

Research Article

Nutrient Evaluation of Composite Flours from White Yam (*Dioscorea rotundata*) and Orange-Fleshed Sweet Potato (*Ipomoea batatas* L.) Flour Blends

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Abstract

The purpose of this study was to assess the quality of composite flour made from whole orange-fleshed sweet potatoes (*Ipomoea batatas* L.) and white yam (*Dioscorea rotundata*) blends. Coded as Y10 for 100% White yam flour, Y8 for 80% White yam flour + 20% Orange flesh sweet potato flour, Y7 for 70% White yam flour + 30% Orange flesh sweet potato flour, Y6 for 60% White yam flour + 40% Orange flesh sweet potato flour, and Y5 for 50% White yam flour + 50% Orange flesh sweet potato flour, a number of flour blends were created. The flour blends' pasting, carotenoid, phytochemical, chemical, and functional qualities were assessed. SPSS was used to do statistical analysis on the data gathered from the analyses. The flour blends' moisture percentage ranged from 6.18% to 7.20%, while their ash level ranged from 1.25% to 2.08%, according to the proximate composition data. While the protein concentration ranged from 5.95% to 7.60%, the crude fiber level varied from 1.06% to 1.75%. Energy values ranged from 362.01 to 375.21 kcal, and the percentage of carbohydrates ranged from 69.80% to 79.10%. With a bulk density range of 0.795 to 0.870 g/cm³ and a water absorption capacity (WAC) ranging from 2.55 to 3.80 ml/g, the flour blends showed good functional qualities. Swelling capacity ranged from 54.56% to 72.22%, with significant variation ($p < 0.05$). According to the pasting properties, the final viscosity values ranged from 5946.00 to 9304.00 RVU, while the peak viscosity ranged from 4793.00 to 8108.00 RVU. Dietary fiber levels varied from 0.56% to 1.08% for soluble fiber, 5.32% to 8.15% for insoluble fiber, and 5.88% to 9.23% for total fiber. The range of total carotenoid concentration was 19.10 to 424.77 µg/100g, whereas the range of beta-carotene content was 6.06 to 121.05 µg/100g. With tannin levels ranging from 1.48 to 2.77 mg/100g, total phenol values from 11.58 to 42.00 mg/100g, and flavonoid content ranging from 5.78% to 15.89%, the flour blends also demonstrated notable phytochemical activity. Significant differences in the concentrations of other bioactive substances, such as saponins, cardiac glycosides, alkaloids, and vitamins, were also observed in the study. These results imply that composite flours made from orange-fleshed sweet potatoes and white yams have good nutritional qualities, good functional qualities, and would work well for dumplings and other baked goods.

Keywords

Yam, Flour, Proximate Composition, Dietary Fibre, Sweet Potatoes

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1. Introduction

Six of the more than 500 species of annual root tuber-bearing plants, including yams (*Dioscorea* species), are significant to society and the economy in terms of food, money, and medicine [11]. The yam, a tropical root or tuber with numerous species, is a member of the genus "Dioscorea" and family "Dioscoreaceae." It was introduced to West Africa in the 16th century from South East Asia. The white yam (*Dioscorea rotundata*), water yam (*Dioscorea alata*), yellow yam (*Dioscorea cayenensis*), and three-leaf yam are among the yam species [11]. In terms of output volume and value, yam is one of the main tuber crops in the Nigerian economy [58]. White yam (*Dioscorea rotundata*) is the predominant yam species in West Africa due to its highly viscous starch, lower moisture content, high fiber content, and significant levels of potassium and magnesium. It also features a stable color resistant to enzymatic browning, provides essential vitamins, and has a lower glycemic index relative to other varieties [1].

Sweet potato (*Ipomoea batatas* L.) is a member of the Convolvulaceae family. The common varieties are usually identified by the color of their skin: yellow, purple, pink, white, and orange varieties. There is little awareness on other characteristics for differentiating varieties besides skin, flesh level of sweetness and colour [41]. According to Bose et al. [21] Nigeria is one of the largest producers of sweet potato in Sub-Saharan African (SSA) with annual production estimated at 3.46 million tonnes per year sweet potato is a tuber of tropical and subtropical environments and can be easily grown with great adaptability, resistance, and low cost of production. Sweet potatoes (*Ipomoea batatas* L.) utilization have become a trending research topic in recent years due to their special nutritional and functional properties. Sweet potato leaves and roots contain a variety of bioactive nutrients, including carbohydrates, proteins, carotenoids, flavonoids, anthocyanins, phenolic acids, and minerals [13]. Traditional foods in Nigeria derivable from yam tubers include roasted yam, fried chips, amala and pounded yam. Pounded yam is a stable food, which is consumed in many tribes of Nigeria and some other West African countries [47]. Dumplings are a staple food in many cultures, and exploring alternative ingredients can enhance their nutritional value and sustainability. However, using sole White Yam for dumpling production poses several technical, sensory, scalability, and nutritional challenges. Technically, White Yam's low gluten content makes it difficult to form and maintain dumpling shape. The elevated starch content may result in dense or heavy dumplings, whereas restricted elasticity influences texture and mouthfeel. Achieving the desired texture is also challenging, with dumplings potentially becoming too soft or too hard. Sensory issues arise from White Yam's neutral flavor, which may not provide enough taste excitement. The pale color of White Yam dumplings can be uninviting, and texture variability may result in sticky or dry dumplings. From

a nutritional perspective, White Yam's relatively high glycemic index may affect blood sugar levels. Its limited nutrient profile lacks essential micronutrients, potentially impacting overall nutritional value [58].

