable increase in antioxidant activity, suggesting their potential as natural alternatives in dietary antioxidant supplementation.

The carbohydrate content of various food samples, as presented in Table 4.2, indicates that a ripe banana contains 26.00 ± 0.15 grams of carbohydrates per 100 grams, which is significantly higher than both ripe and unripe *M. paradisiaca*. This higher carbohydrate content in ripe bananas suggests that they are a rich source of quick energy due to the presence of simple sugars like glucose and fructose, which are readily absorbed by the body Smith, [2]. In comparison, the carbohydrate content of ripe *M. paradisiaca* is lower at 12.00 ± 0.23 grams per 100 grams. This difference may be attributed to the higher starch content in *M. paradisiaca*, which gradually converts to sugars as the fruit ripens, thus influencing the overall carbohydrate profile Jones, [19]. Unripe *M. paradisiaca*, on the other hand, contain 16.70 ± 0.21 grams of carbohydrates per 100 grams, indicating a higher starch content compared to ripe *M. paradisiaca* but still less than ripe bananas. The elevated starch levels in unripe *M. paradisiaca* could have significant implications for individuals seeking lower glycemic index foods, as the slower digestion of starches leads to a more gradual release of glucose into the bloodstream Brown and Miller, [20].

The data presented in Table 4.3 on the serving size of the test food samples have notable biochemical implications, particularly in the context of carbohydrate metabolism and glycemic response. The serving sizes represent the quantity of food (in grams) needed to provide 1 gram of carbohydrate. Ripe banana has the smallest serving size (3.85 ± 0.06 g), indicating that it is the most carbohydrate-dense among the samples. This suggests that consuming a smaller amount of ripe banana can deliver a significant carbohydrate load, which could lead to a rapid increase in blood glucose levels, given the high glycemic index typically associated with ripe fruits Wolever, [21].

In contrast, ripe *M. paradisiaca* has the largest serving size (8.33 ± 0.31 g) to provide the same carbohydrate content. This implies that ripe *M. paradisiaca* is less carbohydrate-dense compared to the ripe *M. acuminata*, which might result in a slower rise in blood glucose levels due to its potentially lower glycemic index Brand-Miller *et al*., [22]. The unripe *M. paradisiaca*, with a serving size of 5.99 ± 0.23 g, falls in between the two, suggesting a moderate carbohydrate density and possibly a different glycemic response compared to both the ripe *M. acuminata* and ripe *M. paradisiaca*. The differences in carbohydrate density across these food samples reflect variations in their biochemical composition, particularly the type and structure of carbohydrates present, which can influence their metabolic processing and impact on blood glucose regulation.

The blood glucose levels over time for different test foods: glucose, ripe banana, ripe plantain, and unripe plantain. Each food item demonstrates a distinct pattern of blood glucose response, reflecting its biochemical impact on glucose metabolism. As expected, the glucose curve shows a rapid increase in blood glucose levels, peaking sharply around 60 minutes before gradually declining. This immediate spike is due to the rapid absorption of glucose into the bloodstream,

which is consistent with its high glycemic index (GI). Foods with high GI values cause quick and significant increases in blood sugar levels Atkinson *et al*, [23]. The curve for ripe banana peaked at 30 minutes after administration and then reduced up to the 3 hour of monitoring. The slower increase can be attributed to the presence of sugars like fructose and dietary fiber in bananas, which delay glucose absorption. This may be what resulted in a lower glycemic response, which is beneficial for maintaining stable blood sugar levels over time Foster-Powell *et al*, [24]. The blood glucose response to ripe plantain shows a moderate rise after 60 mins of administration with a more sustained elevation. This suggests the reason for the high glycaemic index of ripe plantain, likely due to its carbohydrate composition, which includes resistant starch that slows down the digestion and absorption of glucose Englyst *et al*, [25]. The unripe plantain curve displays a more gradual increase in the blood glucose level, which is possibly the reason for a high glycaemic index. Unripe plantains are rich in resistant starch, which resists digestion in the small intestine, leading to a slower release of glucose into the bloodstream (Robertson *et al*, [26]. This property makes unripe plantain a potentially beneficial food for managing blood sugar levels, particularly in individuals with insulin sensitivity or diabetes.

The glycemic index (GI) is a measure that ranks foods on a scale from 0 to 100 based on how quickly they raise blood sugar levels after consumption. The results depicted in Table 4.4 provide valuable insights into the glycemic responses elicited by different food samples, specifically a ripe banana, ripe plantain, and unripe plantain. The glycemic index for the ripe banana is observed to be lower than that of both the ripe and unripe plantain, indicating that bananas cause a slower rise in blood sugar levels. This can be attributed to the carbohydrate composition of bananas, which primarily consists of simpler sugars and a higher amount of dietary fiber that can moderate glucose absorption Atkinson *et al*, [23]. The moderate GI of bananas is often beneficial for individuals looking to maintain stable blood glucose levels, making it a preferable option for those managing diabetes or other metabolic conditions Jenkins *et al*, [11]. The ripe plantain shows a significantly higher glycemic index compared to the banana, suggesting that it causes a more rapid increase in blood glucose levels. This is likely due to the higher starch content in plantains, which, when ripe, becomes more readily digestible, thus leading to quicker glucose release into the bloodstream Englyst *et al*, [1]. Ripe plantains may be less suitable for individuals needing to control postprandial blood glucose spikes. Interestingly, the unripe plantain also exhibits a higher glycemic index, although slightly lower than the ripe plantain. The unripe plantain contains more resistant starch, which is a type of starch that resists digestion, potentially slowing down glucose release Fuentes-Zaragoza *et al*, [27]. However, the overall GI still remains high, indicating that while the resistant starch might moderate the glucose response to some extent, it does not significantly lower the glycemic index compared to the ripe banana.

5. Conclusion

This study highlights the importance of food choice in managing blood glucose levels. Foods with lower glycemic indices, such as unripe plantains and ripe bananas, contribute to a more controlled and sustained release of glucose, reducing the risk of hyperglycemia and promoting better long-term metabolic health. The findings show that bananas may be a better option for controlling blood sugar levels compared to plantains, whether ripe or unripe. These biochemical implications are crucial for dietary recommendations, particularly for individuals at risk of or managing hyperglycemia.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

Statement of ethical approval

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