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Antinutritional, antioxidant and invitro antidiabetic properties of plantain flour supplemented with African locust beans

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ABSTRACT

The aim of the study was to determine the antinutritional, antioxidant, and in vitro antidiabetic properties of plantain flour supplemented with African locust beans. Flour blends were produced from plantain and locust beans in the following ratios of plantain: locust beans: 95:5, 90:10, 85:15, 80:20, and 100% plantain as control. Antinutritional (oxalate, phytate, saponin, and alkaloid), antioxidant (DPPH, FRAP, ABTS, and OH), and in vitro antidiabetic (α-amylase and α-glucosidase inhibitory) analyses were carried out on the flour blends. The antinutritional results showed that oxalate ranged from 6.10 to 12.83 mg/g, phytate ranged from 36.66 to 52.24 mg/g, saponin content ranged from 2.82 to 30.24 mg/g, and total alkaloid content ranged from 6.92 to 23.59%. The antioxidant results indicated that the DPPH value ranged from 51.95 to 57.89%, ABTS ranged from 30.41 to 48.37%, the FRAP value ranged from 42.37 to 65.77 mg Vit. C/g, phenol content ranged between 3.99 and 9.46 mg GAE/g, and flavonoid content ranged between 0.44 and 5.79 mg QE/g. The α-amylase inhibitory activity ranged from 36.56 to 91.24%, and α-glucosidase inhibitory activity ranged from 39.09 to 82.34%. It can be concluded that the supplementation of plantain flour to African locust beans exhibits promising antioxidant and antidiabetic properties, which could be beneficial in boosting the immune system and reducing blood sugar levels. Therefore, the blended flour can be exploited as a functional ingredient in food products such as baked foods, snacks, and cereals targeting consumers seeking health benefits.

Contribution/Originality: This study contributes to the existing literature by evaluating plantain flour supplemented with African locust beans. It provides new data on their combined antioxidant and antidiabetic effects. This investigation is among the few studies on this composite flour. It documents improved functional health properties.

1. INTRODUCTION

Plantain (Musa parasidiaca) is one of the important staple food crops consumed in the tropics, behind rice, wheat, and maize, and is obtainable in about 120-130 tropical countries worldwide [1]. It is an essential food crop in sub-Saharan Africa that serves as a source of nutrients and household income for many people around the world [1]. It is well patronized as a staple food in many parts of West and Central Africa [2]. It is a rich source of nutrients such as iron, zinc, potassium, and sodium. Adeniji et al. [2] reported between 14.275 to 36.500 µg/g of iron in plantain, depending on the cultivar. The aggregated world production is estimated at over 76 million metric tons [3], with

over 12 million metric tons harvested annually in Africa. Nigeria harvests sizeable tons of plantains annually and is the largest producer of plantains in West Africa, with an estimated production of about 2.7 million metric tons, most of which are produced and harvested from the southern part of the country. Despite large harvests, up to 40% of plantains are lost annually due to the unavailability of appropriate storage facilities to prevent postharvest losses [4]. These large productions and postharvest losses necessitate the development of new and suitable technologies for processing and preservation of plantain flour. Usually harvested at a mature but unripe stage, plantains undergo rapid respiration after harvest, making them short-lived agricultural products that require urgent attention immediately after harvest. Plantain can be processed into flour, which has become increasingly popular due to its versatility and nutritional value [5].

The African locust bean (Parkia biglobosa), commonly called Iru (Yoruba), is a tree that is widely distributed in Northern Nigeria. It belongs to the legume family, Leguminosae. The pods are flat, large, and form irregular clusters from which the locust bean seeds are obtained [6]. The seeds have also been shown to have high antioxidant activity, which is attributed to their phenolic and flavonoid content. It contains about 14.3% water, 25.4% protein, 1.5% fat, 7.1% fiber, 3.2% ash, and 48.5% carbohydrate. The African locust bean is consumed mainly because the fruit is rich in minerals and provides valuable protein. The raw African locust beans are nutritionally deficient and unpalatable, but when fermented into a condiment (iru), the physical, chemical, and nutritional characteristics of the seeds change [7]. It is normally used as a soup and flavoring material in stew and constitutes an essential ingredient in the preparation of local soup or stew. Iru is a cheap source of protein in Southwestern Nigeria [7].