Incorporating orange fleshed sweet potato, a root crop which is rich in carotenoids, beta carotene, ascorbic acid, lysine, anti-oxidants, and soluble fibre into yam flour for the production of composite could help in lowering cholesterol levels and reducing the risk of heart diseases, and also promote better eyesight, particularly in the tropical regions where the flours are used for the production of dumpling dough is a staple food. Thus, the study evaluated the quality of composite flour made from white yam (*Dioscorea runtudata*) and whole orange fleshed sweet potato (*Ipomoea batatas* L.) flours blends.

2. Materials and Methods

2.1. Source of Materials

Fresh and wholesome tubers of white yam (*Dioscorea rotundata*) was purchased from main market Anyigba in Kogi State, Nigeria, the orange flesh sweet potato (*Ipomoea batatas*) was purchased from the National Root Crops Research Institute, Umidike, Abia State, Nigeria. Sodium metabisulphite and all reagent used which are of analytical quality was obtained from the Food Chemistry Laboratory of Prince Abubakar Audu University, Anyigba, Kogi State, Nigeria.

2.2. Experimental Design

The experiment is a 1×1×4 factorial design in a complete randomized design and 100% yam flour as control.

Table 1. Formulation Table.

Composite Samples	White Yam Flour (YF, %)	Orange Fleshed Sweet Potato Flour (SP, %)
Y10	100	–
Y8	80	20
Y7	70	30
Y6	60	40
Y5	50	50

Sample codes: Y10 = 100% White yam flour; Y8 = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y7 = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y6 = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y5 = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

2.3. Preparation of Yam Flour

Yam flour was prepared from wholesome yam tubers, which was washed, peeled, cut into flakes and soaked in sodium metabisulphite solution (80mg/100g H₂O for 5 min.)

to prevent enzymatic browning. The flakes were blanched at 100 °C for 10 minutes after which it was drained and dried. The dried flakes were milled and put into an air tight polythene bag. The flow chart is as shown in [Figure 1](#) below.

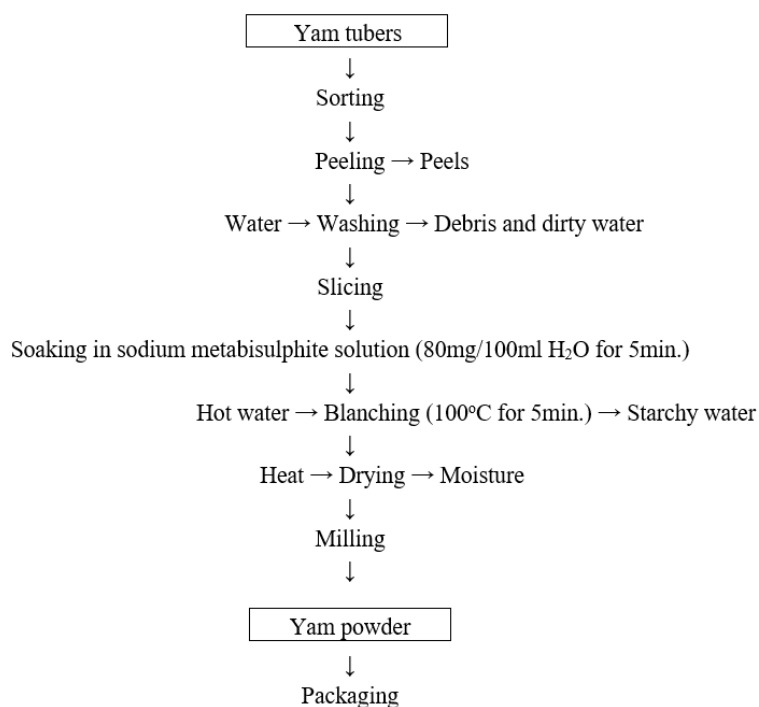


Figure 1. Production of yam powder. [2].

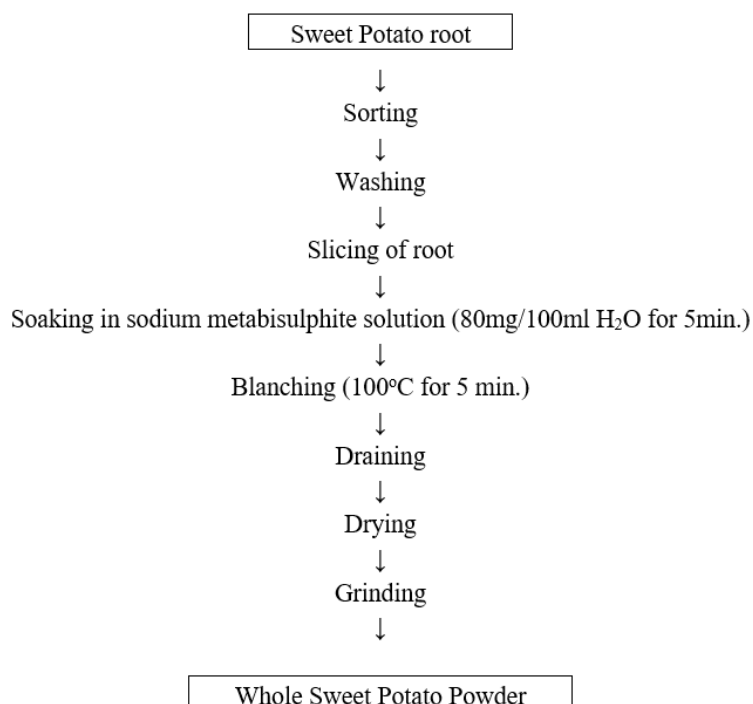


Figure 2. Production of whole sweet potato powder. [4].

