



Compositional and Functional Analyses of *Dioscorea odoratissima* (Bush Yam) Flour and Starch as Influenced by Pre-Treatment

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Abstract

Dioscorea odoratissima (DO), an under-utilized famine crop is usually cooked, either peeled or unpeeled before consumption. Information on the effect of peeling on the nutritional attributes of *D. odoratissima* is scanty. In this study, nutritional and functional properties of flour and starch from peeled (P) and unpeeled (U) DO tuber were evaluated. Flour (UF) and the extracted starch (SU) from unpeeled yam tuber were significantly higher in starch content compared to peeled yam flour (PF) and starch (PS), respectively. Crude protein content was significantly higher in UF and SU, compared to PF and PS. Alkaloids, phenolics, flavonoid, tannins, and trypsin inhibitor levels were significantly higher in UF and SU compared to PF and PS. PS exhibited significantly higher solubility, pasting clarity and swelling capacity compared to SU. *In vitro* starch digestibility, α -amylase and α -glucosidase activities positively correlate with amylose/amylopectin ratio in both flour and starch samples. UF and SU exhibited significantly higher antioxidant activity compared to PF and PS. These data emphasize the importance of pre-treatment with regard to applicability of DO flour and starch.



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Introduction


The challenge of food security coupled with increasing global population has necessitated the

need to search for additional sources of nutrients. Nigeria and indeed Africa has a rich diversity of plant food sources which have been grossly underutilized.

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From time immemorial, fruits and vegetables have played significant roles in meeting the nutritional needs of animals and humans thus improving global nutrition and wellness.¹ Plant fruits constitute a rich source of both macro and micronutrients required for animal growth and development.² Thus, researches aimed at exploring and evaluating the potential nutritional potential of indigenous wild fruits and vegetables will not only contribute to reducing hunger but also improving global nutrition and wellness.

Several studies focusing on the nutritional and functional compositions of tuber and root starches from numerous edible yam species have been reported in Literature,³ less research attention has been devoted to wild yam species⁴ which most time served as famine food.⁵ Prominent among these lesser known root crops is *Dioscorea odoratissima* commonly referred to as "bush yam". In spite of significance as famine crop especially among cocoa farmers in the tropics, it has received little or no research attention. Besides its nutritional attributes it has been traditionally used as a medicinal crop. Research studies aimed at evaluating the nutritional value of lesser-known plant food are considered important since information obtained from such studies may help identify long forgotten food resources. The aim of the present study therefore was to evaluate the nutritional, anti-nutritional as well as functional properties of *D. odoratissima* tuber flour and starch.

Materials and Methods

Yam Sample

Freshly harvested tubers of *D. odoratissima* were bought from Ipele in Ose Local Government Area of Ondo State (Nigeria). It was transported to Landmark University in jute sac. The yam was identified and authenticated by Mr Ajayi Bolu, a taxonomist in the Department of Plant Biology, University of Ilorin, Nigeria. Where specimen sample was deposited.

Starch Preparation

D. odoratissima tuber was washed using tap water and cut into two halves. A portion was washed and peeled while the other portion was unpeeled. The two portions were cut separately into small pieces and sun-dried for four days. The dried pieces were then milled into flours using mechanical grinder and stored in airtight container until required for further analysis.

The method described by Daiuto *et al.*⁶ was followed in the extraction of starch. Briefly, freshly batches harvested tuber (500 g) was peeled, diced and homogenized into slurry using Warring blender with the addition of 1 % sodium metabisulfite. The resulting slurry paste was transferred into a 4% sodium chloride solution, stirred vigorously and then filtered through sieves of varying mesh size in the order 500, 250 and 100 μm . The residue was decanted and washed several times with distilled water. The filtrate was pooled together and allowed to stand overnight at room temperature after which the filtrate was discarded and the resulting starch dried to constant weight in an oven at 50°C and stored in an airtight container at 4°C.

