

# Chemical Composition, Functional and Antioxidant Properties of Unripe Plantain (*Musa parasidiaca*) and Marble Vine (*Dioclea reflexa*) Flour Blends

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## ABSTRACT

**Background:** Unripe plantain (*Musa parasidiaca*) and mable vine (*Dioclea reflexa*) is an underutilised seed with numerous health benefits, and potential antidiabetic properties is crucial for developing effective management strategies of Non-communicable diseases.

**Objective:** The study evaluated the nutritive value, functional, pasting and antioxidant activity of flour blends from unripe plantain and marble vine using response surface methodology (RSM).

**Methods:** Proximate composition analysis was carried out on samples with varying percentages (10, 20, 30 and 40%) of raw (PR), roasted (PRO) and defatted Marble vine DDP and plantain. The protein, crude fibre content, functional, pasting, antioxidants, and colour were evaluated on DDP1, DDP2, DDP3, DDP4 AND PLT using standard procedures.

**Results:** A significant decrease ( $p < 0.05$ ) in moisture content of flour was observed for 90% Plantain: 10% Defatted *D. reflexa* (DDP1) with lower value 6.97% while a high value (11.57%) was observed for sample PRO3. Crude fibre and protein content increased with DDP4 having the highest value (5.95 and 25.76%) respectively. The L values ranged from 81.86 to 82.91, a (2.47–2.60), b (9.75–10.47) and Chroma (10.82–10.97). The ability to scavenge free radicals increased significantly ( $p < 0.05$ ) with sample 40% substituted defatted marble vine (DDP4) having the highest value (278.25 mg GAE/g), 77.53 mM Trolox/g and 0.55 mg AAE/g for DPPH, ABTS and ferric reducing respectively.

**Conclusion:** Samples with 40% substituted defatted marble vine and 60% plantain blends (DDP4) are ideal innovative food formulations in Nigeria.

**Keywords:** Marble vine, plantain flour, proximate, functional properties, antioxidant,

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## INTRODUCTION

Attention has been given to medicinal plants as alternative therapeutic tools in the prevention or management of these diseases. Also, there is an increase in the demand for natural antioxidant to this effect. Much emphasis has been placed on utilising locally sourced legumes in developing high-value nutritional foods with health benefits and pharmacological properties (1).

*Dioclea reflexa* (*D. r*) Hook F. (Papilionaceae) seeds are found in Africa, Asia and some other part of the world (2). It is called marble vine or sea pulse or sea bean in English, "Agba-arin" by

the Yorubas in South-western part and Ukpo or Ebba by the Igbos in the South-eastern part of Nigeria. *D. r* is an annual crop and a climber that can be cultivated more than once a year, the plant is high yielding, bears pod containing between three and four seeds which are usually dark brown, light brown and black, sometimes speckled, depending on variety (3,4). *Dioclea reflexa* has appreciable amount of protein ranged from 15 to 33% (5). Among the natives, the endosperm, which is rich in gum is pulverised, and used as thickener in many traditional food preparations. Legumes are targeted crops because they offer high sources of protein and it

has been reported to be rich in essential amino acids, polyunsaturated fatty acids, and dietary fibre, along with beneficial compounds (6). The presence of polyphenolic compounds in legumes is beneficial as natural polyphenols and it has been reported to exert potential health benefits in the prevention of cardiovascular diseases; this is mainly due to their antioxidant capacity, thus, interact with and scavenge the free radicals, and active antioxidant enzymes (7).

Plantain (*Musa paradisiaca*) is a big perennial herb that can be found in many tropical and subtropical countries across the world. After yam and cassava, it is Nigeria's third most important staple. It is high in carbohydrate, iron, potassium, and vitamin A, but it is low in fat and protein (8). Ripe Plantains can be eaten raw or cooked, and they can be boiled, fried, or roasted. Unripe plantain can be milled into flour and used to make native dough dish called 'amala', which can be consumed by people with diabetes (9). In many regions of underdeveloped countries, it has remained the ultimate source of nutrients and non-nutrients that are beneficial to humans. Quite a number of studies have utilized plantain, soybean and maize in the production of foods but there is dearth of information on the combinations of plantain flour and marble vine. Therefore, the study evaluated the nutrient content, functional properties and antioxidant activity of plantain and marble vine flour blends. This will effectively provide useful information on the utilization of an underutilised marble vine seed.

## MATERIALS AND METHODS

### Materials

Marble vine (*Dioclea reflexa*) seeds and plantain were purchased from an indigenous farmer at Oja Oba Market in Akure, Ondo State, Nigeria. All the chemicals and reagents used for the analyses were of analytical grade.

### Production of unripe plantain flour

The method of (10) with slight modifications was used in the production of plantain flour. Unripe plantain was peeled, sliced and soaked in sodium metabisulphite solution (0.25g/L) for 10 min and oven dried at 80°C for 12 h using electric Hot oven (Model: OV-160). The dried plantain slices were milled into flour using hammer mill, sieved (250µm) and packed in an air tight container for further analysis.

### Production of marble vine (*Dioclea reflexa*)

The Marble vine (*Dioclea reflexa*) seeds (200 g) was sorted, washed and dried at ambient temperature for 2 days. Roasting was carried out in a hot-air oven (OV-160) based on runs generated by response surface Methodology (RSM) using Design – Expert (version 13). Roasting was carried out in a hot air oven according to runs generated from response surface methodology at temperatures in the range (110 – 200 °C) and time range of (10 - 40min) and cooled (2). Also, a part of the roasted seeds was defatted using n-hexane.