2.4. Chemical Analyses

2.4.1. Carotenoid Profile

Beta-carotene and lycopene contents of the samples were determined according to the method of Udensi *et al.* [59].

2.4.2. Dietary Fibre Profile

The dietary fibre was determined by enzymatic extraction according to AOAC (2020) method.

2.4.3. Phytochemical Profile

Total saponin content was determined by the method [61]. Tannin was determined by Folin-Ciocalteu method [61]. The total phenol content was determined by Folin-Ciocalteu method [61]. The total flavonoid content was determined by method described by Kaviarasan *et al.*, (2007). The cardiac glycoside content was determined according to Udensi *et al.* [59]. Alkaloid was determined according to the method

described [44].

2.4.4. Vitamins

The Vitamin A, B₁ were analyzed in samples using the AOAC (2005) method.

2.5. Minerals Analysis

The method described by [13] was used to determine the mineral compositions.

2.6. Statistical Analysis

Data was obtained in duplicate and subjected to one-way analyses of variance (ANOVA) using Statistical Package for the Social Sciences (SPSS version 26); and data that were significantly different at $p \leq 0.05$ was separated using Duncan Multiple Range Test (DMRT).

3. Results and Discussion

Table 2. Proximate composition (%) and energy value (Kcal) of white yam and orange flesh sweet potatoes flour blends.

Samples	Moisture	Ash	Crude fibre	Crude fat	Crude protein	Carbohydrates	Energy value
Y ₁₀	6.18 ^c ±0.03	1.25 ^e ±0.00	1.06 ^e ±0.03	1.03 ^d ±0.00	6.77 ^b ±0.05	84.71 ^a ±0.03	375.21 ^a ±0.08
Y ₈	7.10 ^a ±0.49	1.38 ^d ±0.03	1.21 ^d ±0.00	1.10 ^c ±0.00	5.95 ^c ±0.21	83.09 ^b ±0.00	366.0 ^b ±0.85
Y ₇	6.90 ^{ab} ±0.00	1.50 ^c ±0.07	1.36 ^c ±0.00	1.17 ^b ±0.03	6.65 ^b ±0.14	82.42 ^c ±0.03	366.81 ^b ±0.93
Y ₆	7.20 ^a ±0.14	1.67 ^b ±0.00	1.49 ^b ±0.01	1.24 ^a ±0.01	6.80 ^b ±0.00	81.17 ^d ±0.03	363.08 ^b ±0.24
Y ₅	6.42 ^b ±0.06	2.08 ^a ±0.03	1.75 ^a ±0.07	1.19 ^b ±0.00	7.60 ^a ±0.03	80.97 ^e ±0.00	362.01 ^b ±0.04

Values are mean ± S.D (n = 3). Values with the same superscript along same column are not significantly ($p > 0.05$) different. Y₁₀ = 100% White yam flour; Y₈ = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y₇ = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y₆ = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y₅ = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

3.1. Proximate Composition of White Yam and Orange Flesh Sweet Potatoes Flour Blends

The moisture content of the samples, as shown in Table 2, ranged from 6.18% to 7.20%, with Sample Y₆ exhibiting the highest mean value, while Sample Y₁₀ had the lowest. A significant difference ($p < 0.05$) was observed among the samples. Moisture plays a crucial role in determining the shelf stability of food products, as lower moisture levels help extend shelf life by reducing susceptibility to microbial growth [28]. Additionally, the moisture content in flour is an indicator of its dry matter composition. The values obtained in

this study fall within the recommended moisture limit of 10% or lower, which is essential for long-term flour storage [52]. The relatively low moisture content in white yam and orange-fleshed sweet potato flour blends enhances their storage stability by inhibiting mold growth and other biochemical changes [52].

The ash content of the samples ranged from 1.25% to 2.08%, with Sample Y₅ having the highest mean value and Sample Y₁₀ (the control sample) recording the lowest. A statistically significant difference ($p < 0.05$) was observed among the samples. Ash content is a measure of the total mineral composition in food, making it an important factor in processing since it influences the physicochemical properties

of food. The results suggest that incorporating orange-fleshed sweet potato flour into white yam flour enhances the overall mineral content of the flour blends. The higher the proportion of orange-fleshed sweet potato flour, the richer the flour is in minerals. Boakye et al. [22] reported that sweet potato contains higher mineral levels than most other root crops. The ash values obtained in this study are consistent with the range of 1.84% to 4.01% reported by Oluwaseun et al. [50] in their study on fufu analog flour made from cassava and cocoyam flour blends.

The crude fiber content of the samples ranged from 1.06% to 1.75%, with Sample Y5 exhibiting the highest value and Sample Y10 the lowest. A statistically significant difference ($p < 0.05$) was observed among the samples. The findings indicate that fiber content increased as more orange-fleshed sweet potato flour was added to the blends. Dietary fiber plays a critical role in digestion, cholesterol reduction, stool softening, and the prevention of diseases such as colon irritation, diabetes, and cancer [28]. The fiber content recorded in this study aligns with the range (1.30% to 5.99%) reported by Olugbenga et al. [49] in their research on fufu flour produced from sweet cassava and guinea corn flour.

The fat content of the samples ranged from 1.03% to 1.24%, with Sample Y6 having the highest value and Sample Y10 the lowest. A significant difference ($p < 0.05$) was observed among the samples. The relatively low fat content found in this study may be attributed to fat oxidation during the drying process. Additionally, the drying process may have contributed to the breakdown of fats into other substances, making the final flour suitable for diabetes management. The low-fat content is also advantageous for extending the flour's shelf life by reducing the likelihood of rancidity. The findings are consistent with the fat content values (1.20% to 1.21% and 5.06% to 5.34%) reported by Oluwaseun et al. [50] and

Olugbenga et al. [49] in their studies on fufu flour made from cassava, cocoyam, sweet cassava, and guinea corn blends. The flour blends in this study could be beneficial for individuals with diabetes due to their low fat content.