Proximate Composition Analysis

The proximate composition of the flour and starch samples were analyzed according to the methods of AOAC.⁷ Crude protein was determined by the Kjeldahl method.⁸ The method described by Nalle *et al.*⁹ was followed in the analysis of amino acids present in both flour and starch samples. The method described by Juliano *et al.*¹⁰ was followed to estimate amylose, sugar and starch contents.

Anti-Nutritional Analysis

Alkaloid content was estimated following Ojinnaka *et al.*¹¹ method with little modifications. Briefly, 5 g of each sample was weighed into a 250 mL conical flask and 200 mL ethanol in 10% acetic acid was added. The resulting mixture was covered with foil and allowed to stand at room temperature for 4 h. Thereafter, the mixture was placed on water bath at 50°C and allowed to evaporate until the total volume reduced to one quarter of the original level. Fifteen drops of concentrated ammonia solution was added and the resulting mixture was allowed to settle. The precipitate was removed using What man filter paper (number 1) and oven dried at 45°C to a constant weight. The alkaloid content was calculated in percentage as:

$$\% \text{ Alkaloid} = (W_2 - W_1) / (\text{Weight of sample}) \times 100$$

Where: W_1 = mass of empty filter paper; W_2 = mass of filter paper + residue

The terpenoid content was estimated following Ojinnaka *et al.*¹¹ method with little modifications. Briefly, 100 mg (W_1) of the sample was soaked in

10 mL of ethanol for 24 h and then filtered. The resulting filtrate was extracted with 10 mL of petroleum ether using separating funnel. Then, the ether extract was removed into a glass vial of known weight, weighed and allowed to dry completely (W_f). Following the evaporation of the solvent (ether), the total terpenoid content was obtained using the formula:

$$(W_i - W_f) / W_i$$

Saponin and flavonoid levels were determined as described by Elekofehinti *et al.*¹² For saponin, 1 g of the sample in 20 mL of 20% ethanol while stirring was heated at 50°C over a water bath for 4 h. The resulting mixture was filtered and the residue re-extracted through the same procedure and the combined filtrate was concentrated over a water bath at 85°C. Thereafter, 2.5 mL of diethyl ether was added to the concentrate in a 250 mL separating funnel and stirred vigorously. The mixture was allowed to settle and the aqueous layer carefully separated out. To the aqueous layer, 60 cm³ of n-butanol was added after which 10 cm³ of 5% sodium chloride was introduced and stirred and allowed to settle. The sodium chloride layer removed and discarded. The remaining layer was concentrated in a water bath before being transferred into a crucible and dried in an oven to a constant weight. The saponin content was calculated as a percentage:

$$\text{Saponin content (\%)} = \frac{\text{Weight of saponin}}{\text{Weight of sample}} \times 100$$

Functional Properties

Water absorption capacity: Water absorption capacity (WAC) and oil absorption capacity (OAC) was determined according to the procedure described by Lawal and Adebowale.¹³ Briefly, 0.5 g into a 10 mL centrifuge tube of a known weight and mixed with 5 mL distilled water (WAC) or soybean oil (for OAC). The mixture was then stirred and left to stand for 30 min before being centrifuged at room temperature for 30 mins at 3000 rpm. The supernatant was decanted and the sample was kept to drain at an angle of 45° for 10 min followed by the draining of excess water (or oil) in the upper phase. The tube containing the residue was then reweighed to determine the amount of water or oil retained per gram of sample.

$$\text{WAC/OAC (g/g)} = \frac{\text{fresh weight of residue (g)} - \text{dry weight of residue (g)}}{\text{dry weight of residue (g)}}$$

Solubility Index

The solubility index and swelling power of both the flour and starch samples were estimated following the modified procedure of Mandala and Bayas.¹⁵

One percent (1%) suspension of the sample was prepared in distilled water. The suspension was then agitated for 2 h using an orbital shaker and then centrifuged at 10,000 rpm for 20 min at 4°C. The protein content of the solution was then determined according to Kamizake *et al.* method¹⁶ with BSA as standard protein. The solubility of protein was expressed as grams of soluble protein per 100 g of protein.