### Flour blending

Plantain and *Dioclea reflexa* flours were blended in the following ratios (100:0, 0:100, 90:10, 80:20, 70:30 and 60:40, using response surface methodology (RSM) Design – Expert (version 13). The *Dioclea reflexa* is mixed in a Kenwood blender (Model Km 201 for 15 min). The blends were packed in thick polyethylene bags (0.7mm), sealed and stored in the refrigerator (10 °C) until required.

### Determination of proximate composition

The proximate composition was determined according to AOAC (11). Moisture content was determined in a Hot-air circulating oven (Gallenkamp OV-160). Total ash was determined by incineration (550 °C) of known weights of the samples in a muffle furnace (Hotbox oven, Gallenkamp, UK). Crude fat was determined by exhaustively extracting a known weight of sample in petroleum ether. Protein content was determined by the micro-Kjeldahl method. Crude fiber was determined after digestion and carbohydrate content was determined by difference.

### Functional properties determination

The bulk density activities were determined as described by (12) The water absorption capacities was determined according to the methods of (13), and the values were expressed as percent water absorbed by 1 g flour. Solubility were determined using the method according to (14) as described by (10).

### In vitro antioxidant assay

DPPH Radical Scavenging (1, 1-diphenyl-2-picrylhydrazyl) Activity Assay

The DPPH scavenging activity of the extracts was evaluated according to the method described by (15).

% scavenging activity = ((Ac – As)/Ac) x 100

Where  $A_c$  is the absorbance of control and  $A_s$  is the absorbance of the extract.

2,2'-Azino-bis-(3-ethylbenzothiazoline-6-sulphonic Acid) (ABTS) Radical Scavenging Activity Assay.

ABTS radical scavenging activity of the plant extract was determined according to the method of (16).

$$\% \text{ scavenging activity} = ((A_c - A_s)/A_c) \times 100$$

Where  $A_c$  is the absorbance of control and  $A_s$  the absorbance of the extract.

### Determination of ferric reducing-antioxidant power (FRAP) assay

The ability of the methanolic plant extracts of black and dark brown varieties to reduce ferric iron and 2,4,6-tripyridyl-s-triazine (TPTZ) to the ferrous complex was determined by the method described by (17).

### Determination of colour parameter

Colour parameters (Hunter L, a, and b values) were measured for samples using a hand colorimeter Minolta Chroma Meter- 400 (Ramsey, New Jersey, USA). Hunter lab colour standards and their Hunter 'L' (lightness), 'a' (redness to greenness) and 'b' (yellowness to blueness) as described by (18). Three readings were taken for each sample and the mean values with standard deviations were reported.

### Statistical analysis

Data generated were subjected to Analysis of Variance (ANOVA) using Statistical Package for Social Sciences (SPSS) V. 17.0. The means were separated using Duncan Multiple Range Test (DMRT) at 95% confidence level. Response surface methodology (RSM) design expert software (version 13) was used to generate compositions for samples. The P-value was used to evaluate the significance of model and terms

## RESULTS

The samples showed a significant difference in moisture, ash, crude protein, fibre and fat, carbohydrate content as presented in Table 1. The proximate composition of the plantain marble vine blends, result showed that the moisture content for sample PR4 (Plantain 60%: 40% Raw

*D. reflexa*) ranked highest value (11.55%) while DDP1 (90% Plantain: 10% Defatted *D. reflexa*) had the lowest value (6.97%), for ash content, the highest value (3.21%) was observed for sample DDP4 (60% Plantain: 40% Defatted *D. reflexa*). Sample DDP4 ranked highest while PRO1 (8.36%) ranked lowest in protein content, DDP4 (5.95%) ranked highest while PR1 (1.56%) ranked lowest in fiber content among the samples, the fat content showed that sample PRO4(Plantain 60%: 40% roasted raw *D. reflexa*) had the highest value (10.53%) while DDP1 (90% Plantain: 10% Defatted *D. reflexa*) had the lowest value (4.69%) among the samples and was significantly different from the control value 2.18% of 100% plantain (PLT). The control (PLT) had the highest value (80.96%) while DDP4(60% Plantain: 40% defatted *D. reflexa* flours) ranked the lowest (51.88%) ranked lowest in carbohydrate and sample PRO4 (387.57%) ranked highest in energy value while PLT (357.65%) ranked lowest in energy value.

### Functional properties of the plantain -D. Reflexa composite flour

Table 2 reveal the functional properties of the plantain marble vine, result indicate the bulk density for all samples ranked the same, DDP3 ranked highest ( $254.07 \pm 0.27$ ) while PLT ( $224.23 \pm 0.91$ ) ranked lowest in water absorption, PLT ( $2.55 \pm 0.03$ ) ranked highest while DDP1 ( $0.77 \pm 0.03$ ) ranked lowest in solubility index and DDP3 ( $9.81 \pm 0.01$ ) ranked highest while DDP1 ( $7.41 \pm 0.01$ ) ranked lowest in gelation.

### Colour analysis of the plantain-D. reflexa flour blends

Table 3 reveal the colour analysis of the plantain marble vine, result indicate the lightness (L), redness (a) and chroma for all samples ranked the same. Yellowness in all sample ranked the same except for sample DDP4 ( $9.75 \pm 0.01^d$ ).

### DPPH radical scavenging activity of plantain- marble vine blend

The potential of the formulated composite flour to scavenge free radical against 2, 2-diphenyl-1-picrylhydrazyl (DPPH) assay is reported in Figure 1. %. The DPPH inhibition capacity of the formulated flour ranged from 50.20 to 75.21%. All the formulated dough had significantly ( $p \leq 0.05$ ) higher activities than PLT except DDP1.

