EFFECT OF PROCESSING METHODS ON THE PHYSICOCHEMICAL AND ANTIOXIDANT PROPERTIES OF BITTER YAM *(Dioscorea dumetorum)* FLOUR

Aniebosi, A.C[1]; Ikegwu, T. M.[1,3]; Aniekwu, C. C.[2]; Orafa, P. N.[3] & Agbo, A. O.[4]

[1]Department of Food Science and Technology, Faculty of Agriculture, Nnamdi Azikiwe University, Awka

[2]Departmment of Applied Microbiology and Brewing, Nnamdi Azikiwe University, Awka.

[3]Department of Food Science and Technology, Faculty of Agriculture, Federal University, Wukari

[4]Deparament of Science Laboratory Technology, School of Science and Technology, Federal Polytechnic, Ohodo, Enugu State

*Corresponding Author: Ikegwu, T. M.

Article History	Abstract
  	The research study evaluated the effect of soaking and blanching on the physicochemical and antioxidant properties of seven (7) bitter yam (Dioscorea dumetorum) flour samples using laboratory standard methods. Fresh yams obtained from a farm in Agulu, Anambra State, Nigeria, were peeled, washed, and then sliced to 2, 4- and 6-mm thicknesses with a sterile kitchen knife. Three portions were soaked at 27 °C for 6 (BYM₁), 12 (BYM₂) and 18 h (BYM₃). Another three (3) portions were blanched at 90 °C for 5 (BYM4), 10 (BYM₅) and 15 min (BYM₆). A sample was neither soaked nor blanched (CYM). The soaked and blanched portions were drained, dried (Laboratory oven at 105 °C), and the dried chips were milled, sieved and packaged in low-density polyethylene bags to obtain bitter yam flour samples. The samples were analyzed for physicochemical and antioxidant properties using simple lattice mixture design. All data obtained were subjected to statistical analyses. The results obtained showed significant (p<0.05) variations in both the physicochemical and antioxidant properties. The results of the physicochemical properties showed that pH, total titratable acidity, amylose, amylopectin and total soluble solids ranged from 4.73-9.97, 9.25-12.30 mg/100g, 30.35-40.98%, 59.02-69.65% and 8.77-10.24 mg/100g, respectively. Furthermore, the results of the antioxidant properties revealed that the total phenolic content ranged from 10.23 to 19.84 mg/100g, while the total flavonoid content, nitric oxide scavenging activity, reducing power and ferric reducing antioxidant power ranged from 7.50 to 9.83 mg/100g, 58.57 to 70.86 mg/100g, 42.68 to 68.06 mg/100g and 68.46-70.96 mg/100g, respectively. The best prospects for physicochemical and antioxidant properties were observed in samples BYM₃ and BYM₅. ***Keywords:*** *Soaking, blanching, antioxidant activity, phytochemical properties, bitter yam.*

1.0 Introduction

More than six hundred species of yam tuber exist, but few are important as staple food in the tropics. According to Otoo *et al.* (2018) and Ike and Inoni (2006), these include white yam *(Dioscorea rotundata)*, yellow yam *(Dioscorea cayenensis)*, water yam *(Dioscorea alata)*, bitter yam *(Dioscorea dumetorum)*, aerial yam *(Dioscorea bulbifera)* and Chinese yam *(Dioscorea esculenta)*. Yam consists of high energy, protein and iron content, but low calcium and zinc. There are several reports by different researchers that yam provides that are three times more superior than that of either cassava or sweet potato (Ezeocha and Ojimelukwe, 2012; Makanjuola and Coker, 2019). Apart from food, yams are also sources of nutraceutical compounds like saponins and sapogenins, which are precursors of cortisone used medically in the treatment of arthritis and some allergies.

Yam (*Dioscorea spp.*) is a tuber crop that comes from Africa and Asia and has spread to other parts of the world (FAO, 2023). It is a key food crop, especially in West Africa and other sub-Saharan African countries (IITA,

2023). It belongs to the Dioscoreaceae family and the Dioscorea genus. The tuber is the most important part of the plant for both food and money. It can be stored for longer than many other root and tuber crops, which makes it a big help for families when food is scarce. Yam is the third most significant tropical root and tuber crop in the world, behind cassava and sweet potato. It is very important for the diets and livelihoods of people in West Africa, the Caribbean, parts of Asia, and Oceania (Iweala *et al.*, 2020). Yam is important for more than only its nutritional benefits; it is also important for social, economic, and cultural reasons. In Igbo society, yam is seen as a high-status crop and is often the main feature of traditional rites and festivals (Chinma *et al.*, 2020). Also, yam harvesting, processing, and marketing are key ways for households with few resources to make money, especially for women. They also have deep-rooted ritual and cultural importance in West and Central Africa.

Yam tubers have been utilised as traditional meals at home and not much in factories. However, the traditional applications are many, and the crop has more uses. People eat yams in a variety of ways, but mostly they boil, fry, or bake them. People often dry the tubers and grind them into flour to make different things. You might also pound boiled yam and eat it with sauce. Yam can be fried or roasted as a snack, and new developments in composite flour formulations make yam a good choice for making new food products. The traditional yam porridge is a local dish that many people like. It can be made with ingredients like onions, pepper, a protein source, oil, and more. In West Africa, notably Nigeria and Benin, people often eat boiled yam, pounded yam, and amala (Akissoe *et al.*, 2006). Some types of yams are also grown and eaten as health food and for therapeutic purposes (Adegunloye *et al.*, 2011). Because yam has a lot of moisture in it, it doesn't last very long. So, it needs to be turned into something that won't spoil as quickly, such as instant pounded yam flour (IPYF). IPYF is yam that has been peeled, washed, sliced, blanched or boiled, dried, ground into flour, and then transformed into a stiff dough meal by boiling water. It is tested for texture, which includes how smooth, elastic, consistent, sticky, and firm it is. Barau *et al.* (2013) say that turning yam into IPYF after it is picked will make it easier to use and keep. Even though yam has many uses and is important to the economy, the species Discorea dumetorum is still not used enough.