Diabetes is a chronic metabolic disorder characterized by high blood sugar levels. It is a significant public health problem globally, particularly in developing countries, including West Africa [8, 9]. In recent years, there has been a growing interest in exploring the nutritional and medicinal properties of traditional African food sources. Among these, plantain flour holds promise due to its potential health benefits [9, 10]. Additionally, African locust beans, known for their rich nutrient content and therapeutic properties, have been traditionally used in various culinary applications across the continent.

Therefore, this study investigated the antinutritional, antioxidant, and in-vitro antidiabetic properties of plantain flour supplemented with African locust beans. Antinutritional factors, which are compounds that interfere with the absorption of nutrients, are of concern in food products and can have detrimental effects on human health.

2. MATERIALS AND METHOD

2.1. Sources of Raw Materials

Freshly harvested plantains were purchased from Alade Market, Idanre, while locust bean seeds were sourced from Oja Oba Market, Akure, Ondo State. Equipment used was provided by the Department of Biochemistry, FUTA, and all chemicals and reagents used were of analytical standard.

2.1.1. Preparation of Plantain Flour

Plantain flour was produced following a recent method [9]. Plantain fingers were detached, thoroughly washed to remove dirt, manually peeled, and sliced with a knife. The slices were blanched at 70°C for 5 minutes to prevent enzymatic browning, then drained with a sieve and sun-dried for 3 days. The dried slices were milled into flour, sieved using a 250-µm mesh, packaged in sealed plastic (Ziploc) bags, and stored at room temperature (25°C ± 2) until further use.

2.1.2. Preparation of Locust Bean Flour

The locust bean seeds were sorted to remove debris, then pressure-cooked for 3 hours to soften them. After cooling, dehulling was done by vigorously rubbing the seeds between the palms to separate the pulp from the seed coat. The dehulled seeds were thoroughly washed, and the husk was removed. The clean seeds were sun-dried for 4

days to reduce moisture content, milled into flour using a milling machine, sieved through a 250-µm mesh, packaged in sealed plastic (Ziploc) bags, and stored at room temperature (25°C ± 2) until further use.

2.1.3. Preparation of the Various Flour Blends

Plantain flour was supplemented with varying proportions of locust bean flour (5%, 10%, 15%, and 20%) by mixing the appropriate amounts of each flour.

2.1.4. Extraction of Samples

A flour extract concentration of 10 mg/mL was prepared by weighing the appropriate amount of sample into 2 mL microcentrifuge tubes. Distilled water was added to achieve the desired concentration, and the mixture was vortexed for approximately one minute to ensure dispersion. The suspension was then allowed to hydrate at room temperature for 10 minutes. After a brief additional mixing (15 seconds), the tubes were centrifuged at 10,000 × g for 10 minutes using a KX3400C centrifuge (KENXIN International Co., China). The clear supernatant obtained after centrifugation was collected and used for subsequent analyses.

2.2. Determination of Phytochemical Contents

2.2.1. Total Phenolic Content

The total phenol content (TPC) was determined using the Folin–Ciocalteu assay [11] with gallic acid serving as the standard. In this procedure, 0.2 mL of the sample extract was mixed with 0.5 mL of 10% Folin–Ciocalteu reagent and 2 mL of 7.5% sodium carbonate solution. The mixture was incubated at 45°C for 40 minutes to allow for color development. After incubation, the absorbance was measured at 700 nm using a Healicom 721S spectrophotometer (China). Gallic acid was used as the reference standard, and the total phenolic content of the sample was expressed in milligrams of gallic acid equivalent (mg GAE).

2.2.2. Total Flavonoid Content

The total flavonoid content of the sample was determined using a modified method [12]. In brief, 200 µL of the extract was mixed with 300 µL of 5% sodium nitrate solution. After standing for 5 minutes, 600 µL of 10% aluminum chloride was added. Following an additional 6 minutes, 2 mL of 1 M sodium hydroxide was introduced into the mixture, and 2.1 mL of distilled water was added to bring the final volume to a consistent level. The absorbance was then measured at 415 nm using a Healicom 721S UV-visible spectrophotometer (China), with a reagent blank serving as the reference. The total flavonoid content was expressed as milligrams of rutin equivalent.