The protein content of the samples ranged from 5.95% to 7.60%, with Sample Y5 having the highest value and Sample Y8 the lowest. Statistically, a significant difference ($p < 0.05$) was observed among the samples. The variation in protein content across different samples was evident, and an increase in protein content was noted at 40% and 50% substitution levels of orange-fleshed sweet potato flour. This trend may be due to the fact that orange-fleshed sweet potatoes are naturally richer in protein than white yam [22]. The protein values reported in this study are similar to those (1.68% to 10.10%) documented by Olugbenga et al. [49] in their analysis of fufu flour blends made from sweet cassava and guinea corn. However, the values are lower than the protein content (17.01% to 41.80%) reported by Peter [56] for instant fufu flour formulated from corn, cassava, and soybean blends.

The carbohydrate content of the flour samples ranged from 69.80% to 79.10%, with Sample Y10 exhibiting the highest value (84.71 Kcal) and Sample Y5 the lowest. Statistically significant differences ($p < 0.05$) were found among the samples. The study revealed a decrease in carbohydrate content as the proportion of orange-fleshed sweet potato flour increased. Carbohydrates play a crucial role in supplying energy to cells, including those in the brain, muscles, and blood. Additionally, they aid fat metabolism, act as mild natural laxatives, and help preserve proteins by serving as an energy source [48]. The carbohydrate values obtained in this study are similar to the range (64.5% to 85.20%) reported by Peter [56] for instant fufu flour made from blends of corn, cassava, and soybean.

Table 3. Functional properties of white yam and orange fleshed sweet potato flour blends.

Samples	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Bulk density (g/cm ³)	Swelling capacity (%)
Y ₁₀	2.55 ^c ±0.10	0.88 ^c ±0.03	0.870 ^a ±0.00	54.56 ^e ±0.01
Y ₈	3.10 ^b ±0.14	0.56 ^d ±0.03	0.840 ^a ±0.02	61.24 ^d ±0.00
Y ₇	3.55 ^a ±0.07	1.63 ^a ±0.02	0.860 ^a ±0.03	70.76 ^b ±0.03
Y ₆	2.95 ^b ±0.21	1.41 ^b ±0.01	0.795 ^b ±0.00	72.22 ^a ±0.03
Y ₅	3.80 ^a ±0.14	0.40 ^e ±0.00	0.800 ^b ±0.00	68.75 ^c ±0.01

Values are mean ± S.D (n = 3). Values with the same superscript along same column are not significantly ($p > 0.05$) different. Y₁₀ = 100% White yam flour; Y₈ = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y₇ = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y₆ = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y₅ = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

3.2. Functional Properties of Composite Flour from White Yam and Orange Flesh Sweet Potatoes

3.2.1. Bulk Density

Bulk density serves as an indicator of a product's porosity and reflects its wettability, which influences packaging design and helps determine the most suitable packaging material [30]. The bulk density of the composite flour samples showed significant variation ($p < 0.05$), with values ranging from 0.795 to 0.870 g/cm³. This property also reflects the weight a sample can support when stacked. The bulk density recorded for these flour samples was higher than the 0.69 g/cm³ and 0.57-0.71 g/cm³ previously reported for taro flours [36], as well as the 0.31-0.51 g/cm³ documented for African yam bean (AYB) flour and its protein isolates [44]. However, the findings were comparable to the 0.86 g/cm³ reported by Ezeocha et al. [29] for cooked trifoliate yam flour. Variations in bulk density have been linked to differences in particle size. According to Ekunseitan et al. [27], bulk density is affected by the structure of starch polymers, with a looser structure corresponding to lower bulk density. The bulk density of these flour samples is crucial in determining packaging requirements, material handling, and their applicability in wet-processing food industries [38]. Additionally, while high bulk density is desirable in food formulations aimed at increasing bulk, low bulk density is advantageous for developing complementary foods [56].

3.2.2. Water Absorption Capacity (WAC)

Water absorption capacity (WAC), which measures the ability of flour to retain water, varied significantly among the tested samples. The values ranged from 2.55 to 3.80 ml/g, and this property directly affects the flour's ability to form a paste, which in turn influences its physicochemical behavior in food applications such as soups, dough, and baked goods [20]. The ability of a food material to absorb water is often associated with its protein and starch content, as well as the effect of heat, which can cause protein molecules to dissociate into monomeric subunits with additional water-binding sites [14]. The WAC values obtained in this study suggest that white yam and orange-fleshed sweet potato flour blends would be

suitable for use in bakery products, where hydration is essential for better handling properties. Additionally, WAC tends to increase with higher protein levels. The values reported in this study are lower than the 47.09-80.99 ml/g range observed by Chinelo and Jennifer for trifoliate yam flour. A low WAC indicates a more compact molecular structure, whereas a higher WAC suggests a looser starch polymer arrangement, making it suitable for composite flour in bread-making applications [6].

3.2.3. Swelling Capacity

The swelling capacity of the flour samples exhibited significant variation ($p < 0.05$), with values ranging from 54.56% to 72.22%. Sample Y10 recorded the lowest swelling capacity (54.56%), while Sample Y5 had the highest. These findings align with the results of Ukom et al. [60], who reported swelling capacity values between 46.33% and 60.03% for cocoyam flour processed under different conditions. Swelling capacity refers to the degree of expansion that occurs when molecules absorb water, leading to the formation of a colloidal suspension. Expansion continues until further uptake is prevented by intermolecular forces acting on the swollen particles [20]. A higher swelling capacity indicates stronger associative forces within the flour's structure.