**Table 1: Proximate compositions (%) and energy values (kcal/100g) of plantain-marble vine blended ratios using RSM**

SAMPLE	M.C	ASH	CRUDE PROTEIN	CRUDE FIBRE	FAT	CHO	ENERGY
PR1	11.33±0.25 <sup>c</sup>	2.85±0.01 <sup>c</sup>	12.66±0.53 <sup>f</sup>	1.56±0.12 <sup>i</sup>	7.82±0.16 <sup>f</sup>	63.78±0.74 <sup>c</sup>	376.14±0.61
PR2	11.45±0.04 <sup>b</sup>	2.88±0.27 <sup>c</sup>	13.37±0.14 <sup>e</sup>	1.72±0.93 <sup>i</sup>	6.83±0.18 <sup>g</sup>	63.75±0.51 <sup>c</sup>	369.95±0.93
PR3	11.13±0.53 <sup>d</sup>	2.97±0.03 <sup>b</sup>	15.76±0.43 <sup>d</sup>	2.05±0.18 <sup>i</sup>	7.82±0.16 <sup>f</sup>	60.27±0.10 <sup>b</sup>	374.50±1.02
PR4	11.55±0.22 <sup>a</sup>	2.98±0.17 <sup>b</sup>	17.75±0.53 <sup>c</sup>	2.25±0.18 <sup>h</sup>	7.92±0.15 <sup>e</sup>	57.55±0.02 <sup>d</sup>	372.48±1.31
PRO1	10.33±0.23 <sup>e</sup>	2.61±0.44 <sup>e</sup>	8.36±0.43 <sup>l</sup>	2.33±0.32 <sup>g</sup>	8.66±0.52 <sup>d</sup>	67.71±0.41 <sup>b</sup>	382.22±2.01
PRO2	10.35±0.02 <sup>e</sup>	2.64±0.13 <sup>e</sup>	9.30±0.05 <sup>i</sup>	2.86±0.33 <sup>f</sup>	9.24±0.01 <sup>c</sup>	65.61±0.12 <sup>bc</sup>	382.8±1.03
PRO3	11.57±0.04 <sup>a</sup>	1.96±0.01 <sup>f</sup>	9.69±0.53 <sup>h</sup>	3.02±0.25 <sup>e</sup>	9.50±0.02 <sup>b</sup>	64.26±0.11 <sup>bc</sup>	381.3±1.43
PRO4	10.08±0.01 <sup>f</sup>	2.72±0.42 <sup>d</sup>	11.76±0.44 <sup>g</sup>	3.47±0.27 <sup>c</sup>	10.53±0.12 <sup>a</sup>	61.44±0.11 <sup>bc</sup>	387.57±2.04
DDP1	6.97±0.01 <sup>k</sup>	1.98±0.72 <sup>f</sup>	18.08±0.40 <sup>c</sup>	2.59±0.22 <sup>f</sup>	4.69±0.27 <sup>k</sup>	65.69±0.02 <sup>bc</sup>	377.29±2.17
DDP2	8.55±0.05 <sup>h</sup>	2.94±0.36 <sup>c</sup>	22.04±0.21 <sup>b</sup>	3.19±0.13 <sup>d</sup>	4.84±0.02 <sup>i</sup>	58.44±0.08 <sup>e</sup>	365.48±1.10
DDP3	7.70±0.34 <sup>i</sup>	2.98±0.37 <sup>b</sup>	22.87±0.03 <sup>b</sup>	4.42±0.32 <sup>b</sup>	5.90±0.01 <sup>h</sup>	56.13±0.32 <sup>f</sup>	369.1±0.98
DDP4	7.50±0.56 <sup>i</sup>	3.21±0.53 <sup>a</sup>	25.76±0.02 <sup>a</sup>	5.95±0.28 <sup>a</sup>	5.70±0.01 <sup>i</sup>	51.88±0.28 <sup>g</sup>	361.89±2.02
PLT	9.56±0.63 <sup>g</sup>	2.94±0.21 <sup>c</sup>	2.13±0.04 <sup>l</sup>	1.6±0.0 <sup>k</sup>	2.81±0.11 <sup>i</sup>	80.96±0.04 <sup>a</sup>	357.65±2.21

Values are mean ± SEM. The same alphabet within the column are not significantly different ( $p < 0.05$ ). M.C: Moisture; CHO: Carbohydrate; PR1: Plantain 90%: 10% raw *D. reflexa*, PR2: Plantain 80%: 20% raw *D. reflexa*, PR3: Plantain 70%: 30% raw *D. reflexa*, PR4: Plantain 60%: 40% raw *D. reflexa*, PRO1: Plantain 90%: 10% roasted raw *D. reflexa*, PRO2: Plantain 80%: 20% roasted raw *D. reflexa*, PRO3: Plantain 70%: 30% roasted raw *D. reflexa*, PRO4: Plantain 60%: 40% roasted raw *D. reflexa*, DDP1: 90% Plantain: 10% defatted *D. reflexa*, DDP2: 80% Plantain: 20% defatted *D. reflexa* flours, DDP3: 70% Plantain: 30% defatted *D. reflexa* flours, DDP4: 60% Plantain: 40% defatted *D. reflexa* flours, PLT: 100% Plantain