2.3. Determination of Antinutritional Contents

2.3.1. Phytate Content

Phytate content was determined using the bipyridine colorimetric method [13]. Two grams of the sample were soaked in 50 mL of 0.2 N HCl and shaken for 30 minutes. The mixture was filtered, and 0.5 mL of the extract was mixed with 1 mL of acidified ferrous ammonium sulfate solution, then boiled for 30 minutes and cooled to room temperature. After centrifugation at 3000 rpm for 5 minutes, 1 mL of the supernatant was combined with 1.5 mL of 2.2 bipyridine solution. A standard solution was treated similarly. Absorbance readings of both standard and sample were taken at 519 nm using a spectrophotometer (Spectrumlab 752x, Japan), with a blank as reference.

2.3.2. Oxalate Content

Oxalate content was determined titrimetrically [13]. Five grams of the sample were weighed into a 100 mL beaker, mixed with 20 mL of 0.3 N HCl, and stirred on a magnetic hot plate for 1 hour. The mixture was filtered into a 100 mL volumetric flask and diluted to volume. A 5 mL aliquot was pipetted into a conical flask, made alkaline with

1.0 mL of 5 N ammonium hydroxide, and confirmed using indicator paper. Two to three drops of phenolphthalein were added, followed by 1 mL of glacial acetic acid to decolorize. Next, 1 mL of 5% $CaCl_2$ was added and left to stand for 3 hours, then centrifuged at 3000 rpm for 15 minutes. The precipitate was washed three times with hot water, centrifuging after each wash. Two milliliters of 3 N H_2SO_4 were added to the precipitate, and the mixture was warmed at 70–80°C to dissolve. The content was transferred to a conical flask and titrated with freshly prepared 0.05 M $KMnO_4$ at room temperature until a faint pink color appeared. The solution was then warmed again and titrated to a stable pink endpoint. Oxalate content was calculated as sodium oxalate equivalent.

2.3.3. Saponin Content

The saponin content of the sample was determined following the method described by Ayo and Gidado [14] with slight modifications. Briefly, 20 g of the sample was weighed and extracted with 200 mL of 20% ethanol. The mixture was heated in a water bath at 55°C for 4 hours with continuous stirring. After filtration, the residue was re-extracted with 200 mL of diethyl ether under vigorous agitation. The aqueous layer was carefully separated, and the diethyl ether layer was discarded. This purification process was repeated to ensure thorough extraction. Next, 60 mL of n-butanol was added to the aqueous layer, and the solution was washed repeatedly with 10 mL portions of 5% aqueous sodium chloride. The resulting solution was concentrated by evaporation in a water bath, and the residue was dried in an oven to a constant weight. The saponin content was then calculated using.

$$Saponin\ content\ (\%) = \frac{weight\ of\ residue}{weight\ of\ sample} \times 100 \quad (1)$$

2.3.4. Alkaloid Content

The alkaloid content of the sample was determined according to the method described by Aderinola et al. [12]. Approximately 5 g of the sample was weighed into a 250 mL beaker, and 200 mL of 10% acetic acid prepared in ethanol was added. The mixture was allowed to stand for 4 hours at room temperature to ensure thorough extraction. Following filtration, the extract was concentrated by evaporating it over a water bath to about one-quarter of its original volume. Concentrated ammonium hydroxide was then added gradually to the concentrated extract until complete precipitation occurred. The solution was left to settle, after which the precipitate was collected, washed with a dilute solution of ammonium hydroxide, and filtered. The dried residue was weighed, and the alkaloid content was expressed as the weight of this residue.

2.4. Determination of Antioxidant Properties

The antioxidant assays described below were carried out using a recently reported method [15].

2.4.1. 2, 2-Diphenyl-1-Picrylhydrazyl (DPPH) Radical Scavenging Ability

Briefly, 1 mL of the extract was combined with 1 mL of a 0.4 mM DPPH solution prepared in methanol. The mixture was incubated in the dark for 30 minutes to prevent light-induced degradation. Following incubation, the absorbance was read at 517 nm using a Healicom 721S spectrophotometer (China). A control solution containing methanol in place of the extract was used as a baseline. The percentage of radical scavenging activity was calculated using the formula below.

$$\%\ DPPH = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (2)$$

2.4.2. 2,2'-Azino-Bis (3-Ethylbenzothiazoline-6-Sulfonic Acid) (ABTS) Scavenging Ability

To generate the ABTS radical cation ($ABTS^+$), 7 mM ABTS solution was mixed with 2.45 mM potassium persulfate and kept in the dark for at least 15 hours. Before use, the absorbance of the resulting solution was adjusted to 0.70 at 734 nm using ethanol. For the assay, 200 µL of the ABTS solution was combined with 20 µL of the extract,

and the absorbance was recorded at 734 nm using a Healicom 721S spectrophotometer (China). The radical scavenging activity of the extract was then calculated using the equation.