The bitter yam (*Dioscorea dumetorum*), although underutilized root tuber, is widely cultivated in West and Central African countries with a premium on its high carbohydrate content and potential functional food applications (Ikeuchi *et al.*, 2017). Processing technologies such as drying, fermenting, blanching, and roasting have been used to process the yam tuber in order to enhance the

functional attributes, nutritional content, and sensory appeal of the resulting flours (Akissoe *et al.,* 2003; Onwuka, 2018).

Although bitter yams are nutritious, bitter glycosides and antinutritional factors limit their direct consumption and industrial use (Ezeonu and Ejiofor, 2011). Yam tubers have been processed using techniques like drying, fermentation, blanching, and roasting to enhance the functional qualities, nutritional value, and sensory aspects of derived flours (Onwuka, 2018).

Functional qualities like water absorption and swelling capacities, as well as physicochemical characteristics like moisture content, particle size distribution, and pasting characteristics, profoundly impact how well flours perform in food formulation and processing (Adebowale *et al.,* 2005). These characteristics, which impact the texture, storage stability, and consumer acceptability of food products made with yam flour, are particularly susceptible to modifications brought about by processing methods (Abiodun *et al.,* 2014).

In addition to the basic nutrients, bitter yam contains bioactive substances like flavonoids, phenolics, and antioxidants that have health-promoting properties like scavenging free radicals and reducing oxidative stress (Oboh *et al.,* 2004)). Nevertheless, the kind and degree of processing used can either increase or decrease antioxidant capacity (Chinma *et al.,* 2015). As an example, thermal treatments have the potential to release bound phenolic compounds and cause heat-sensitive antioxidants to oxidatively degrade (Rafiq *et al.,* 2011).

Optimizing *D. dumetorum* flour's industrial applications, enhancing nutritional quality, and encouraging value addition to this underutilized crop all depend on an understanding of how various processing techniques affect the physicochemical and antioxidant qualities of the flour. Thus, this study looks into how common processing methods affect the antioxidant, compositional, and functional properties of bitter yam flour.

2.0 Materials and Method

2.1 Source of Raw Materials

The bitter yam was purchased from a nearby farm in Agulu, Anambra State's Anaocha Local Government. A hammer attrition mill was used to turn it into yam flour samples for the study. The following tools are used: spectrophotometer, crucible, volumetric flask, conical flask, beaker, retort stand, dropper, mesh, petri dish, draft air oven, and laboratory oven. Analytical-grade tools and chemicals such as TPTZ (2,4,6-Tripyridyl-s-Triazine), aluminum chloride, potassium acetate, phosphate

buffer, potassium ferricyanide, trichloroacetic acid, supernatant, deionized water, Griess reagent, HCl, acetate buffer, rutin solution, distilled water, sodium hydroxide solution, methanol, ethanol, acetic acid, iodine solution, Folin–Ciocalteu phenol reagent, Na_2CO_3, $FeCl_3$, and aluminum chloride were obtained from the Food Science and Technology Department, Nnamdi Azikiwe University Awka.
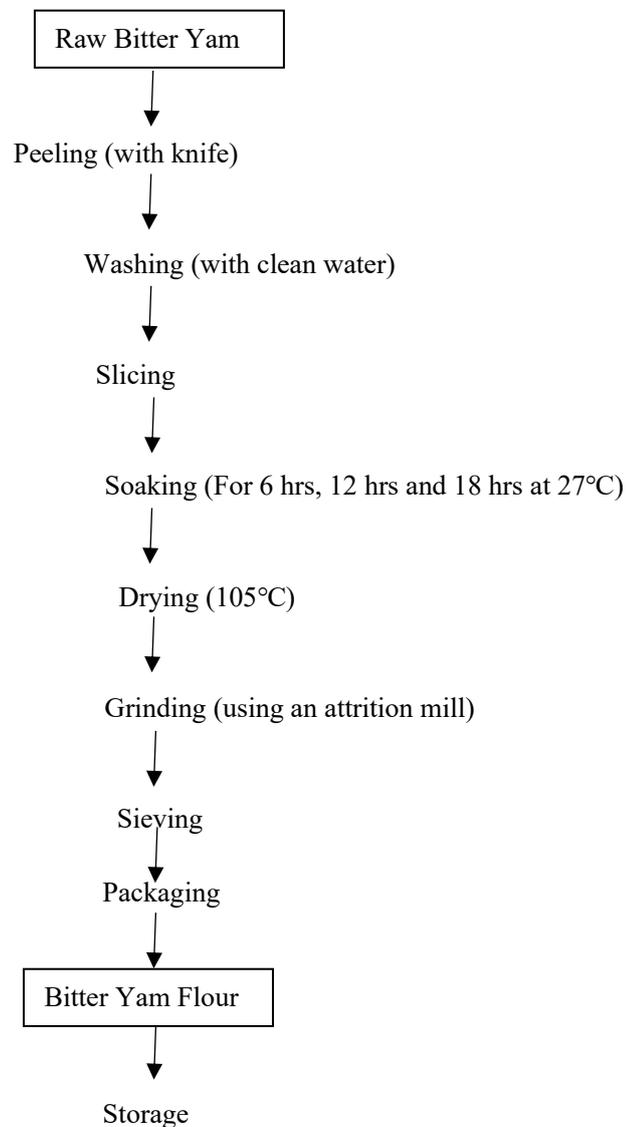
2.2 Sample Preparations