3.2.4. Oil Absorption Capacity (OAC)

The oil absorption capacity (OAC) of the flour blends varied significantly ($p < 0.05$) among the samples, with values ranging from 0.40 to 1.63 ml/g. Sample Y5 exhibited the lowest value (0.40 ml/g), while Sample Y7 recorded the highest (1.63 ml/g). The OAC values in this study were lower than the 22.0-27.5% range reported by Falade and Okafor [30] for soft corm cocoyam. Similarly, they were lower than the 120.00-192.00 ml/g range documented for semolina made from sweet potatoes [9]. Oil absorption capacity is a measure of a food material's ability to retain oil, a property that significantly impacts flavor retention, palatability, and the shelf life of various food products, including bakery items, meat extenders, doughnuts, pancakes, and soup mixes [19, 45]. Additionally, OAC enhances the flavor and mouthfeel of food products, making it a valuable attribute in food formulation [4].

Table 4. Pasting properties of white yam and orange flesh sweet potatoes flour blends.

Samples	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting temperature (°C)
Y ₁₀	8108.00 ^a ± 0.12	6233.00 ^a ± 0.09	1875.00 ^c ± 0.52	9304.00 ^a ± 0.00	3071.00 ^b ± 0.08	5.47 ^a ± 0.00	80.75 ^b ± 0.01
Y ₈	6686.00 ^b ± 0.09	4652.00 ^b ± 0.02	2034.00 ^a ± 0.17	7912.00 ^b ± 0.04	3260.00 ^a ± 0.34	4.87 ^b ± 0.01	79.00 ^b ± 0.05
Y ₇	4793.00 ^e ± 0.98	3458.00 ^e ± 0.04	1335.00 ^d ± 0.07	5700.00 ^e ± 0.01	2242.00 ^d ± 0.01	4.87 ^b ± 0.09	80.75 ^b ± 0.00

Samples	Peak (RVU)	Trough (RVU)	Breakdown (RVU)	Final viscosity (RVU)	Setback (RVU)	Peak time (min)	Pasting temperature (°C)
Y ₆	5863.01 ^c ±0.23	4013.00 ^c ±0.85	1850.00 ^c ±0.32	6435.00 ^c ±0.09	2422.00 ^c ±0.02	4.87 ^b ±0.04	81.55 ^a ±0.07
Y ₅	5528.00 ^d ±0.01	3524.00 ^d ±0.23	2004.00 ^b ±0.92	5946.00 ^d ±0.07	2422.00 ^c ±0.01	4.87 ^b ±0.00	81.50 ^a ±0.05

Values are mean ± S.D (n = 3). Values with the same superscript along same column are not significantly (p>0.05) different. Y10 = 100% White yam flour; Y8 = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y7 = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y6 = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y5 = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

3.3. Pasting Properties of Composite Flour from White Yam and Orange Flesh Sweet Potatoes

3.3.1. Peak Viscosity

Pasting properties describe the behavior of a starch suspension when heated beyond a critical temperature. At elevated temperatures, starch granules undergo irreversible swelling, leading to the leaching of amylose into the surrounding aqueous phase, which increases viscosity. The peak viscosity (PV) of the flour samples ranged between 4793.00 and 8108.00 RVU, with significant differences (p<0.05) observed among all samples. PV represents the ability of starch to form a paste and expand before undergoing structural breakdown (Sanni et al. 2021). Since PV is closely linked to starch damage, the control sample Y10 (100% white yam flour) exhibited a significantly higher viscosity compared to the other samples. The PV values recorded in this study were higher than those previously reported for sorghum starch (325-398 RVU) by Aviara et al. (2020) and yam starches (639-726 RVU) by Amoo et al. [15]. The high PV observed suggests the potential application of these flour samples in food products requiring high gel strength, elasticity, and thick pastes, such as custard.

3.3.2. Trough Viscosity

Trough viscosity represents the minimum viscosity reached during the constant-temperature phase of the Rapid Visco Analyzer (RVA) profile, indicating the paste's resistance to breakdown upon cooling. Significant differences (p<0.05) were observed among all samples, with trough viscosity values ranging from 3458.00 to 6233.00 RVU. Sample Y10 had the highest trough viscosity, while Sample Y7 had the lowest. The ability of a paste to resist heat and shear stress is a crucial factor in food processing and influences the quality of starch gels. The values obtained in this study were higher than those reported for Gru (93.34 RVU) and Una-ngwa (190.79 RVU) by Amoo et al. [15]. A high trough viscosity indicates strong paste stability, a critical requirement for industrial

starch applications [42]. Maintaining stable paste properties is essential in preventing undesirable texture changes during and after processing. The high trough viscosity observed in white yam flour suggests a superior ability to withstand shear stress at high temperatures and retain paste stability after cooking.

3.3.3. Breakdown Viscosity

Breakdown viscosity serves as an indicator of starch stability [35]. It is determined by the difference between peak viscosity and trough viscosity, reflecting the rate of gel breakdown, which depends on the composition of the sample. Significant differences (p<0.05) were recorded for all samples, with breakdown viscosity values ranging from 1335.00 to 2034.00 RVU. Breakdown viscosity, also referred to as shear thinning, measures how easily swollen starch granules disintegrate under applied shear forces [64]. Sanni et al. [57] reported that starch breakdown is influenced by the nature of the starch source, processing temperature, and degree of shear stress applied. The values obtained in this study were significantly higher than those reported for sorghum starch (145-216 RVU) and yam starches (15-385 RVU) [20].