For the swelling power (SP) determination, 0.5 g of the powdered sample was mixed with 10 mL of distilled water and stirred vigorously in a graduated 100 mL cylinder and kept at room temperature for 18 h. The SP expressed as percentage was measured using the formula below and expressed as mL of sample volume per gram of sample.

$$\text{SC (\%)} = \frac{\text{volume occupied by sample (mL)}}{\text{dry weight of sample (g)}} \times 100$$

Paste Clarity

The paste clarity (measured as % transmittance, T) of *D. odoratissima* tuber flour and starch was determined following the method of Bhandari and Singhal.¹⁷ One percent aqueous suspension of each of the sample was heated at 85°C in a water bath for 1 h with constant stirring. The resulting slurry was allowed to cool at room temperature. Thereafter, the transmittance (T) was determined with a UV-visible spectrophotometer at 640 nm and the paste clarity expressed as percentage transmittance (%T).

Antioxidant Assays

Dpph Scavenging Activity

The capacity of the flour and starch samples to scavenge DPPH radical was estimated following the procedures of Bersuder *et al.*¹⁸ as described by Oluba *et al.*¹⁹ Briefly, 2 g of the respective sample was dispersed in 25 mL ethanol (70%), left over night at room temperature and then filtered. To 0.1 mL of the filtrate, 3.9 mL DPPH (0.02%) in 99.5% ethanol was

added and kept in the dark at room temperature for 30 min. A separate blank was prepared by adding 0.1 mL distilled water in lieu of the sample. There after, the absorbance was read at 517 nm with a UV/Vis spectrophotometer. The DPPH inhibitory activity expressed as percentage was estimated using the expression:

$$\% \text{ inhibition of DPPH} = \frac{\text{Absorbance (blank)} - \text{Absorbance (sample)}}{\text{Absorbance (blank)}} \times 100$$

$$A(\text{blank}) = \text{absorbance of blank at } t_0; A(\text{sample}) = \text{absorbance of sample at } t_{30 \text{ min}}$$

The analysis was carried out in triplicate.

Metal (Fe²⁺) Chelating Activity

The potential of the flour and starch samples to chelate metallic ion was evaluated according to the methods of Dorman *et al.*²⁰ as described by Oluba *et al.*¹⁹ Briefly, 3.7 mL of distilled water was added to 1 mL of the sample solution at different concentrations (0.2 – 1.0 mg/mL). Thereafter, 100 µL of 2 mM FeCl₂ was added and left standing for 3 min before the reaction was terminated with the addition of 200 µL of 5 mM ferrozine solution. The resulting mixture was stirred vigorously and left at 37°C for 10 min before reading the absorbance at 562 nm. In the same way, a blank was run using distilled water in lieu of sample. The iron chelating activity was calculated in percentage according to the formula:

$$\text{Iron chelating activity (\%)} = \frac{1 - A_{\text{sample}} - A_{\text{sample control}}}{A_{\text{blank}}} \times 100$$

Determination of *In vitro* Starch Digestibility

The modified method of Ghavidel *et al.*²¹ utilizing glucose oxidase/peroxidase kit in lieu of dinitrosalicylic reagent was followed to determine the *In vitro* starch digestibility of the samples.

About 12.5 mL phosphate buffer solution (pH 6.5) and 2.5 mL of α-amylase (2 × 10⁻⁴ mg/mL) from porcine pancreas were added to 150 mg of the respective sample in a test tube. This was then incubated for 3 h at 37°C with constant shaking. At an interval of 30 min, 0.2 mL aliquot was taken into a test tube and the α-amylase activity inactivated immediately by placing the tubes in a boiling water

bath for 5 min. Following α-amylase inactivation, 0.6 mL of 0.4 M sodium acetate buffer (pH 4.7) and 0.2 mL of a solution containing 0.833 µL of amyloglucosidase from *A. niger* (300 U/mL, Sigma-Aldrich) were added before being incubated at 55 °C for 50 min. Thereafter, the volume was made up to 20 mL with distilled water following which the glucose concentration in the digesta was estimated using the glucose oxidase / peroxidase Kit (Randox Laboratory Ltd., Antrim, UK). The *In vitro* starch digestibility was calculated using the equation:

$$\text{In vitro starch digestibility} = \frac{\text{Glucose concentration}}{0.9 \times V}$$

$$W_s \times T_s$$

Where, 0.9 = the stoichiometric constant of glucose content conversion into starch; V = digesta volume; W_s = sample weight; T_s = percentage starch in the original sample

Statistical Analyses

Results are reported as mean ± SD and statistically analyzed using One-Way Analysis of Variance (ANOVA) followed by Turkey's multiple comparisons. Confidence value was set at 95%.