2.2.1 Production of bitter yam flour (Soaking Process)

Four portions of the peeled yam tubers were cut into tiny cubes according to the method described by Akinoso *et al.* (2016). At room temperature (27°C), the portions were soaked for 6, 12, and 18 h, while one portion was used as a control. Following that, the samples were dried at 105 °C in an air convection oven. For the evaluation of their physicochemical and antioxidant qualities, the resultant dried chips were placed in white polyethylene sample bags at 20 °C after being ground into fine flour using an attrition mill (LFT-300, China).
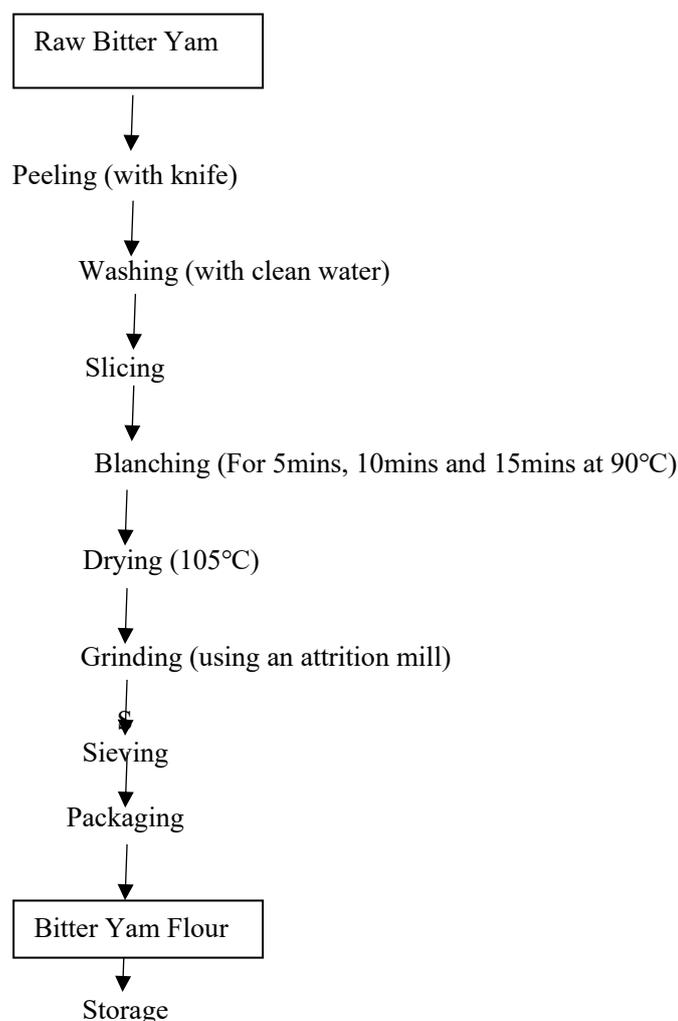
2.2.2 Production of bitter yam flour (Blanching Process)

The method of Akinoso *et al.* (2016) was used for the blanching of the biter yam cubes. Four portions of the peeled yam tubers were cut into tiny cubes. The portions were blanched for 5, 10, and 15 min at 90 °C. One portion was used as a control. Following that, the samples were dried at 105 °C in an air convection oven. In order to evaluate their physicochemical and antioxidant qualities, the resulting dried chips were ground into fine flour using an attrition mill (LFT-300, China) and kept at 20 °C in white polyethylene sample bags.

Raw Bitter Yam

↓

Peeling (with knife)

↓

Washing (with clean water)

↓

Slicing

↓

Soaking (For 6 hrs, 12 hrs and 18 hrs at 27°C)

↓

Drying (105°C)

↓

Grinding (using an attrition mill)

↓

Sieving

↓

Packaging

↓

Bitter Yam Flour

↓

Storage

***Figure 1: The Production of Bitter Yam Flour** (Soaking Process).*
***Source**: Akinoso et al. (2016)*

```
                        ┌─────────────────────┐
                        │   Raw Bitter Yam    │
                        └─────────────────────┘
                                  │
                                  ▼
                         Peeling (with knife)
                                  │
                                  ▼
                      Washing (with clean water)
                                  │
                                  ▼
                              Slicing
                                  │
                                  ▼
           Blanching (For 5mins, 10mins and 15mins at 90℃)
                                  │
                                  ▼
                           Drying (105℃)
                                  │
                                  ▼
                    Grinding (using an attrition mill)
                                  │
                                  ▼
                              Sieving
                                  │
                                  ▼
                             Packaging
                                  │
                                  ▼
                        ┌─────────────────────┐
                        │  Bitter Yam Flour   │
                        └─────────────────────┘
                                  │
                                  ▼
                              Storage
```

Figure 2: The Production of Bitter Yam Flour

Source: *Akinoso et al. (2016)*

2.3   Experimental Design

The following pretreatment combination studies the soaking time (h), blanching (mins), and drying (°C).

Table 1:   Experimental design with specific soaking time, blanching time and drying temperature for processing bitter yam flour samples.