**Table 2: Functional properties of the plantain -D. Reflexa composite flour**

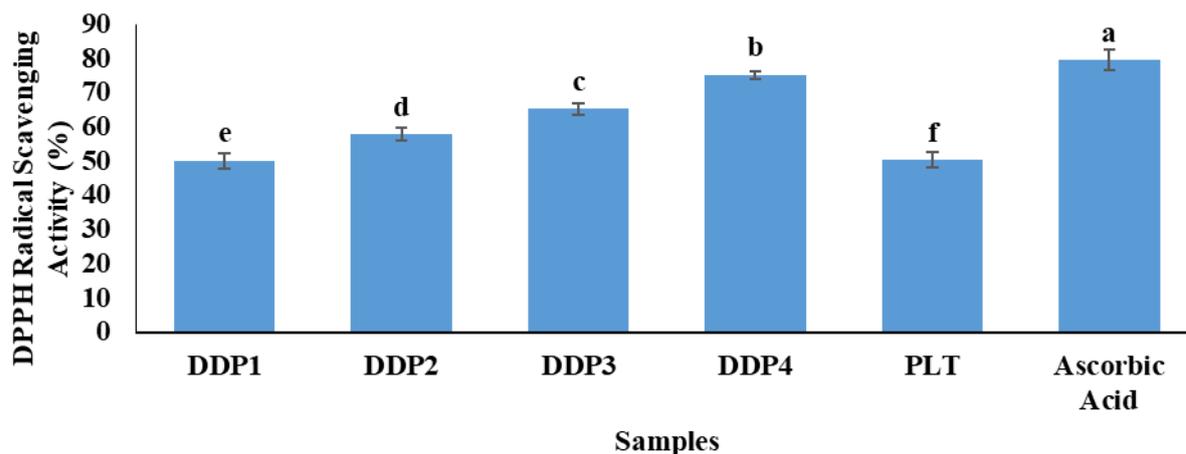
Samples	Bulk density g/cm <sup>3</sup>	Water absorption (ml/100g)	Solubility Index	Least gelation concentration%
DDP1	0.75±0.02 <sup>ab</sup>	237.05±0.70 <sup>c</sup>	0.77±0.03 <sup>d</sup>	7.41±0.01 <sup>c</sup>
DDP2	0.77±0.01 <sup>a</sup>	243.59±0.74 <sup>b</sup>	0.92±0.01 <sup>c</sup>	8.61±0.01 <sup>b</sup>
DDP3	0.79±0.01 <sup>a</sup>	254.07±0.27 <sup>a</sup>	0.98±0.01 <sup>c</sup>	9.81±0.01 <sup>a</sup>
DDP4	0.74±0.01 <sup>ab</sup>	251.00±0.79 <sup>a</sup>	1.26±0.01 <sup>b</sup>	9.41±0.01 <sup>a</sup>
PLT	0.50±0.01 <sup>b</sup>	224.23±0.91 <sup>c</sup>	2.55±0.03 <sup>a</sup>	8.41±0.01 <sup>c</sup>

Values are mean ± SEM. The same alphabet within the column are not significantly different ( $p < 0.05$ ) PLT=100%Plantain, DDP1= 90% PL:10% Defatted roasted *D. reflexa*, DDP2= 80%PL:20% Defatted roasted *D. reflexa*; DDP3= 70%PLT:30% Defatted roasted *D. reflexa*, DDP4= 60%PL:40% Defatted roasted *D. reflexa*

**Table 3: Colour analysis of the plantain-D. reflexa flour blends**

SAMPLES	L*	a*	b*	Chroma	Hue	ΔE
DDP1	81.86±0.21 <sup>c</sup>	2.62±0.01 <sup>a</sup>	10.47±0.04 <sup>a</sup>	10.82±0.01 <sup>c</sup>	75.16±0.07 <sup>c</sup>	0.03±0.05 <sup>c</sup>
DDP2	81.87±0.11 <sup>bc</sup>	2.61±0.01 <sup>a</sup>	10.40±0.02 <sup>b</sup>	10.83±0.02 <sup>c</sup>	76.15±0.05 <sup>c</sup>	0.05±0.53 <sup>c</sup>
DDP3	82.31±0.57 <sup>a</sup>	2.54±0.02 <sup>b</sup>	10.10±0.05 <sup>c</sup>	10.88±0.05 <sup>b</sup>	76.27±0.05 <sup>b</sup>	0.57±0.03 <sup>b</sup>
DDP4	82.91±0.13 <sup>a</sup>	2.47±0.06 <sup>c</sup>	9.75±0.01 <sup>d</sup>	10.97±0.01 <sup>a</sup>	76.71±0.01 <sup>a</sup>	1.09±0.01 <sup>a</sup>
PLT	81.86±0.23 <sup>c</sup>	2.60±0.03 <sup>a</sup>	10.45±0.07 <sup>a</sup>	10.82±0.07 <sup>c</sup>	75.01±0.06 <sup>d</sup>	

Means with different alphabetical superscripts in the same column are significantly different ( $p < 0.05$ ). DDP1= 90%, PLT:10% Defatted roasted *D.r*; DDP2= 80% PL:20% Defatted roasted *D.r*; DDP3= 70% PLT: 30% Defatted roasted *D.r*, DDP4= 60% PLT:40% Defatted roasted *D.r*; RAW: raw *D.r*; DEF: Defatted roasted *D.r* 100%, PLT=100% Plantain.