Results

The proximate composition (on dry weight basis) of the flour and starch of *D. odoratissima* tuber, is presented in Table 1. Flour obtained from the unpeeled tuber had significantly (p < 0.05) higher moisture (14.31 ± 0.17), crude protein (20.69 ± 0.21), crude fat (2.90 ± 0.04) and ash (1.41 ± 0.06) contents compared to the peeled tuber with 11.21 ± 0.06, 17.19 ± 0.60, 1.55 ± 0.09, and 0.27 ± 0.26 respectively. However, the peeled tuber flour contained significantly (p < 0.05) higher fiber (1.37 ± 0.01) and carbohydrate (67.87 ± 0.04) levels compared to unpeeled tuber flour (0.46 ± 0.11, 57.58 ± 0.23, respectively). The unpeeled tuber starch was significantly (p < 0.05) higher in protein and fiber compared to starch obtained from the peeled tuber (Table 1).

The amino acid profile composition analysis of the unpeeled and peeled *D. odoratissima* tuber flour and starch showed similar profile but for higher lysine (3.52 ± 0.01) in the unpeeled tuber flour compared

to $2.51 \pm 0.05\%$ in the peeled tuber flour. On the other hand, the peeled tuber starch contained higher lysine (3.52 ± 0.02) content compared to unpeeled tuber starch ($3.33 \pm 0.01\%$) (Table 2).

Table 1: Proximate composition (g/100g) of *D. odoratissima* flour and starch

(%) Composition	UF	PF	SU	PS
Moisture	14.31 ± 0.17^c	11.21 ± 0.06^b	8.76 ± 0.12^a	11.76 ± 0.11^b
Protein	20.69 ± 0.21^d	17.19 ± 0.60^c	7.98 ± 0.05^b	5.37 ± 0.20^a
Fat	2.90 ± 0.04^c	1.55 ± 0.09^a	2.39 ± 0.13^b	2.22 ± 0.12^b
Fiber	0.46 ± 0.11^a	1.37 ± 0.01^b	5.75 ± 0.07^d	2.07 ± 0.04^c
Ash	1.41 ± 0.06^b	0.27 ± 0.26^a	1.20 ± 0.06^b	3.73 ± 0.02^c
Carbohydrate	57.58 ± 0.23^a	67.87 ± 0.04^b	70.77 ± 0.07^a	70.48 ± 0.06^a
Energy	318.28 ± 0.60^a	340.71 ± 0.08^a	338.63 ± 0.12^a	338.19 ± 0.24^a

Results are means \pm standard deviation of triplicate readings. Values in the same row carrying different superscript are significant ($p > 0.05$). Note: UP, unpeeled yam flour; PF, peeled yam flour; SU, unpeeled yam starch; PS, peeled yam starch.