3.3.4. Final Viscosity

Final viscosity represents the starch's ability to withstand heat and shear stress during processing, which is particularly important for applications requiring stable pastes with minimal retrogradation or syneresis [57]. Significant differences (p<0.05) were observed in the final viscosity values, which ranged between 5946.00 and 9304.00 RVU. This parameter is widely used to evaluate the capacity of starch-based materials to form viscous pastes or gels after cooking and cooling. Additionally, it indicates the resistance of pastes to shear forces during stirring [2].

3.3.5. Setback Viscosity

Setback viscosity (SBV) measures the re-association of starch molecules after gelatinization, indicating the cohesiveness of the paste. Jimoh et al. [34] described setback viscosity as an indicator of the retrogradation tendency of flour starch. The values ranged from 2242.00 to 3260.00 RVU, with significant differences (p<0.05) recorded among the

samples. The setback viscosity in this study was higher than the 104-140 RVU reported for sorghum flour and the 79-339 RVU range for yam flour, as documented by Amoo et al. [15] and Aviara et al. [18], respectively. Low setback viscosity is preferable for food products requiring minimal retrogradation and paste stability at lower temperatures, such as weaning foods (Oduro et al. [42]). Conversely, high setback viscosity is beneficial in applications such as bread, cakes, and doughnuts, where strong gel cohesiveness is desirable.

3.3.6. Peak Time

Peak time, which indicates the duration required for a starch sample to reach peak viscosity, ranged between 4.87 and 5.47 minutes, with significant differences ($p < 0.05$) observed between Y10 and other samples. A shorter peak time corresponds to easier and faster cooking [5]. The samples in this study exhibited lower peak times compared to the

17.40-17.55 minutes recorded for yam flour varieties by Aviara et al. (2021). Flours with shorter pasting times are advantageous for food products requiring rapid processing.

3.3.7. Pasting Temperature

The pasting temperature, which represents the temperature at which starch granules begin to swell beyond their gelatinization point and experience an increase in viscosity upon shearing [3], ranged from 79.00 °C to 81.55 °C. Sample Y10 showed no significant difference ($p > 0.05$) from Y8 and Y7 but differed significantly from Y6 and Y5. The pasting temperatures obtained in this study are consistent with the values reported by Wireko-Manu et al. [63] for *Dioscorea alata* (81.89 °C) and *Dioscorea rotundata* (79.88 °C) flours. Pasting temperature provides insight into the minimum cooking temperature required for flour and influences its suitability for various food applications.

Table 5. Carotenoid profile of white yam and orange flesh sweet potatoes flour blends.

Samples	Beta carotenoid (µg/100g)	Total carotenoid (µg/100g)	Lycopene (mg/100g)
Y ₁₀	6.06 ^e ± 0.03	19.10 ^e ± 0.00	0.14 ^e ± 0.00
Y ₈	73.68 ^c ± 0.03	115.74 ^d ± 0.14	7.56 ^d ± 0.03
Y ₇	103.95 ^b ± 0.02	243.06 ^c ± 0.03	11.54 ^c ± 0.06
Y ₆	121.05 ^a ± 0.07	379.63 ^b ± 0.04	16.70 ^b ± 0.14
Y ₅	67.79 ^d ± 0.00	424.77 ^a ± 0.03	20.75 ^a ± 0.06

Values are mean ± S.D (n = 3). Values with the same superscript along same column are not significantly ($p > 0.05$) different. Y10 = 100% White yam flour; Y8 = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y7 = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y6 = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y5 = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

3.4. Carotenoid Profile of Composite Flour from White Yam and Orange Flesh Sweet Potatoes

3.4.1. Beta Carotene

The beta carotene and total carotenoid contents of the flour blends ranged from 6.06 to 121.05 µg/100g and 19.10 to 424.77 µg/100g, respectively. A significant ($P < 0.05$) difference was observed among all samples. The composite flour samples contained higher beta carotenoid levels than the 100% white yam flour. Orange-fleshed sweet potato (OFSP) has been recognized as an excellent and novel source of β-carotene, a naturally occurring compound with health-enhancing properties [10]. The carotenoid levels reported in this study were lower than those found in yellow maize grain flour [19]. The relatively lower carotenoid

content compared to orange maize flour may be attributed to the inclusion of white yam flour, which has inherently low carotenoid concentrations. Carotenoids play essential roles in human health, particularly in disease prevention [16]. The primary function of dietary carotenoids is their provitamin A activity.

3.4.2. Lycopene

The lycopene content of the flour blends varied from 0.14 to 20.75 mg/100g, with the Y5 blend exhibiting the highest concentration. It was noted that as the proportion of orange-fleshed sweet potato flour increased, the lycopene content of the flour blends also rose. This suggests that orange-fleshed sweet potato contains significantly more lycopene than white yam flour. Studies have shown that orange-fleshed sweet potato serves as a valuable source of lycopene, a key carotenoid known for its numerous health benefits [22]. Carotenoids, including lycopene, are widely

recognized for their antioxidant properties, which contribute positively to overall health.

Table 6. Phytochemical composition of fufu flour made from white yam and orange fleshed sweet potato flour blends.