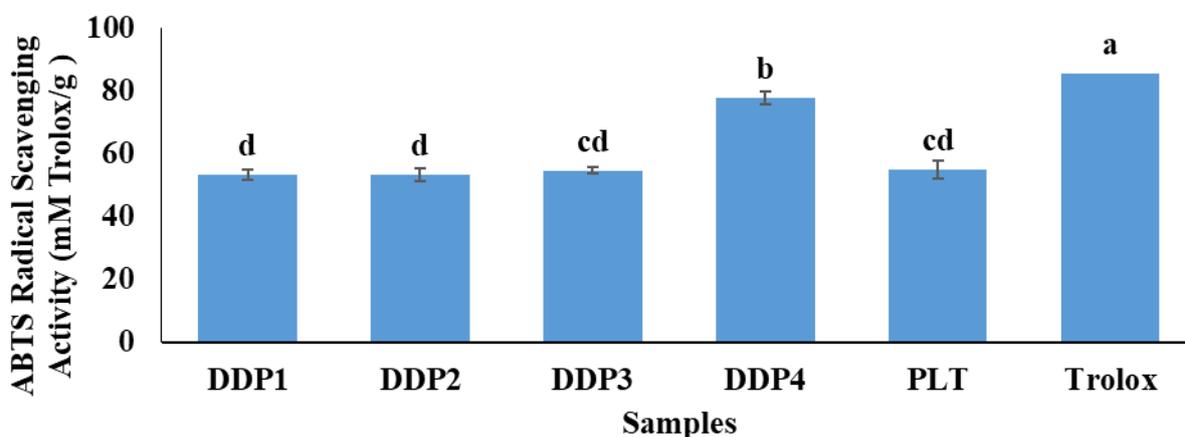
**Figure 1: DPPH radical scavenging activity of plantain- marble vine blend.**

Means with different alphabetical superscripts in the same column are significantly different ( $p < 0.05$ ). PLT=100% Plantain, DDP1=90% PLT: 10% Defatted roasted *D. reflexa*, DDP2= 80% PLT: 20% Defatted roasted *D. reflexa*; DDP3= 70% PLT: 30% Defatted roasted *D. reflexa*, DDP4= 60% PL:40% Defatted roasted *D. reflexa*

### ABTS radical scavenging activity of plantain- marble vine blend

ABTS radical scavenging activity of the blends (plantain-*D. reflexa*) ranged from 53.33 to 77.53 mM Trolox/g as shown in Figure 2. Trolox had significantly ( $p \leq 0.05$ ) highest scavenging activity

compares with other samples. There was no significant difference ( $p \leq 0.05$ ) between the ABTS radical scavenging activity of DDP2, DDP3 and PLT. Although, DDP4 was significantly ( $p \leq 0.05$ ) higher than the three samples DDP1, DPP2 and DDP3.



### Ferric reducing radical scavenging activity of plantain- marble vine blend

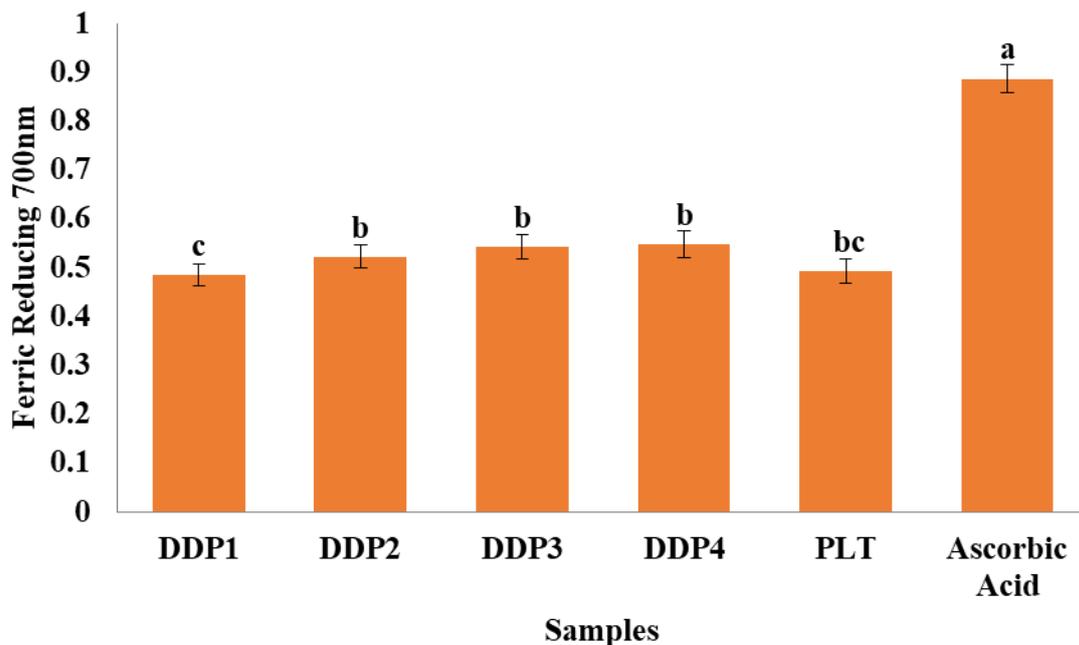
**Figure 2: ABTS radical scavenging activity of plantain- marble vine blend.**

Means with different alphabetical superscripts in the same column are significantly different ( $p < 0.05$ ). PLT=100% Plantain, DDP1=90% PLT: 10% Defatted roasted *D. reflexa*, DDP2= 80% PLT: 20% Defatted roasted *D. reflexa*; DDP3= 70% PLT: 30% Defatted roasted *D. reflexa*, DDP4= 60% PL:40% Defatted roasted *D. reflexa*

### Ferric reducing radical scavenging activity of plantain- marble vine blend

Figure 3 shows the result of the ferric reducing antioxidant property of the formulated composite

flour and it ranged between 0.48 mg AAE/g and 0.55 mg AAE/g with sample DDP4 having the highest reducing potential power but not significantly different from DDP2, DDP3 and PLT.