Sample Codes	Factor 1 Soaking Time(hrs)	Factor 2 Blanching (mins)	Factor 3 Drying (°C)
BYM_1	6	0	105
BYM_2	12	0	105
BYM_3	18	0	105
BYM_4	0	5	105
BYM_5	0	10	105
BYM_6	0	10	105
BYM_7	0	0	105

2.4   Determination of Proximate Composition

2.4.1   Determination of moisture content

The gravimetric approach outlined by the AOAC (2010) was used to accomplish this. A previously weighed moisture can (W_1) was filled with 5 g of the sample. The sample (W_2) in the can was dried for three hours at 105 °C in the oven. The dried sample was weighed after cooling in a desiccator. For additional drying, it was subsequently put back in the oven. Until a constant weight

(W_3) was achieved, drying, cooling, and weighing were repeated every hour. A percentage of the sample weight was used to calculate and express the weight of moisture lost. The following expression was used to calculate the moisture content;

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1}$$

Where:

W_1 = Weight of empty moisture can

W_2 = Weight of empty can + Sample before drying

W_3 = Weight of can + Sample dried to constant weight

2.4.2   Determination of crude fat

Kirk and Sawyer (2016) explain the gravimetric solvent extraction method that was used to find this out. A thimble with five grams of sample (W_1) was put within a porous paper (Whatman filter paper). In an empty, weighted extraction flask (W_2), 200 mL of petroleum ether was put. The thimble was then put inside a Soxhlet reflux flask. The top of the reflux flask had a water condenser on it. The petroleum ether solvent was heated, boiled, turned into gas and then turned back into a liquid in the reflux flask. The solvent immediately covered the sample in the thimble, which made the reflux flask fill up and spill over, bringing the oil extract down to the boiling flask. After doing this process four times, the defatted sample was taken out, the solvent was recovered, and the oil extract was left in the flask. To get rid of any leftover solvent, the flask with the oil extract was put in an oven set to 60 °C for 30 minutes. After it cooled down in a desiccator, it was weighed. Using the difference approach, we found the weight of the oil (fat) extract (W_3) as a percentage of the weight of the sample being tested.

$$\text{Fat content (\%)} = \frac{W_3 - W_2}{W_1}$$

Where:

W_1 = weight (g) of empty extraction flask

W_2 Weight of flask oil (fat) extract

W_3 = Weight of oil extract + Weight of empty extraction flask

2.4.3   Determination of protein content

Chang (2013) talked about the Kjeldahl method for finding out how much protein is in anything. To find the protein content, we multiplied the total nitrogen by 6.25. The material, which weighed 5 grams, was mixed with 10 mL of concentrated H_2SO_4 in a digestion flask. It was heated in a fume cupboard until a clear solution (the digest) formed after adding a selenium catalyst tablet. The digest was put into a volumetric flask and diluted to 100 mL before being utilised for the analysis. A Kjeldahl distillation equipment was used to mix 10 mL of the digest with the same amount of a 45 percent NaOH solution. After distilling the liquid, three drops of a mixed indicator (methyl red/ bromocresol green) were added to 10 mL of 40% boric acid. The distillates, which were 50 mL in volume, were titrated from a green to a deep crimson end point with 0.02 N EDTA. Also, a reagent blank was titrated, distilled, and digested.

2.4.4   Determination of the Ash Content

The AACC Method 08–01 (Hemery et al., 2011) was used to find the ash content. Weighing around 3 to 5 grams of each flour sample into pre-cleaned ash crucibles and burning them in a muffle furnace at 550 °C. The samples were burnt until they turned into a light grey ash or until they reached a consistent weight, which usually took about 7 hours. After being burnt, the samples were cooled in a desiccator and weighed again to find out how much ash they contained. This information was then calculated and published (see Table S2 in the Supplementary Materials). We did both moisture and ash tests three times, and then we used the results to figure out the mean and standard deviation for statistical reliability.

2.4.5   Determination of carbohydrate content

The carbohydrate content was determined by difference by deducting the mean values of other parameters that were determined from 100 (AOAC, 2010). Therefore:

%Carbohydrate = 100 - (%MC + %CP + %fat + %crude fibre +%ash)

Where; MC = moisture content

CP = crude protein.

2.5   Determination of Physicochemical Properties

2.5.1   pH determination

The pH was measured using the procedure outlined by Akpakpunam and Safa-Dedeh (1995), in which 100 ml of distilled water was used to dissolve 10 g of the sample. For 3 min, the mixture was left to equilibrate at room temperature. Following the insertion of the pH meter's electrode into the sample, the pH meter's displayed results were used to calculate the pH.

2.5.2   Total titratable acidity (TTA)

This was ascertained using the methodology outlined by AOAC (2005). Distilled water was used to dissolve the sample and mix it well. A 10 ml of the combined solution was mixed with 1 ml of phenolphthalein indicator. The standard sodium hydroxide solution was used to titrate it until the pink color remained for ten to fifteen seconds in order to completely neutralize it.