$$\%\ ABTS = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (3)$$

2.4.3. Ferric-Reducing Antioxidant Property (FRAP)

In brief, 0.25 mL of the sample's extract was mixed with 0.25 mL of 200 mM sodium phosphate buffer (pH 6.6) and 0.25 mL of 1% potassium ferricyanide. The mixture was incubated at 50°C for 20 minutes. After incubation, 0.25 mL of 10% trichloroacetic acid was added, and the mixture was centrifuged at 2000 rpm for 10 minutes. Subsequently, 1 mL of the resulting supernatant was combined with 1 mL of distilled water and 0.1% ferric chloride ($FeCl_3$). The absorbance was measured at 700 nm using a Healicom 721S spectrophotometer (China). Ascorbic acid (0.01 mg/mL) served as the reference standard.

2.4.4. Hydroxyl Radical Scavenging Ability

The hydroxyl radical scavenging assay was determined using a previously reported method [16]. In this assay, varying volumes (0–100 µL) of freshly prepared extract were added to a reaction mixture containing 400 µL of 0.1 M phosphate buffer (pH 7.4), 120 µL of 20 mM deoxyribose, 40 µL of 20 mM hydrogen peroxide (H_2O_2), and 40 µL of 500 µM ferrous sulfate ($FeSO_4$). The total volume was brought to 800 µL using distilled water. The mixture was incubated at 37°C for 30 minutes to allow for radical generation. The reaction was terminated by adding 0.5 mL of 2.8% trichloroacetic acid (TCA), followed by 0.4 mL of 0.6% thiobarbituric acid (TBA) solution. The samples were then heated in a boiling water bath for 20 minutes. After cooling, absorbance was measured at 532 nm. The hydroxyl radical scavenging capacity of the extract was calculated using this data.

$$\%\ OH\ \ inhibition = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (4)$$

2.5. Determination of Anti-Diabetic Properties

2.5.1. In-Vitro α-Amylase Activity

The α-amylase inhibitory activity of the extract was evaluated based on the method described by Mayomi and Aderinola [15] with slight modifications. In this assay, 100 µL of the sample extract or distilled water (serving as the control) was mixed with 100 µL of α-amylase enzyme solution, which had been prepared in 0.02 M phosphate buffer (pH 6.9) containing 0.006 M sodium chloride. The mixture was incubated at 28°C for 10 minutes to allow enzyme interaction. Following this, 200 µL of 1% starch solution (prepared in the same buffer) was added to initiate the reaction, and the mixture was incubated at room temperature for an additional 10 minutes. The reaction was terminated by adding 1 mL of dinitrosalicylic acid (DNS) reagent, and the tubes were subsequently placed in a boiling water bath for 5 minutes. After cooling to room temperature, the reaction mixture was diluted 1:5 with distilled water (v/v), and absorbance was measured at 540 nm using a Healicom 721S spectrophotometer (China). The percentage inhibition of α-amylase activity by the extract was then calculated using the appropriate formula.

$$\alpha - amylase\ inhibition\ (\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (5)$$

2.5.2. In-Vitro α-Glucosidase Activity

The inhibitory effect of the extract on α-glucosidase activity was determined using a modified version of the method reported by Mayomi and Aderinola [15]. The substrate solution was prepared by dissolving p-nitrophenyl-α-D-glucopyranoside (pNPG) in 20 mM phosphate buffer (pH 6.9). For the assay, 100 µL of α-glucosidase enzyme solution (0.3 U/mL) was pre-incubated with 50 µL of the sample extract at 37°C for 10 minutes. The reaction was initiated by adding 50 µL of 3.0 mM pNPG (prepared in the same buffer), and the mixture was further incubated at 37°C for 20 minutes. To terminate the reaction, 2 mL of 0.1 M sodium carbonate (Na_2CO_3) was added. The enzymatic

activity was assessed by measuring the absorbance of the released p-nitrophenol at 405 nm using a spectrophotometer. The percentage inhibition of α-glucosidase was then calculated using the corresponding formula.

$$\alpha - glucosidase\ inhibition\ (\%) = \frac{A_{control} - A_{sample}}{A_{control}} \times 100 \quad (6)$$

2.6. Statistical Analysis

All chemical analyses were performed in triplicates, and the results were expressed as mean values ± standard deviation (SD). Statistical analysis for mean comparison was carried out using one-way analysis of variance (ANOVA), followed by Duncan's Multiple Range Test (DMRT) at a significance level of $p \leq 0.05$. The analyses were conducted using the Statistical Package for the Social Sciences (SPSS) software (version 25).