**Figure 3: Ferric reducing radical scavenging activity of plantain- marble vine blend**

Means with different alphabetical superscripts in the same column are significantly different ( $p < 0.05$ ). PLT=100% Plantain, DDP1=90% PLT: 10% Defatted roasted *D. reflexa*, DDP2= 80% PLT: 20% Defatted roasted *D. reflexa*; DDP3= 70% PLT: 30% Defatted roasted *D. reflexa*, DDP4= 60% PL:40% Defatted roasted *D. reflexa*

### DISCUSSION

Sample DDP1 to DDP4 were observed to have moisture content lower than that of the control sample (PLT) and it is in the limit of FAO/WHO recommended value (<10%). The finding reported in this study is comparable with the study of (19) who reported that the addition of walnut to wheat flour led to a reduction in the moisture content of the flour samples and also was significantly lower than obtained for Mchuchumeysoybean flour reported by (19). The low moisture content of sample DDP1-DDP4 is of advantage because the proliferation of spoilage microorganism was inhibited and thus improve the shelf stability of the flour. The results ranged for raw, roasted and defatted roasted samples were comparatively higher than the findings

reported by (20) in composite flours from breadfruit, breadnut and wheat and compared well with the findings of (21) in plantain sponge-cake supplemented with watermelon rind flour. The high ash content of the flour blends is an indication that it could be an important source of minerals which could be used to manage macro and micronutrients deficiency in both young and old.

The low protein content of the plantain is in agreement with findings of (8) who reported that plantain is a good source of calorie but deficient in protein content. Samples DDP1 to DDP4 have higher protein content than other samples, this is as a result of the addition of defatted *D. reflexa* to the plantain flour. Defatting and roasting of the

seeds help to reduce the oil content and also increase the protein concentration of the seed. The relatively higher protein content of sample DDP1 to DDP4 suggest its potential usage in the formulation of dough meal for diabetic patient as the recommended daily allowance (RDA) for proteins in diabetic patients is 15-20% of the total calories.

The flour blends with the inclusion of roasted *D. reflexa* seed was observed to have a higher crude fibre content than the other blends. This could be an indication that roasting helps to increase the crude fibre content of food products. Therefore, samples with the inclusion of roasted *D. reflexa* seed flour could help to relieve constipation, lower cholesterol, prevent colon cancer and regulate blood glucose. The finding of this study favourably compares well with the result (4.64–2.95%) obtained from plantain sponge-cake supplemented with watermelon rind flour by (22). Recently, epidemiological studies have reported on the health benefits associated with dietary fibre intakes such as inhibiting the absorption of glucose and lipids in the small intestine, slows gastric emptying, maintaining levels of satiety and contributing towards less weight gain.

Low-fat content observed in this study could be advantageous in delaying the onset of rancidity in the flour blends during storage. It could also enhance the storage stability of the flour blends as mould growth and moisture-dependent biochemical reactions was retarded. The available carbohydrate values ranged from 51.88 to 80.96%. The carbohydrate content of mushroom has been used to represent the bulk of fruiting bodies accounting for 50 – 65% on a dry weight basis.

The bulk density of composite flour increased with an increasing amount of *D. reflexa* flours substitution. However, DDP1 and DDP2 were not significantly differ from each other. The bulk density obtained in this study were higher than the range of values reported by (23 and 24). The particle size of flour is inversely proportional to the bulk density (25). The bulk density is critical in the determination of the packaging requirement, handling and application of food flours in the food industry (26). Higher bulk densities are usually desirable in the food industries for the packaging advantages they offer (27). The water absorption capacity is indicative of the amount of water required to develop dough consistency and causes the dough to rise when gluten is fully developed (28). High WAC ensures product

cohesiveness, while low WAC suggests easy digestibility (29).

The increased solubility could be due to the defatting process on the *D. reflexa* seed coupled with the roasting that enabled the release of protein. Similarly, (30) had reported an effect of roasting on increased the solubility index of roasted peas and lentils. The increase observed in the least gelation could be due to the increased levels of roasted defatted *D. reflexa* seed flour substitution thus supporting the report of (31) on increased least gelation in African yam bean which is a legume. The gelation properties are dependent on the nature of the protein and other non-protein components of the sample (32).

The increase in lightness observed in the plantain –*D. reflexa* substituted blends could be as a result of bleaching or loss of pigment (carotenoid) that occur during the defatting process (33).

A decrease in the  $a^*$  value (redness) was observed as the incorporation of *D. reflexa* increases in the composite flour. The low redness of sample DDP4 might be as a result of loss in lipid-soluble pigment such as carotenoid and xanthophyll during the defatting process (34). The addition of defatted *D. reflexa* to plantain flour was observed to decrease the yellow content of the composite flour due to the addition of defatted *D. reflexa* the samples. Food high in  $b^*$  colour have been reported to obtain their colour from carotenoid (phytochemical) which are reported to have antioxidant properties (15).

Chroma ( $C^*$ ) reckoned as the quantitative indicator of colourfulness during colour analysis. It is used to determine the degree of difference in a hue in comparison to grey colour with the same lightness. Colour characteristics of a food product are important quality parameter that influence its performance in the market. Food colour is governed by the chemical, biochemical, microbial and physical changes which occur during growth, maturation, postharvest handling and processing.