Table 2: Amino acid composition (g/100g) of *D. odoratissima* flour and starch

Amino acid	UF	PF	SU	PS
Arginine	2.30 ± 0.08^a	1.90 ± 0.13^a	1.81 ± 0.12^a	2.08 ± 0.14^a
Cysteine	$1.27 \pm 0.05^{b,c}$	1.45 ± 0.07^c	0.94 ± 0.04^a	$1.09 \pm 0.07^{a,b}$
Isoleucine	1.41 ± 0.06^c	$1.29 \pm 0.00^{b,c}$	0.89 ± 0.01^a	1.20 ± 0.02^b
Leucine	$2.48 \pm 0.06^{b,c}$	2.82 ± 0.11^c	1.97 ± 0.16^a	$2.25 \pm 0.11^{a,b}$
Lysine	3.52 ± 0.01^c	2.51 ± 0.05^a	3.33 ± 0.01^b	3.52 ± 0.02^c
Methionine	0.26 ± 0.05^a	0.43 ± 0.10^a	0.44 ± 0.03^a	0.31 ± 0.08^a
Threonine	$1.12 \pm 0.03^{b,c}$	1.32 ± 0.07^c	0.83 ± 0.07^a	$0.98 \pm 0.08^{a,b}$
Tryptophan	0.08 ± 0.04^a	0.03 ± 0.02^a	0.03 ± 0.04^a	0.52 ± 0.68^a
Valine	1.98 ± 0.07^b	2.16 ± 0.09^b	1.48 ± 0.12^a	$1.79 \pm 0.10^{a,b}$

Results are means \pm standard deviation of triplicate readings. Values in the same row carrying different superscript are significant ($p > 0.05$). Note: UP, unpeeled yam flour; PF, peeled yam flour; SU, unpeeled yam starch; PS, peeled yam starch.

Table 3: Anti-nutritional composition of *D. odoratissima* flour and starch

Anti-nutrients (%)	UF	PF	SU	PS
Alkaloid contents	0.40 ± 0.01^a	0.60 ± 0.02^a	0.50 ± 0.00^a	0.60 ± 0.02^a
Terpenoid content	24.0 ± 0.03^d	7.0 ± 0.05^b	17.00 ± 0.02^c	3.50 ± 0.04^a
Saponin content	0.52 ± 0.01^a	0.44 ± 0.02^a	0.44 ± 0.01^a	0.54 ± 0.02^a
Flavonoid content	7.20 ± 0.01^c	5.60 ± 0.03^b	6.8 ± 0.01^c	1.6 ± 0.02^a

Results are means \pm standard deviation of triplicate readings. Values in the same row carrying different superscript are significant ($p > 0.05$). Note: UP, unpeeled yam flour; PF, peeled yam flour; SU, unpeeled yam starch; PS, peeled yam starch.

The alkaloid content of both peeled and unpeeled flour and starch ranged from 0.40 to 0.60. The differences observed in alkaloid concentration in both peeled and unpeeled flour and starch were not statistically significant. Terpenoid level was significantly ($p < 0.05$) higher in the unpeeled tuber for both flour (24.0) and starch (17.0) compared to the peeled flour (7.0) and starch (3.5). Saponin concentration in the peeled and unpeeled flour and starch was similar (0.44 – 0.52). Flavonoid level was significantly ($p < 0.05$) higher in the unpeeled tuber for both flour (7.2) and starch (6.8) compared to the peeled flour (5.6) and starch (1.6) (Table 3).

The water absorption capacity of the flour ranged between 56.7% (unpeeled tuber) to 57.0% (peeled tuber). These values showed that water absorption capacity was not significantly different

between peeled tuber flour and unpeeled tuber flour. Similarly, the variation in water absorption capacity between unpeeled tuber starch (49.8%) and peeled tuber starch (50.7%) was not statistically significant. *D. odoratissima* flour exhibited higher solubility value compared to the starch. The solubility index for unpeeled flour (49.4%) and peeled flour (44.8%) were significantly ($p < 0.05$) higher compared to solubility index for unpeeled starch (33.8% and peeled starch (34.1%). *D. odoratissima* unpeeled and peeled tuber starch showed a significantly higher paste clarity (63.8% and 67.0% respectively) compared to unpeeled tuber flour (32.4%) and peeled flour (37.7%). The unpeeled tuber flour had a significantly ($p < 0.05$) higher (23.3%) swelling index compared to both peeled (16.0%) and unpeeled (12.3%) tuber starch (Table 4).