3. RESULTS AND DISCUSSION

3.1. Phytochemical Contents of the Composite Flour

The phytochemical contents of the samples, measured through total phenolic content (TPC) and total flavonoid content (TFC), are shown in Figure 1 (A & B). TPC increased significantly from 3.99 mg GAE/g in CNTP to 9.46 mg GAE/g in ALP20, likely due to the high phytochemical content of locust beans. These phenolic compounds provide several health benefits, including the inhibition of lipid autoxidation and prevention of oxidized low-density lipoprotein (LDL) formation, which is associated with cardiovascular disease [17, 18]. Flavonoid content also increased from 0.44 mg QE/g in CNTP to 5.79 mg QE/g in ALP20, mirroring the rise in antioxidant activity and highlighting the strong correlation between phenolic/flavonoid content and antioxidant potential. Phenolic compounds enhance antioxidant status by acting as electron donors, metal chelators, and hydrogen atom donors [19]. These findings support previous studies showing that phenols and flavonoids exhibit a wide range of biological and health benefits, including antioxidant, antimicrobial, and anti-allergic effects [20].

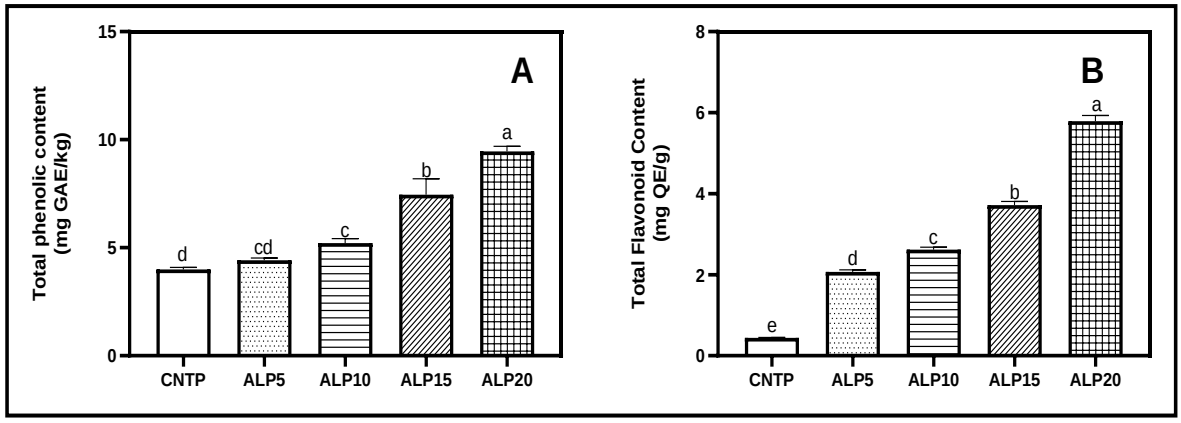

Figure 1. Phytochemical properties of plantain flour supplemented with African locust beans.
Note: Bars (Mean ± standard deviation) with different alphabets are significantly different ($p<0.05$).

CNTP: 100% Plantain Flour.
ALP5: 95% Plantain Flour, 5% Locust Beans.
ALP10: 90% Plantain Flour, 10% Locust Beans.
ALP15: 85% Plantain Flour, 15% Locust Beans.
ALP20: 80% Plantain Flour, 20% Locust Beans.

3.2. Antinutritional Properties of Plantain Flour Supplemented with African Locust Beans

The results of the antinutritional properties of plantain flour supplemented with African locust beans, as influenced by varying levels of supplementation, are presented in Figure 2 (A-D). The main antinutritional factors examined include oxalate (Figure 2A), phytate (Figure 2B), saponin (Figure 2C), and alkaloid (Figure 2D). The