2.5.3   Amylose and amylopectin content

The techniques of Juliano (1971) and Hoover and Ratnayake (2002) were employed to ascertain the amylose content. The samples were put into a 100 ml volumetric flask, which held roughly 0–1 g (100 mg). Carefully add one millilitre of 99–7–100 percent (v/v) ethanol and nine millilitres of 1N-sodium hydroxide (NaOH). Cover the mouth of the flask with foil or parafilm. The materials were blended up well. The samples were put in a boiling water bath for 10 minutes to gelatinise the starch. The timer started when the water started to boil. After being taken out of the water bath, the samples were left to cool for a long time. Then, it was shaken well and filled to the top with distilled water. After that, about 5 ml of the liquid was put into a second 100 ml volumetric flask using a pipette. After adding 2 ml of iodine solution and 1 N,1.0 ml of acetic acid, distilled water was added to the top to mark. A spectrophotometer was then used to measure absorbance (A) at a wavelength of 620 nm. In the blank, 1 ml of ethanol and 9 ml of sodium hydroxide were mixed together, boiled, and then distilled water was added to the top. Then, 5 ml was added to a 100 ml volumetric flask using a pipette. We set the spectrophotometer to 620 nm by adding around 1 ml of 1N acetic acid and 2 ml of iodine solution and then filling the rest of the space to the right level. This is how we figured out how much amylose there was.

Amylose content (%) (3.06) A (20) = 61.20(A)

Where A = Absorbance value

Amylopectin (%) = 100 – amylose

2.5.4 Determination of Total Soluble Solids

A 5 ml of the samples were blended to ensure homogeneity in 100 ml of water. The suspension was used to determine the total soluble solids (TSS) using a digital bench top Hanna Digital Refractometer (HI 96801, China) according to the method described by Alam *et al.* (2024).

2.6 Determination of Antioxidant Properties

2.6.1 Total phenolic content assay

The method of Singleton *et al.* (1999) was used to measure the total phenolic content. After gradually adding 0.5 mL of the sample to 4.5 mL of distilled water, the mixture was combined with 0.2 mL of the Folin–Ciocalteu phenol reagent and 0.5 mL of the saturated solution of Na_2CO_3. Finally, 4.3 mL of distilled water was added to the mixture. After the reaction mixtures were allowed to sit at room temperature for 60 min in the dark, the absorbances at 725 nm were measured. In milligrams of gallic acid equivalents (GAE) per gram of dry sample (mg GAE/g), the total phenolic content was expressed.

2.6.2 Determination of flavonoids

We employed the method that Kumaran and Karunakaran (2006) described, with only a few changes, to find out how much flavonoid was in the sample. We mixed 5 ml of methanol with 100 ml of plant extracts in methanol (10 mg/ml), 100 ml of 20 percent aluminium trichloride in methanol, and a drop of acetic acid. After 40 minutes, the absorbance was checked at 415 nm. To make blank samples, a drop of acetic acid and 100 L of plant extracts were mixed together. Then, 5 ml of methanol was used to dilute the samples. We utilised the identical conditions to measure how much a standard rutin solution (0.5 mg/ml) in methanol absorbed. The quantity of flavonoids in the plant extract was quantified in rutin equivalents (RE) using the subsequent procedure.

Flavonoid content $= \frac{A \times Mo}{Ao \times m}$

Where;

A = Absorbance of sample extract solution,

Ao = Absorbance of standard rutin solution,

m = Weight of the sample(mg) and

mo = Weight of rutin in the solution (mg).

2.6.3 Reducing Power Assay

The approach was modeled after Hue *et al.* (2012) processes with adjustments. 0.2 mL of 0.2 M phosphate buffer (pH 6.6) and 0.2 mL of 1% potassium ferricyanide were added to the extracts (0.05 mL) of the various concentrations. The mixture was incubated at 50°C for 20 min in a water bath. The mixture was mixed with trichloroacetic acid (0.25 mL), and it was centrifuged for 10 minutes at room temperature at 1000 rpm. Deionized water (0.5 mL) and 0.1 percent $FeCl_3$ (0.1 mL) were added to the supernatant (0.5 mL). The absorbance at 700 nm was measured. The reducing power assay was measured in milligrams of GAE/L.

2.6.4 Ferric reducing antioxidant power

Using the method outlined by Sudha *et al.* (2012), the ferric reducing antioxidant power assay was measured with a few changes. Exactly 25 mL of 300 mM acetate buffer (pH 3.6), 2.5 mL of a 10 mM TPTZ (2,4,6-Tripyridyl-s-Triazine) solution in 40 mM HCl, and 2.5 mL of 10 mM $FeCl_3 \cdot 6H_2O$ were all included in the FRAP reagent. It was made from scratch and heated to 37°C. Exactly 90 μL of water, 30 μL of the extract, and 900 μL of FRAP reagent were combined. After 10 min of incubation at 37 °C, the absorbance at 593 nm was measured for the reaction mixture. A μM de $FeSO_4$/g of dry sample was used to express FRAP.

2.6.5 Nitric Oxide Scavenging Activity

We mixed sodium nitroprusside (5 mM) in phosphate-buffered saline with varied amounts of the 2 g of flour samples that had been dissolved in 100 ml of water. We then let them sit at 25 °C for 150 minutes. The 0.5 ml samples of the above mixture were reacted with Greiss reagent, which is made up of 1% sulfanilamide, 2% H_3PO_4, and 0.1% naphthylethylenediamine dihydrochloride. We measured the absorbance of the chromophore that developed when nitrite was diazotised with sulfanilamide and then coupled with naphthylethylenediamine. We compared this to the absorbance of standard solutions of potassium nitrite that had been handled the same manner using Greiss reagent. We used the following equation to figure out the proportion of nitric oxide inhibition:

Percentage (%) of nitric oxide radical scavenging assay = $[(A_0-A_1)/A_0] \times 100$.

Where;

A_0 = Absorbance of control, and

A_1 = Absorbance of the treated sample

2.7 Statistical Analysis

All the analyses were conducted in duplicates for accuracy and precision of results findings. The results were computed using Microsoft Excel software (Microsoft Corporation, Redmond, WA, USA) and followed by analysis of variance (ANOVA) Duncan's multiple range test to compare the means that showed a significant variation by using SPSS version 11.09 for Windows (IBM SPSS, Inc., Armonk, NY, USA). The significance level was set at $P<0.05$.