Table 4: Functional properties of *D. odoratissima* flour and starch

Functional properties	UF	PF	SU	PS
Water absorption capacity (g/mL)	56.7 ± 3.06 ^a	57.0 ± 5.0 ^a	49.8 ± 2.5 ^a	50.7 ± 2.52 ^a
Solubility index (%)	49.4 ± 16.3 ^b	44.8 ± 10.3 ^b	38.8 ± 6.4 ^a	34.1 ± 7.29 ^a
Paste clarity (%T)	32.4 ± 1.2 ^a	37.7 ± 0.4 ^a	63.8 ± 1.5 ^b	67.0 ± 0.4 ^b
Swelling index (%)	23.3 ± 2.0 ^b	19.7 ± 1.8 ^{a,b}	12.3 ± 0.6 ^a	16.0 ± 2.0 ^a

Results are means ± standard deviation of triplicate readings. Values in the same row carrying different superscript are significant ($p > 0.05$). Note: UP, unpeeled yam flour; PF, peeled yam flour; SU, unpeeled yam starch; PS, peeled yam starch.

The unpeeled tuber flour showed significantly ($p < 0.05$) higher scavenging activity against DPPH

radical compared to peeled flour, unpeeled and peeled tuber starch (Figure 1a).

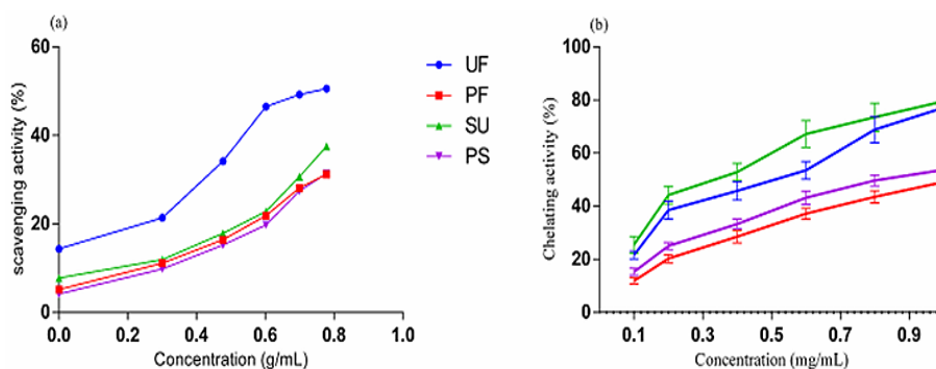


Fig. 1: (a) DPPH scavenging and (b) iron chelation activities of flour and starch extract of *Dioscorea odoratissima* tuber. Values are mean ± SD of triplicate determinations. UF, unpeeled flour; PF, peeled flour; SU, starch extract of the unpeeled tuber; PS, starch extract of peeled tuber

The starch samples (peeled and unpeeled) exhibited significantly ($p < 0.05$) higher inhibitory action against alpha amylase (Figure 2a) and alpha glucosidase (Figure 2b) activities compared to both peeled and

unpeeled tuber flour. However, the PS exhibited better inhibitory activity against α -amylase and α -glucosidase compared to US.

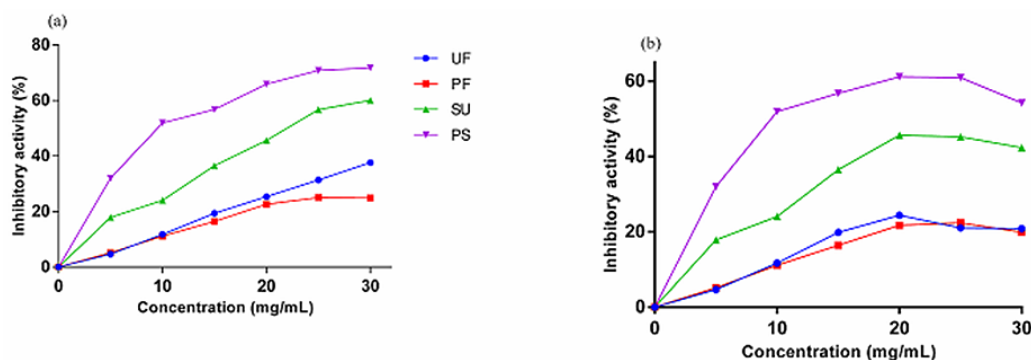


Fig. 2: (a) Alpha amylase and (b) alpha glucosidase inhibitory activities of flour and starch extract of *Dioscorea odoratissima* tuber. Values are mean \pm SD of triplicate determinations. UF, unpeeled flour; PF, peeled flour; SU, starch extract of the unpeeled tuber; PS, starch extract of peeled tuber