oxalate content in the supplemented flours ranged from 6.10 mg/g to 12.83 mg/g. Among the samples, ALP20 recorded the lowest oxalate content (6.10 mg/g), while ALP5 had the highest (12.83 mg/g). The elevated oxalate content observed in ALP5 may be attributed to the presence of compounds that either bind with oxalates or inhibit their absorption during digestion. Certain phytochemicals found in legumes, for instance, can interact with oxalic acid, thereby reducing its bioavailability. The phytate content of the control sample was relatively low (36.66 mg/g). ALP5 showed the highest value (52.24 mg/g), which may indicate that even a small addition of African locust beans significantly increases phytate levels. As supplementation increased, phytate content initially rose, peaking at ALP5 and ALP10, then declined at higher levels (ALP15 and ALP20), possibly due to matrix interactions or enzymatic degradation. This trend aligns with previous studies [17], which reported a similar pattern in Kunu from pearl millet supplemented with African locust bean pulp. Although phytates offer health benefits such as antioxidant and potential anti-cancer properties through mineral binding and oxidative stress reduction, they can also inhibit the absorption of essential minerals like zinc, iron, and calcium [21].

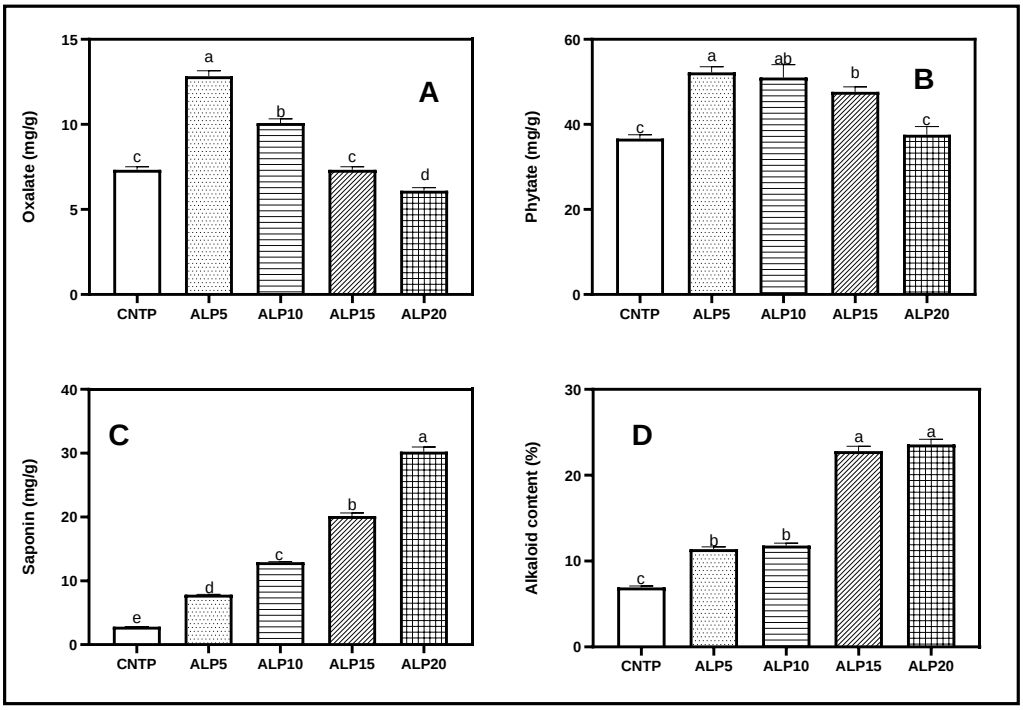

Figure 2. Antinutritional content of plantain flour supplemented with African locust beans.
Note: Bars (Mean ± standard deviation) with different alphabets are significantly different ($p<0.05$).

CNTP: 100% Plantain Flour.
ALP5: 95% Plantain Flour, 5% Locust Beans.
ALP10: 90% Plantain Flour, 10% Locust Beans.
ALP15: 85% Plantain Flour, 15% Locust Beans.
ALP20: 80% Plantain Flour, 20% Locust Beans.

Similarly, oxalates can bind strongly with minerals, and their insoluble salts may accumulate in the urinary tract, contributing to kidney stone formation [22]. A substantial increase in saponin content was observed with rising levels of supplementation. The control sample (CNTP) had the lowest saponin content at 2.82 mg/g, while ALP20 recorded the highest at 30.24 mg/g, indicating that African locust beans are naturally rich in saponins. These compounds are known for their functional and pharmacological properties, including antioxidant, anti-inflammatory, anti-apoptotic, anti-cancer, and immune-stimulant effects, as well as their ability to lower blood cholesterol and reduce the uptake of glucose and cholesterol offering potential protection against heart diseases [23, 24]. However, in large

doses, saponins can be toxic and may reduce the bioavailability of minerals [25, 26]. Reported saponin contents in dried locust beans range from 0.20 to 0.35 mg/100 g, further supporting their presence in the beans. Alkaloid content increased progressively from 6.92% in the control sample (CNTP) to 23.59% in ALP20, with a statistically significant rise beginning at 10% supplementation. This trend likely reflects the alkaloid-rich composition of African locust beans, which may contribute to the therapeutic potential of the final product. Afolayan et al. [27] also reported high alkaloid levels in the fruit pulp of locust beans.