Hue angle ( $h^*$ ), considered the qualitative attribute of colour, is the attribute according to which colours have been traditionally defined as reddish, greenish and so on. It is used to define the difference of a certain colour concerning grey colour with the same lightness. This attribute is related to the differences in absorbance at different wavelengths. A higher hue angle represents a lesser yellow character in the assays.

The result obtained for radical scavenging activity was higher to the values (40- 57.76%) (35) for plantain-based dough meal enriched with tigernut and defatted soybean flour. Inclusion of defatted roasted of *D. reflexa* seed flour enhances the antioxidant capacity of the blends with plantain. Result obtained was significantly higher than 6.5 and 18.95 mM Trolox/g for plantain flour fortified with 30% defatted okra seed (36). The composite flour's DDPH radical scavenging ability is attributed to its ability to donate hydrogen from its phenolic constituents. The DPPH free scavenging ability is similar to ABTS radical scavenging ability. The addition of *D. reflexa* seed to plantain flour increased its scavenging abilities against both radicals.

The findings reported in this study is significantly lower with the reducing power activity of plantain flour fortified with Okra seed flour (36). The results of the reducing power of the formulated flour in this study agrees with earlier results reported for total phenol content. Transition metal ions like Fe<sup>2+</sup> can lead to cellular injury when available in excess amount in the body through the generation of reactive oxygen species that promote oxidative damage to cellular compounds such as DNA and proteins (36).

## CONCLUSION

Samples with 40% substituted defatted marble vine and 60% plantain blends (DDP4) had the high content of protein and fibre, and was able to scavenge free radical. The incorporation of defatted marble vine into plantain flour will help with varieties of products laden with dietary fibre and antioxidant potentials thus having nutraceutical potential. Therefore, it could be of great use in phytomedicine to prevent disease associated with oxidative stress.

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## CONFLICT OF INTERESTS

The authors have declared no conflicts of interest for this article.

## REFERENCES

1. International Diabetes Federation (2017). IDF diabetes atlas. Brussels, 7th edn. Brussels, Belgium: *International Diabetes Federation*, 33(2).
2. Ajatta, M. A., Akinola, S. A., Otolowo, D. T., Awolu, O. O., Omoba, O. S. & Osundahunsi, O.

- F. (2019). Effect of Roasting on the Phytochemical Properties of Three Varieties of Marble Vine (*Dioclea reflexa*) Using Response Surface Methodology. *Preventive Nutrition and Food Science*, 24(4), 468.
3. Ajatta, M. A., Akinola, S. A., Osundahunsi, O. F., & Omoba, O. S. (2021). Effect of roasting on the chemical composition, functional characterisation and antioxidant activities of three varieties of marble vine (*Dioclea reflexa*): An underutilised plant. *Heliyon*, 7(5).
4. Alabi O.O & Aletor O. (2011). Nutritional anti-nutritional composition and in vitro protein digestibility of tropical edible pulse bean 'Diocle reflexa' – an under-utilised legume. *Journal sustainable Technology*, 2(1):74-84.
5. Akinyede, A. I., Fagbemi, T. N., Osundahunsi, O. F. & Aluko, R. E (2016). Physicochemical Composition and Oil Characterization of *Dioclea reflexa* and *Monodora myristica* Seeds. *Tropical Agriculture*, 21(3), 1-11.
6. Aremu M. O., Olaofe, O., Basu, S. K., Abdulazeez G. & Acharya. S.N. (2010). Processed cranberry bean (*Phaseolus coccineus* L.) seed flour for the African diet. *Canadian Journal. Plant Science*, 90(5) 719-728.
7. Wang, L & Weller, C. L. (2006). Recent advances in extraction of nutraceuticals from plants. *Trends in Food Science & Technology*, 17(6), 300–312
8. Odenigbo, M. A., Asumugha, V. U., Ubbor, S., Nwauzor, C., Otuonye, A. C., Offia-Olua, B. I. & Ukaegbu, P. (2013). Proximate composition and consumption pattern of plantain and cooking-banana. *Current Journal of Applied Science and Technology*, 1035-1043.
9. Salome, K. K., Awofadeju, O. F. J., & Olapade, A. A. (2021). Chemical and functional properties of blends made from unripe plantain (*Musa paradisiaca*) and African yam bean (*Sphenostylis stenocarpa*) flours for stiff dough (Àmàlà) preparation. *Journal of Applied Sciences and Environmental Management*, 25(5), 741-749.
10. Osundahunsi, O. F. (2006). "Functional properties of extruded soybean with plantain flour blends". *Journal of Food Agriculture and Environment* 4(1), 57-60.
11. AOAC (2012). Official Methods of Analysis, 19th edn. Association of Official Analytical Chemists, Washington, D.C.