Starch from the peeled yam tuber (PS) showed significantly ($p < 0.05$) lower *In vitro* starch digestibility compared to US (Table 5). The flour from the peeled yam had significantly ($p > 0.05$) higher amylose

to amylopectin ratio compared to flour from the unpeeled yam as well as the starch samples (Table 5).

Table 5: amylose/amylopectin content and *in-vitro* digestibility of the flour and starch samples

Samples	Amylose/amylopectin ratio (%)	<i>In-vitro</i> digestibility (mg/g)
UF	18.40 \pm 0.07 ^a	0.431 \pm 0.06 ^c
PF	27.91 \pm 0.04 ^b	0.439 \pm 0.03 ^c
SU	19.34 \pm 0.02 ^a	0.136 \pm 0.04 ^b
PS	18.76 \pm 0.01 ^a	0.048 \pm 0.03 ^a

Values are mean \pm SD of triplicate determinations. UF, unpeeled flour; PF, peeled flour; SU, starch extract of the unpeeled tuber; PS, starch extract of peeled tuber

Discussion

The moisture content of *D. odoratissima* tuber flour and starch as observed in this study were higher than previously reported for oven-dried flour of different ascension of *D. alata*.²² Oyeleke *et al.*²³ however reported lower moisture (3.95 %) for sun dried arils. The high moisture content of *D. odoratissima* flour and starch in this study may account for the relatively short post-harvest shelf life of this yam species. The high rate of perishability of *D. odoratissima* has been responsible in part for its cultivation as well as utilization. Thus, study on preservation techniques

aimed at improving the shelf life of this under-utilized yam species or its products is warranted. The crude fiber values obtained for *D. odoratissima* tuber flour and starch in this study were similar to those reported in literature by Afoakwa and Sefa-Dedeh²⁴ for *Dioscorea dumetorum*; Bhandari *et al.*¹⁷ and Shanthakumari *et al.*²⁵ for wild yams. Crude protein values for both unpeeled and peeled *D. odoratissima* tuber flour in the present study were relatively high compared to the value reported by Afoakwa and Sefa-Dedeh²⁴ for white and yellow varieties of *D. dumetorum*.

The water absorption capacity for both flour and starch obtained from *D. odoratissima* in this study were relatively higher than those reported for Nigerian local wheat flour (140 - 150 %), different yam flours (194 - 207 %), sorghum flour (219 - 235 %), irradiated and non-irradiated cowpea flours (110 - 113 %).^{26,27} The principal component of *D. odoratissima* tuber according to this study are carbohydrates and protein. These two components have been established to exhibit significant influence on the water absorption capacity of foods as a result of the presence of highly charged hydrophilic components in their structures. The presence of highly charged polar amino acid residues enhances the formation of hydrogen bonds with water molecules and so more water molecules are entrapped.²⁸ The starch content of food plays a significant role with regard to water absorption capacity due to the weak intermolecular forces existing between starch molecules.²⁹ Flours with high water absorption capacity find very good applications in dough, meat processing and custard production.²⁶

The solubility of the *D. odoratissima* flours obtained in this study was higher than those reported for the cassava and sweet potato cultivars (12.06 - 24.44 %).³⁰ Solubility and swelling power are influenced by the water binding capacity of the flour sample (which is a function of proteins and carbohydrates present in the flour). A low swelling power in association with high solubility is indicative of weak associative forces within the flour sample, which reduces its elastic and plastic properties. Viscosity is an important sensory attribute of dough, pasta and food gels. For a more elastic and viscous dough, flour with high swelling power in association with low solubility is recommended.^{30,31} This implies that *D. odoratissima* flours may form less viscous gels or dough due their high solubility compared to cassava and sweet potato flours. Pasta made from cassava or sweet potato composited wheat flour had less firmness in comparison with that of absolute wheat flour, although the cassava and sweet potato had low solubility.³² Thus, it can be inferred that the *D. odoratissima* flours having less potential to form viscous dough due to higher solubility may not be suitable for compositing with wheat flour in pasta formulation. This potential to form less viscous gels and dough could make them suitable as thickeners for sauces and soups and as binders for meat products.