Samples	Tannin (mg/100g)	Total phenol	Flavonoid (%)	Saponin (mg/100g)	Cardiac glycoside (mg/100g)	Alkaloid (mg/100g)
Y ₁₀	1.48 ^d ±0.02	11.58 ^e ±0.03	5.78 ^e ±0.03	0.37 ^d ±0.06	0.58 ^e ±0.003	0.03 ^d ±0.00
Y ₈	2.37 ^c ±0.03	29.92 ^d ±0.03	9.68 ^d ±0.11	0.62 ^c ±0.06	1.01 ^d ±0.00	0.08 ^c ±0.02
Y ₇	2.41 ^c ±0.06	35.58- ^c ±0.03	10.22 ^c ±0.06	0.67 ^c ±0.00	1.56 ^c ±0.06	0.13 ^b ±0.00
Y ₆	2.61 ^b ±0.01	38.84 ^b ±0.06	11.22 ^b ±0.03	0.82 ^b ±0.05	2.00 ^b ±0.14	0.18 ^{ab} ±0.03
Y ₅	2.77 ^a ±0.03	42.00 ^a ±1.41	15.89 ^a ±0.03	0.95 ^a ±0.03	2.69 ^a ±0.03	0.23 ^a ±0.02

Values are mean ± S.D (n = 3). Values with the same superscript along same column are not significantly (p>0.05) different. Y₁₀ = 100% White yam flour; Y₈ = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y₇ = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y₆ = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y₅ = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

3.5. Phytochemical Properties of Composite Flour from White Yam and Orange Flesh Sweet Potatoes

3.5.1. Tannin

The tannin content in the samples varied between 1.48 and 2.77 mg/100g, with sample Y₅ exhibiting the highest concentration and sample Y₁₀ the lowest. A significant difference (p<0.05) was observed among the samples. Tannins are polyphenolic plant compounds known for their astringent and bitter characteristics, capable of binding and precipitating proteins. The term "tannin" applies to large polyphenolic molecules with sufficient hydroxyl and other functional groups that enable them to form strong complexes with proteins and other macromolecules [19]. The tannin values found in this study were lower than the 30 mg/kg reported by Oyetayo [52] in his analysis of nutrient and antinutrient composition in cassava steeped in various water types for pupuru (fufu) flour production. Additionally, these values were below the recommended safe limit of less than 100 mg/kg [31].

3.5.2. Total Phenol

The total phenol content ranged from 11.58 to 42.00 mg/100g, with sample Y₁₀ recording the lowest value and sample Y₅ the highest. These findings indicate a relatively higher total phenol concentration compared to the values reported for *Ipomoea batatas* [6]. Phenolic compounds are known to inhibit digestive and hydrolytic enzymes such as amylase, trypsin, chymotrypsin, and lipase. They also possess various health-related functional properties, including

anticarcinogenic, antiviral, antimicrobial, anti-inflammatory, antihypertensive, and antioxidant effects [7]. Since phenolics are water-soluble compounds, their levels can be reduced through soaking and cooking [5].

3.5.3. Flavonoid

The flavonoid content of the samples ranged from 5.78% to 15.89%, with sample Y₅ exhibiting the highest concentration (15.89%) and sample Y₁₀ the lowest (5.78%). It was observed that incorporating a higher proportion of orange-fleshed sweet potatoes into the flour blends increased their flavonoid content. Flavonoids act as antioxidants and free radical scavengers, which help prevent oxidative cell damage, possess potent anticancer properties, and protect cells at all stages of carcinogenesis [10]. Additionally, flavonoids in the intestinal tract contribute to reducing the risk of heart disease [60].

3.5.4. Saponin

The saponin content ranged from 0.37 to 0.95 mg/100g, with significant (p<0.05) differences among all samples. The results indicate that increasing the proportion of orange-fleshed sweet potato flour led to an increase in saponin content. Previous studies [33-35] documented saponin concentrations of 643.03 mg/100g and 2.18 mg/100g in their research on the nutritional and antinutritional composition of yellow yam flour. The values obtained in this study were lower than those previously reported, which may be attributed to variations in analytical techniques and processing methods.

3.5.5. Cardiac Glycoside

The cardiac glycoside content of the flour blends ranged

from 0.58 to 2.69 mg/100g, with sample Y10 showing the lowest value and sample Y5 the highest. A significant ($p < 0.05$) difference was observed among all samples. It was noted that adding orange-fleshed sweet potato flour to white yam flour resulted in an increase in cardiac glycoside content, suggesting that orange-fleshed sweet potatoes contain a higher level of cardiac glycosides than white yam. The findings of this study reported lower cardiac glycoside levels than the 3.14 to 4.09 mg/100g range observed by Omosuli et al. [48] in stored cassava and fufu. Cardiac glycosides function by inhibiting sodium efflux across cell membranes, leading to increased intracellular sodium levels, which subsequently facilitate calcium accumulation within cells [53].

3.5.6. Alkaloids

Alkaloids are among the most therapeutically potent plant-derived compounds, with pure forms and synthetic derivatives serving as essential medicinal agents due to their analgesic, antispasmodic, and antibacterial properties. The alkaloid content observed in this study ranged from 0.03% to 0.23%, with significant ($p < 0.05$) differences among all samples. These values were lower than those reported by Ajai et al. [11] in their study on the phytochemical composition and nutrient evaluation of black rhun palm, where alkaloid levels ranged from 22.02% to 24.16%. Similarly, Rignero et al. [54] documented alkaloid concentrations between 0.76% and 1.00% in their study on the mineral and nutritional profile of cassava flour, which was also higher than the values obtained in the present study.

Table 7. Vitamin composition of white yam and orange sweet potatoes flour blends.