12. David, O., Arthur, E., Kwadwo, S. O., Badu, E., & Sakyi, P. (2015). Proximate composition and some functional properties of soft wheat flour. *International Journal of Innovative Research in Science, Engineering and Technology*, 4(2), 753-758.
13. Agume Ntso, A. S., Njintang, Y. N., & Mbofung, C. M. F. (2017). Physicochemical and pasting properties of maize flour as a function of the interactive effect of natural-fermentation and roasting. *Journal of Food Measurement and Characterization*, 11(2), 451-459.
14. Leach, H. W., McCowen, L. D., & Schoch, T. J. (1959). Structure of starch granules. I. Swelling and solubility patterns of various starches. *Cereal Chemistry*, 36(6), 534-544.
15. Leong, L. P., & Shui, G. (2002). An investigation of antioxidant capacity of fruits in Singapore markets. *Food Chemistry*, 76(1), 69-75.
16. Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, 26(9-10), 1231-1237.
17. Haida, Z., & Hakiman, M. (2019). A comprehensive review on the determination of enzymatic assay and nonenzymatic antioxidant activities. *Food Science and Nutrition*, 7(5), 1555-1563.
18. HunterLab. (2012). Measuring Color using Hunter L, a, b versus CIE 1976 Lab\*. Application Note AN 1005.00. Retrieved from <https://www.hunterlab.com/media/documents/duplicate-of-an-1005-hunterlab-vs-cie-lab.pdf>
19. Almorai, N. M. (2019). The effect of walnut flour on the physical and sensory characteristics of wheat bread. *International Journal of Food Science*, 2019(1), p5676205.
20. Alphonse, S., Kaale, L. D., Rweyemamu, L. M. & Millinga, F. (2019). Proximate composition of fermented cassava meal "mchuchume" fortified with soya bean flour and Moringa oleifera leaves powder. *Journal of food science and technology*, 56(8), 3660-3667.
21. Malomo, S. A., He, R. & Aluko, R. E. (2014). Structural and functional properties of hemp seed protein products. *Journal of food science*, 79(8), C1512-C1521.
22. Adegunwa, M. O., Adelekan, E. O., Adebawale, A. A., Bakare, H. A. & Alamu, E. O. (2017). Evaluation of nutritional and functional properties of plantain (*Musa paradisiaca* L.) and tigernut (*Cyperus esculentus* L.) flour blends for food formulations. *Cogent Chemistry*. 3: (1)383 - 707.
23. Lalude, L. O., & Fashakin, J. B. (2006). Development and Nutritional Assessment of a Weaning Food from Sorghum and Oil-Seeds. *Pakistan Journal of Nutrition*, 5(3), 257-260.
24. Akoja, S. S., & Coker, O. J. (2019). Functional properties, nutritional and sensory qualities of wheat biscuit fortified with defatted Dioclea reflexa seed flours. *Journal of Environmental Science, Toxicology and Food Technology*, 13(11), 46-55.
25. Akubor, P. I., Yusuf, D., & Obiegunam, J. E. (2013). Proximate composition and some functional properties of flour from the kernel of African star apple (*Chrysophyllum albidum*). *International Journal of Agricultural Policy and Research*, 1(3), 62-66.
26. Ajanaku, K. O., Ajanaku, C. O., Edobor-Osoh, A., & Nwinyi, O. C. (2012). Nutritive Value of Sorghum Ogi Fortified with Groundnut Seed (*Arachis hypogaea* L.). *American Journal of Food Technology*, 7(2), 82-88.
27. Fagbemi, T. N. (1999). Effect of blanching and ripening on functional properties of plantain (*Musa aab*) flour. *Plant Foods for Human Nutrition*, 54(3), 261-269.
28. Aluge, O. O., Akinola, S. A. & Osundahunsi, O. F. (2016). Effect of malted sorghum on quality characteristics of wheat-sorghum-soybean flour for potential use in confectionaries. *Food and Nutrition Sciences*, 7(13), 1241-1252.
29. Houssou, P., & Ayenor, G. S. (2002). Appropriate processing and food functional properties of maize flour. *African Journal of Science and Technology*, 3(1), 126-131.
30. Ma, Y., Boye, J. I., & Simpson, B. K. (2011). Thermal processing effects on the functional properties and microstructure of lentil, chickpea, and pea flours. *Food Research International*, 44(8), 2534-2544.
31. Obatolu, V. A., Fasoyiro, S. B., & Ogunsumi, L. (2007). Effect of processing on functional properties of yam beans (*Sphenostylis stenocarpa*). *Food Science and Technology Research*, 7(4), 319-322.
32. Omowaye-Taiwo, O. A., Fagbemi, T. N., Ogunbusola, E. M., & Omemu, A. M. (2015). Effect of germination and fermentation on the proximate composition

- and functional properties of full-fat and defatted *Cucumeropsis mannii* seed flours. *Food Science and Nutrition*, 3(6), 589–595.
33. Lawal, S. O., Idowu, A. O., Malomo, S. A., Badejo, A. A. & Fagbemi, T. N. (2021). Effect of Toasting on the Chemical Composition, Functional and Antioxidative Properties of Full Fat and Defatted Sesame (*sesamum indicum* L) Seed Flours. *Journal of Culinary Science and Technology*, 19(1), 18-34.
  34. Aluge, O. O., Akinola, S. A. & Osundahunsi, O. F. (2016). Effect of malted sorghum on quality characteristics of wheat-sorghum-soybean flour for potential use in confectionaries. *Food and Nutrition Sciences*, 7(13), 1241-1252.
  35. Oluwajuyitan, T. D., & Ijarotimi, O. S. (2019). Nutritional, antioxidant, glycaemic index and antihyperglycaemic properties of improved traditional plantain-based (*Musa AAB*) dough meal enriched with tigernut (*Cyperus esculentus*) and defatted soybean (*Glycine max*) flour for diabetic patients. *Heliyon*, 5(4), e01504.
  36. Adetuyi, F. O., & Komolafe, E. A. (2011). Effect of the Addition of Okra Seed (*Abelmoschus esculentus*) Flour on the Antioxidant Properties of Plantain (*Musa paradisiaca*) Flour. *Annual Research & Review in Biology*, 1(4), 143–152.