3.3. Antioxidant and Phytochemical Properties of Plantain Flour Supplemented with African Locust Beans

Figure 3 presents the results of the antioxidant and phytochemical properties of the composite flour samples. The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity increased from 51.95% in the control (CNTP) to 57.89% in ALP20, showing a consistent rise with higher locust bean supplementation. Only ALP20 showed a statistically significant increase, despite slight differences across treatments. This trend confirms the contribution of African locust beans to the antioxidant activity of the composite flour, aligning with findings by Olatoye et al. [17]. However, the DPPH activity of African locust bean pulp remains lower than the 92.81% reported for vitamin E, a potent free radical scavenger [28]. Reactive oxygen species and free radicals produced during metabolism can cause cellular damage with serious health implications [29]. Similarly, the ABTS activity peaked in ALP20 at 48.37%, indicating enhanced neutralization of aqueous-phase free radicals. The observed increase in antioxidant capacity with higher supplementation suggests a dose-dependent effect, where greater inclusion of African locust beans boosts bioactive compounds with health-promoting properties.

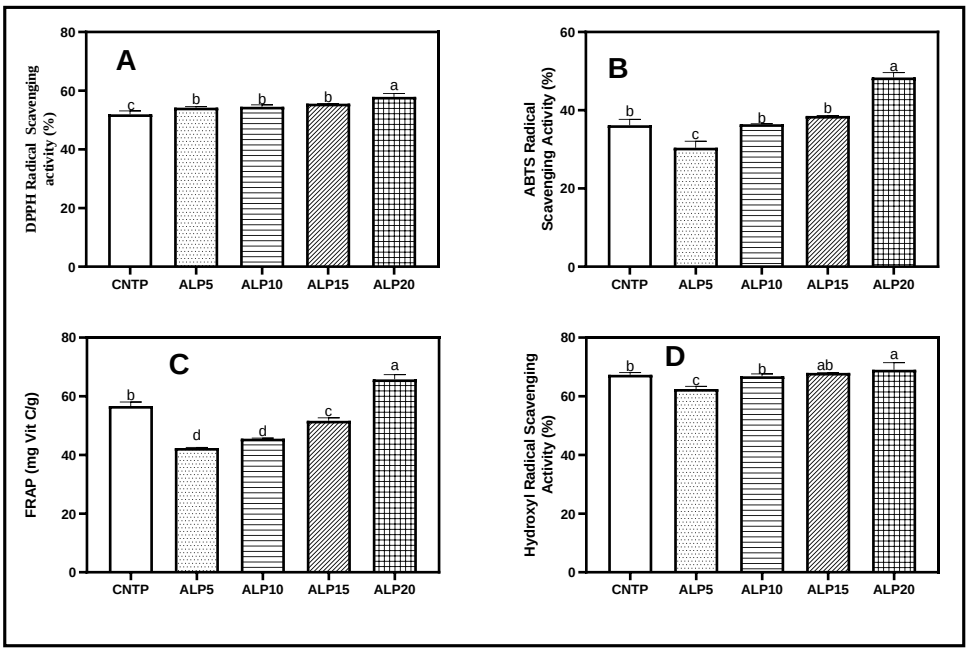

Figure 3. Antioxidant and phytochemical properties of plantain flour supplemented with African locust beans.
Note: Bars (Means ± standard deviation) with different alphabets are significantly different ($p<0.05$).

CNTP: 100% Plantain Flour.

ALP5: 95% Plantain Flour, 5% Locust Beans.

ALP10: 90% Plantain Flour, 10% Locust Beans.

ALP15: 85% Plantain Flour, 15% Locust Beans.

ALP20: 80% Plantain Flour, 20% Locust Beans.