3.0 Results and Discussion

3.1 Proximate Composition of Bitter Yam (*Dioscorea dumetorum*) Flour Samples

The proximate composition of the bitter yam flour samples varied significantly (p<0.05) (Table 2). The findings showed that the nutritional value of the flours were affected by soaking and blanching. These differences have significant effects on food product development's functionality, suitability, and shelf stability.

The samples' moisture contents varied from 0.96% (BYM3, 18 hours) to 2.10% (BYM7). All of the samples showed extremely low moisture levels (less than 3 percent), which were ideal for flour stability. Food products' low moisture content may improve shelf-life stability by lowering microbial growth, enzymatic activity, and biochemical deterioration (Idowu and Adewumi, 2021; Nainggolan *et al*., 2024; Awol *e al,* 2024). Because BYM3 had the least moisture content, longer soaking times (18 h) might have promoted structural softening and increased drying effectiveness. Water absorption during heat treatment could have caused moisture to interact with food constituents like lipids and proteins, whose bonding affected the drying kinetics, as evidenced by the slightly higher moisture content of the blanched samples (BYM4-BYM6) compared to the soaked samples. Flours with a low moisture content are better for long-term storage and for use in quick products like composite flours.

The samples' fat contents varied significantly (P<0.05) from 0.68 to 1.37%, with BYM3 having the least value (0.68%), while BYM4 and BYM7 had the highest (1.37%) value. It was observed that extended soaking led to soluble lipids leaching into the soaking water, which could explain the decrease in fat content. Studies on *Dioscorea* species indicated that bitter yams typically have low fat content (Egbuonu *et al.,* 2014; Padhan and Panda, 2020). Nutritionally speaking, the low lipid content is beneficial, especially when creating diets that are low in fat and calories. Because they are less prone to oxidative rancidity, low-fat flours have a longer shelf life. However, low lipid levels may have an impact on baked goods' mouthfeel and flavour retention, requiring fat supplementation in product formulation (Colla *et al.,* 2018; Syan *et al.,* 2024; Akhlaghi *et al.,* 2025).

The blanching effect generally led to increased amount of crude fiber, which ranged from 2.83% (BYM3) to 3.41% (BYM4). Following the leaching of soluble components, concentration effect could have caused blanched samples' increased crude fiber content. Dietary fiber is crucial for glycaemic control, gastrointestinal health, and satiety (Daley and Shreenath, 2026; Wu *et al.,* 2023; Marc *et al.,* 2025). Better nutritional functionality is suggested by the higher fiber content in blanched samples. For the creation of functional foods like high-fibre biscuits, breakfast cereals, and weaning formulations targeted at lowering postprandial blood glucose response, higher fiber flours (BYM4 and BYM7) had high potentials (Tamene *et al.,* 2025; Klerks *et al.*, 2019).

Table 2: Proximate Composition (%) of Bitter Yam Flour Samples

Samples	Moisture content	Fat content	Fibre content	Protein content	Ash content	Carbohydrate content
BYM$_1$	1.05^c±0.01	1.14^a±0.28	2.96^f±0.01	2.88^c±0.02	0.26^d±0.01	91.71^a±0.00
BYM$_2$	2.03^b±0.01	1.33^a±0.02	3.04^e±0.02	2.88^c±0.01	0.30^c±0.00	90.42^a±0.00
BYM$_3$	0.96^d±0.03	0.68^b±0.01	2.83^g±0.02	2.86^c±0.02	0.24^e±0.00	92.43^a±0.00

BYM$_4$	2.09^a±0.02	1.37^a±0.01	3.41^a±0.01	3.03^a±0.01	0.25^d±0.00	89.85^a±0.00
BYM$_5$	2.08^{ab}±0.02	1.35^a±0.01	3.26^c±0.02	2.93^b±0.02	0.32^b±0.00	90.06^a±0.00
BYM$_6$	2.06^{ab}±0.01	1.33^a±0.01	3.17^d±0.01	2.90^b±0.02	0.31^b±0.00	90.23^a±0.00
BYM$_7$	2.10^a±0.01	1.37^a±0.02	3.30^b±0.02	3.00^a±0.02	0.34^a±0.00	89.89^a±0.00

Results are expressed as mean values ± S.D of duplicate determination. The level of significance is set at P≤0.05.

KEY

BYM$_1$: Bitter yam sample soaked for 6 h

BYM$_2$: Bitter yam sample soaked for 12 h

BYM$_3$: Bitter yam sample soaked for 18 h

BYM$_4$: Bitter yam sample blanched for 5 min

BYM$_5$: Bitter yam sample blanched for 10 min

BYM$_6$: Bitter yam sample blanched for 15 mins

BYM$_7$: Untreated control (neither soaked or blanched)

The protein content varied from 2.86% to 3.03%, with BYM4 and BYM7 having the highest values (3.03% and 3.00%, respectively). It was observed that blanching slightly increased protein retention over soaking, even though bitter yam was not a protein-dense food. Long-term soaking might have resulted in a slight leaching of nitrogen. According to earlier research, yam flours had protein contents ranging from 2 to 13% (Awoyale *et al.,* 2015; Omohimi *et al.,* 2018). Although bitter yam flour has a low protein content, it can be used as an energy base in composite formulations. Products that are nutritionally balanced, like baby food or fortified staples, would require protein enrichment (using legumes or soybean flour).