Samples	Vitamin A ($\mu\text{g}/100\text{g}$)	Vitamin B1 ($\text{mg}/100\text{g}$)	Vitamin C ($\text{mg}/100\text{g}$)
Y ₁₀	3.34 ^e $\pm$ 0.03	0.16 ^e $\pm$ 0.03	2.95 ^e $\pm$ 0.03
Y ₈	58.04 ^d $\pm$ 0.03	0.32 ^d $\pm$ 0.06	7.60 ^d $\pm$ 0.00
Y ₇	75.57 ^c $\pm$ 0.03	0.59 ^c $\pm$ 0.01	9.09 ^c $\pm$ 0.03
Y ₆	84.50 ^b $\pm$ 0.14	0.85 ^b $\pm$ 0.06	10.22 ^b $\pm$ 0.01
Y ₅	97.91 ^a $\pm$ 0.02	1.03 ^a $\pm$ 0.04	13.13 ^a $\pm$ 0.00

Values are mean $\pm$ S.D (n = 3). Values with the same superscript along same column are not significantly ($p > 0.05$) different. Y10 = 100% White yam flour; Y8 = 80% White yam flour + 20% Orange flesh sweet potatoes flour; Y7 = 70% White yam flour + 30% Orange flesh sweet potatoes flour; Y6 = 60% White yam flour + 40% Orange flesh sweet potatoes flour; Y5 = 50% White yam flour + 50% Orange flesh sweet potatoes flour.

3.6. Vitamin Composition of Composite Flour from White Yam and Orange Flesh Sweet Potatoes

3.6.1. Vitamin A

The vitamin A content of the flour blends ranged from 3.34 to 97.91 mg/100g. There was a significant ($P < 0.05$) difference among all samples. The result showed that vitamin A content increased with increasing proportion of orange flesh sweet potatoes flour. This means orange sweet potatoes have more vitamin A than white yam flour. The inclusion of orange flesh sweet potatoes flour improved the vitamin content of the fufu flour. Vitamin A is a fat soluble vitamin, an important micronutrient needed in the body. It is for night vision, maintenance of skin and mucosal integrity. Vitamin A also stimulates the production of white blood cells and regulate cell growth and division during reproduction. Deficiency results to night blindness or

permanent blindness in severe cases. Vitamin A exists in many forms such as retinol (alcohol), retinal (aldehyde), retinyl acetate (esters) and provitamin A carotenoid. The recommended dietary allowance is 900 mcg daily for males and 700 mcg daily for females [38].

3.6.2. Vitamin B1 (Thiamine)

The values obtained for the thiamin content of the flour blends ranged from 0.16 to 1.03 mg/100g. There was a significant ($p < 0.05$) difference among all samples. The result showed similar trend with that of vitamin A and increased with increasing proportion of orange flesh sweet potatoes flour. The results are lower than those of Futega et al. [32] who recorded a vitamin B1 content of 0.54-0.60 mg/100g for amala produced from sweet potato flour. The inclusion of orange fleshed sweet potato flour increased the vitamin B1 content of the fufu flours. Thiamine or vitamin B1 is a water soluble vitamin which plays a vital role in the growth and proper functioning of most cells in the body. It also helps in

the breakdown of nutrients for energy. The Recommended Dietary Allowance (RDA) for men (19 and older) is 1.2 mg daily while that of women of same age range is 1.1 mg daily. A deficiency of vitamin B1 can lead to Beriberi [33, 58].

3.6.3. Vitamin C

The vitamin C content of the flour blends sample ranged from 2.95 to 13.13 mg/100g. Sample Y10 had the lowest value (2.95 mg/100g), while sample Y5 had the highest value (13.13 mg/100g). There was a significant ($P < 0.05$) difference among all samples. It was observed from the result that vitamin C content of flour blends increase with increasing proportion of orange flesh sweet potatoes flour. This means orange flesh sweet potatoes have more vitamin C than white yam. The vitamin C level (2.95 - 13.13 mg/100 g) in this work was higher than that of plantain flour (1.30 mg/100 g) [7] and traditional yam flour (elubo) by Jonathan *et al.* [35], but lower than that of flour of different varieties of water yam (16.7-35.2 mg/100 g) by Udensi *et al.* [59]. Ascorbic acid activates the functions of the body cells, and it is a powerful antioxidant. Vitamin C enhances the absorption of iron in the intestine, fight against infections, neutralizes blood toxins, and intervenes in the healing of wounds [61].

4. Conclusion

Research on the proximate composition of white yam and orange-fleshed sweet potato flour blends has shown that sweet potato flour has the lowest moisture content among the analyzed samples. This characteristic enhances its microbial stability during processing, making it a preferable starch source. Although roots and tubers alone do not meet the recommended dietary allowance (RDA) for protein, their protein contribution can be optimized when combined with other protein-rich foods such as cereals. The carbohydrate content was found to be highest in pure white yam flour.

This study further demonstrated that the functional and pasting properties of yam flour are significantly influenced by blending ratios, even when subjected to identical processing conditions. All the examined flour blends exhibited potential for the production of value-added products. The substantial variation observed in both functional and pasting characteristics provides a useful reference for selecting and improving yam cultivars for specific food applications. This information could aid in enhancing their industrial processing and utilization.

The phytochemical analysis and carotenoid content assessment indicated that the flour blends contained notable amounts of beta carotenoids, flavonoids, and cardiac glycosides, contributing to their strong antioxidant properties. However, the presence of saponins, alkaloids, and tannins will need to be managed during processing, particularly when preparing the flour blends for dumpling production. Flour blends containing up to 40% orange-fleshed sweet potato and 60% white yam exhibited high nutritional value, making them

a promising ingredient for functional food applications.

Abbreviations

RDA Recommended Daily Allowance

Conflicts of Interest

The authors declare no conflicts of interest.

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