Data from this study showed that flour and starch from the unpeeled yam demonstrated higher antioxidant activity through their enhanced DPPH scavenging and iron reducing activities compared to flour and starch from the peeled yam. This observation could be attributed to the concentration of phytochemicals such as flavonoids, terpenoids and proteins on the outer layer of the yam tuber. These phytochemicals have been proven to exhibit antioxidant activity both *In vitro* and *in vivo*.^{33,34} This outer layer most often coloured, is usually lost to peeling in the peeled samples. For instance, the storage protein, discorin has been reported to scavenge 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical.³⁵ The reported antioxidant activity of *D. odoratissima* flour and starch in this study may involve its ability to quench reactive species by donating hydrogen or electron as demonstrated through DPPH scavenging and iron reducing activities as well as by forming insoluble complexes with metal ions, that catalyze lipid peroxidation as shown through its metal chelating activity.

The starch samples (PS and US) displayed better inhibitory potential against α -amylase α -glucosidase in relation to the flour (PF and UF). The concerted action of α -amylase and α -glucosidase on starch breakdown contributes significantly on the overall effect of starch consumption on circulating blood glucose concentration. Starch is broken down into disaccharides by α -amylase while α -glucosidase, an iso maltase hydrolyses the disaccharide products of α -amylase into glucose. The inhibitory action of *D. odoratissima* starch on α -glucosidase activity reported in this study is of great significance in delaying postprandial glucose release from disaccharides in the gut than α -amylase inhibition. The observed inhibition of α -glucosidase and α -amylase in this study is in agreement with the report of Adedayo *et al.*³⁶ in a similar study. Thus, the inclusion of sufficient amount of slowly digestible starch, such as *D. odoratissima* starch in the diet could serve as a good antidote to diabetes.³⁶ Starch from a number of sources have been demonstrated to show *In vitro* α -amylase and α -glucosidase inhibitory activity. The presence of polyphenolic compounds in *D. odoratissima* demonstrated in this study may have significant contribution on the potential inhibition of α -amylase and α -glucosidase activities. However, moderate α -amylase inhibition with potent α -glucosidase inhibitory activity may offer

better therapeutic strategy that could slow down the availability of dietary carbohydrate substrate for glucose production in gut. From this study, it was observed that high levels of amylose correlate positively with lower *In vitro* starch digestibility. This could be due to the ability of amylose unlike amylopectin to form very compact physical structures that tend to inhibit digestion. Our observation with regard to the impact of amylose/amylopectin ratio on starch digestibility in this study is supported by several *in vivo* studies which have reported a lower blood glucose response due to increased amylose content.^{37,38} The amylose/amylopectin ratio as reported in this study also provides justification for the increased α -amylose and α -glucosidase inhibitory activities observed for peeled starch which had the lowest *In vitro* digestibility and the greatest inhibition to the enzymes' activities.

Conclusion

Data obtained from this study showed that the composition and functional properties of *Dioscorea odoratissima* flour and starch vary with pre-treatment such as peeling. The unpeeled flour and starch were

not only richer in terms of phytochemical content but displayed better antioxidant activity against free radical and inhibitory activity against carbohydrate degradative enzymes. Yam tuber remains a cheap and readily available energy source to low income earners in the tropics. Currently, there is increase demand for starch with specific characteristics in the food industries. The properties of *D. odoratissima* starch as demonstrated in this study provide information on the potential usefulness of the starch in food processing and in the development of new products with desirable qualities.

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Conflict of Interest

The authors do not have any conflict of interest.

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