FRAP (Ferric reducing antioxidant power) increased from 56.67 mg Vit C/g in CNTP to 65.77 mg Vit C/g in ALP20, with ALP20 showing a significantly higher value than all other samples. This aligns with Lobo et al. [30], who noted that strong ferric reducing ability reflects potent antioxidant potential, contributing to reduced oxidative stress and improved health. Hydroxyl radical scavenging activity (OH) also showed a steady increase, peaking at 69.05% in ALP20, suggesting that African locust bean supplementation enhances antioxidant properties capable of mitigating oxidative stress-related conditions such as diabetes, cardiovascular diseases, and neurodegenerative disorders [18].

3.4. Antidiabetic Properties of Plantain Flour Supplemented with African Locust Beans

Figure 4 shows that α-amylase inhibitory activity increased significantly with higher levels of African locust bean supplementation. The control sample (CNTP) had a low inhibition rate of 36.56%, while ALP20 recorded the highest at 91.24%, followed closely by ALP15 at 90.80%. This indicates that plantain flour alone has limited antidiabetic potential compared to the supplemented samples. The trend suggests that African locust beans are rich in bioactive compounds such as phenolics, flavonoids, and saponins, known for inhibiting carbohydrate-hydrolyzing enzymes [31]. The strong inhibition observed at ALP15 and ALP20 aligns with previous findings that leguminous seed extracts, due to their polyphenolic content, serve as effective natural α-amylase inhibitors [29].

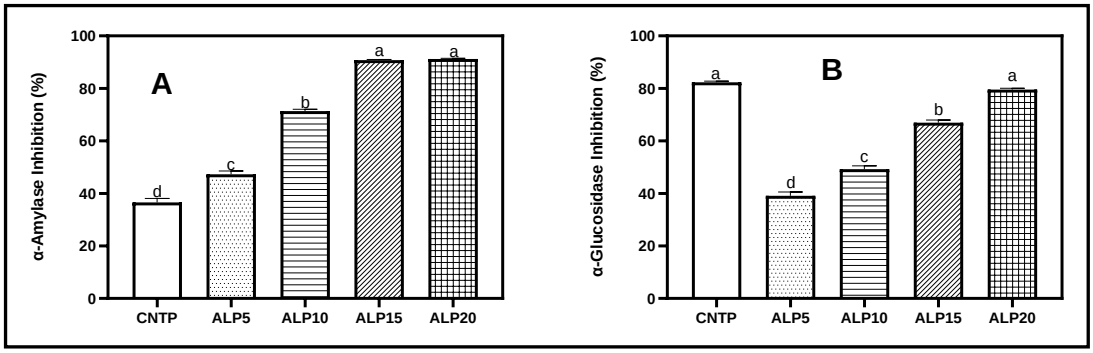

Figure 4. Result of the Antidiabetic Properties of Plantain Flour Supplemented with African Locust Beans.
Note: Bars (Mean ± standard deviation) with different alphabets are significantly different ($p<0.05$).

CNTP: 100% Plantain Flour.
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ALP10: 90% Plantain Flour, 10% Locust Beans.
ALP15: 85% Plantain Flour, 15% Locust Beans.
ALP20: 80% Plantain Flour, 20% Locust Beans.

The α-glucosidase inhibitory pattern was less linear than that of α-amylase. While the control (CNTP) showed high inhibition at 82.34%, there was a significant drop in ALP5 (39.09%) and ALP10 (49.26%), followed by a rise in ALP15 (66.92%) and ALP20 (79.54%). This nonlinear trend likely results from interaction effects between bioactive compounds in plantain and locust beans, which may either enhance or suppress enzyme inhibition depending on concentration and structural compatibility [32]. Despite the initial drop, the increased inhibition in ALP15 and ALP20 suggests a dose-dependent restoration of activity, possibly due to the cumulative effects of saponins and alkaloids, which increased as shown in Figure 2. These compounds are known to inhibit digestive enzymes and delay postprandial glucose absorption, highlighting the functional and therapeutic potential of these blends in managing type 2 diabetes mellitus [33].

4. CONCLUSION

In summary, supplementing plantain flour with African locust beans significantly improves antinutritional, antioxidant, phytochemical, and antidiabetic properties. These enhancements are attributed to the high protein and bioactive compound content of locust beans, which improve nutrient bioavailability and health functionality. The increased antioxidant activity in the supplemented samples confirms the contribution of locust bean phytochemicals in scavenging free radicals and reducing oxidative stress-related conditions. Overall, African locust bean fortification enhances the nutritional and functional quality of plantain flour, supporting its potential as a food-based intervention for managing oxidative stress and type 2 diabetes.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

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