The ash content which was an indicator of the amount of minerals ranged from 0.24% (BYM3) to 0.34% (BYM7). The untreated control sample (BYM7) had the highest ash value, suggesting some mineral leaching during soaking and blanching. Similar mineral reductions due to soaking have been reported in root and tuber crops (Rizvi *et al.,* 2024). The mineral retention is essential in complementary foods and functional formulations (Dehelean *et al.,* 2025; Milkias *et al.,* 2024). Short blanching durations (5 min, BYM4) was observed to balance nutrient retention and detoxification (Mugo *et al.,* 2024).

All samples had extremely high carbohydrate contents (89.85–92.43%), confirming that bitter yam flour is a carbohydrate-rich energy source (Egbuonu *et al.,* 2014). Sample BYM3 had the highest value (92.43%), most likely as a result of concentration effects after lower levels of fat and ash. The high carbohydrate content in bitter yam flour posits it as a potential for energy-dense staple foods, thickening agents in soups and sauces, bakery and snack production, and for extruded ready-to-eat products. However, glycaemic response must be taken into account when starch levels are high, particularly for formulations that are diabetic-friendly (Murillo *et al.,* 2022).

3.2 Physicochemical Properties of Bitter Yam Flour Samples

Physicochemical properties are the characteristics of a substance that can be measured and analysed, such as its chemical composition, physical structure and texture. These properties can affect the quality, processing and functionality of yam flour in food products. The table below shows the physicochemical values of seven yam flour samples. The pH value of samples was slightly different from each other ranging from 4.73-9.77. BYM$_7$, which was the untreated control being more acidic while BYM$_3$ being the most alkaline. BYM$_4$ while differing is of closer acidic value to BYM$_7$. It was observed that pretreated samples had reduction in pH compared to the untreated control. An attribute influenced by interaction with natural water during soaking and blanching. The observation was congruent with the work of Nzabuheraheza *et al.* (2018).

The total titratable acidity of blanched samples BYM$_4$, BYM$_5$ and BYM$_6$ were not significantly different from one another. Similarly, there was no significant difference between BYM$_1$ and BYM$_2$ soaked samples. Though, these two differed from another soaked sample BYM$_3$. Generally, there was a marked difference of pretreated samples in relation to control sample BYM$_7$. It would also be noticed that There was a steady increase in titratable amounts among pretreated samples with the exception of BYM$_2$. This last statement matches pretreatment effect on yam samples recorded by Quayson *et al.* (2021). The values ranged from 9.25 – 11.96 mg/100g.

The amylose percentage of samples varied significantly with control sample BYM$_7$. This is attributable to the pretreatment and drying process before flour conversion which decreases water soluble starch due to leaching (Harijono *et al.,* 2013). Blanched sample portions had decline in value with the lowest being BYM$_6$. This agrees with the work of Sanful *et al.* (2017). However, presoaked samples had a rather erratic climb and decline in amylose availability pattern, with sample BYM$_3$ deviating from the increase course. The value ranged from 30.35-40.98%

In same vein, the amylopectin content with range of 59.02-69.65% experienced simultaneous increase with amylose decline in comparison to reference sample BYM7. This is in fact due to the direct derivation and complementary role both play in food produce such as tubers. There was no fallout in increment, except that BYM_2 had lower amylopectin content in relation to BYM_1 presoaked at half its h. Again, this corresponds with the research observation of Sanful et al. (2017).

Table 3: Physicochemical Properties of Bitter Yam Flour Samples

Samples	pH	TTA (mg/100g)	A (%)	Ap (%)	TSS (mg/100g)	A/Ap
BYM_1	9.77[b]±0.01	11.96[b]±0.01	32.60[f]±0.01	67.40[b]±0.01	9.03[f]±0.01	0.48[e]±0.02
BYM_2	9.52[c]±0.00	11.93[b]±0.01	33.23[e]±0.01	66.77[c]±0.01	9.48[e]±0.01	0.50[c]±0.01
BYM_3	9.97[a]±0.01	12.30[a]±0.01	30.35[g]±0.15	69.65[a]±0.01	8.77[g]±0.01	0.44[f]±0.03
BYM_4	4.93[f]±0.01	12.30[a]±0.01	39.43[b]±0.01	60.57[f]±0.01	9.98[b]±0.01	0.65[b]±0.01
BYM_5	5.50[e]±0.01	11.07[c]±0.01	34.13[d]±0.01	65.86[d]±0.00	9.87[d]±0.02	0.52[d]±0.02
BYM_6	5.70[d]±0.10	11.08[c]±0.01	34.13[d]±0.01	65.86[d]±0.00	9.87[d]±0.02	0.52[d]±0.02
BYM_7	4.73[g]±0.01	9.25[d]±0.15	40.98[a]±0.01	59.02[g]±0.01	10.24[a]±0.01	0.69[a]±0.03

Results are expressed as mean values ± S.D of duplicate determination. The level of significance is set at P≤0.05. Key: TTA (Total Titratable Acidity); TSS (Total Soluble Solids); A (Amylose); AP (Amylopectin)

KEY

BYM_1: Bitter yam sample soaked for 6 h

BYM_2: Bitter yam sample soaked for 12 h

BYM_3: Bitter yam sample soaked for 18 h

BYM_4: Bitter yam sample blanched for 5 min

BYM_5: Bitter yam sample blanched for 10 min

BYM_6: Bitter yam sample blanched for 15 min

BYM_7: Untreated control (neither soaked or blanched)

The untreated sample (BYM7) showed the highest amylose content (40.98%) and highest A/Ap ratio (0.69), whereas prolonged soaking (BYM3) significantly (p<0.05) reduced amylose (30.35%) and lowered the A/Ap ratio (0.44). However, blanching resulted in intermediate values which could be adduced to processing-induced reduction in amylose as a result of leaching of soluble amylose fractions during soaking, structural rearrangement of starch granules, and partial gelatinization and molecular disorganization during heat treatment

Hydrothermal treatments break hydrogen bonds in starch granules, which causes molecular mobility and may result in amylose migration (Kim and Baik, 2021; Subroto et al., 2022). Furthermore, the crystalline structure and functional behavior of starch are significantly influenced by changes in the proportions of amylose and amylopectin (Varghese et al., 2023). The yam starch normally gelatinizes at relatively high temperatures (around 70-85 °C) which reflects strong intragranular order and crystalline arrangements (Pérez et al., 2025). Adewumi et

al. (2020) stated that acetylation of *Dioscorea dumetorum* flours lowered the gelation temperature due to disruption of hydrogen bonding and weaken granule crystallinity

As the proportion of amylose in the total starch composition decreases, the proportion of amylopectin increases proportionately in blanched samples, which was consistent with the inverse relationship between amylose and amylopectin that has been observed. One important factor that determines how well flour works in food processing systems is the ratio of amylose to amylopectin. Because of its linear structure, which encourages intermolecular hydrogen bonding and network formation during cooling, amylose is mainly responsible for gel formation. Gels made with high-amylose flours are firmer and less sticky (Varghese et al., 2023; Subroto et al., 2022). Conversely, amylopectin, being highly branched, enhances viscosity and contributes to softer, more cohesive textures. Therefore, high amylose (higher A/Ap ratio) could result to firmer gels and stronger structure useful in noodles and extruded snacks., while high amylopectin (lower A/Ap ratio) influences higher paste viscosity and improved thickening ability useful in sauces, gravies, and baby foods.

The peak viscosity and starch swelling during heating are controlled by the amylopectin in the sample flours. Higher peak viscosity and superior thickening qualities are typically displayed by amylopectin-rich starches (Varghese et al., 2023). Amylose, on the other hand, improves paste stability and limits swelling. For extrusion processing, baking, instant flour formulation, and thickener production, the A/Ap ratio thus establishes

suitability. Moreover, retrogradation results to the reassociation of starch molecules upon cooling which was accelerated by high amylose content, increasing baked goods' firmness and possibly increasing their staling (Hoover, 2001). Nonetheless, resistant starch formation and increased nutritional value could result from controlled retrogradation. Furthermore, higher amylose starches frequently result in more resistant starch when cooled, which enhances gut health and reduces glycemic response (Jane *et al.*, 1999). Therefore, flours can be tailored for functional or health-oriented purposes by adjusting the A/Ap ratio through processing condition manipulation.

3.3 Antioxidant Properties of Bitter Yam (*Dioscorea dumetorum*) Flour Samples

The antioxidant properties of bitter yam flour were significantly (P ≤ 0.05) influenced by soaking and blanching methods used for the processing. The results revealed significant (p<0.05) variations in total phenolic content (TPC), total flavonoid content (TFC), nitric oxide scavenging activity (NSA), reducing power assay (RPA), and ferric reducing antioxidant power (FRAP) among the samples.

The untreated sample (BYM7) recorded the highest total phenolic content (19.84 mg GAE/g), followed closely by the blanched samples (BYM4-BYM6), while soaked samples (BYM1-BYM3) showed markedly lower values, particularly BYM3 (10.23 mg GAE/g). The trend observed suggested that soaking significantly (p<0.05) reduced phenolic compounds, likely due to leaching of water-soluble phenolics into the soaking medium. Prolonged soaking (18 h) resulted in the least TPC, confirming

diffusion losses over time. Similar reductions in phenolic content after soaking have been reported in *Dioscorea* species and other tubers (Setyawan *et al.,* 2021; Ratnaningsih *et al.,* 2018). Conversely, blanching preserved relatively high phenolic content, possibly due to enzyme inactivation of polyphenol oxidase, which prevents oxidative degradation. Short-duration blanching (5 min) showed slightly higher retention than longer times, indicating that extended heat exposure could begin to degrade thermolabile phenolics (Oluwole *et al.,* 2018).

TFC followed a similar pattern. The untreated control (9.83 mg QE/g) and blanched samples (9.06–9.73 mg QE/g) were significantly (p<0.05) higher than soaked samples (7.50–8.45 mg QE/g). Again, prolonged soaking (18 h) resulted in the least flavonoid content. Flavonoids are largely water-soluble; hence soaking promotes their migration into water (Setyawan *et al.,* 2021). Heat treatment through blanching may enhance extractability of bound flavonoids by disrupting cell walls, explaining why blanched samples maintained comparatively high TFC.

NSA ranged from 58.57% (BYM3) to 70.86% (BYM7). The untreated sample (control) and blanched samples demonstrated significantly higher scavenging activity than soaked samples (Oladele *et al.*, 2016; Oboh *et al.,* 2015). The strong alignment between TPC, TFC and NSA suggested that phenolics and flavonoids are major contributors to nitric oxide scavenging activity. This agrees with findings that antioxidant activity in yam and other root crops strongly correlates with phenolic concentration (Adomėnienė and Venskutonis (2022; Ukom *et al.,* 2014). The reduced NSA in soaked samples was therefore attributable to phenolic losses.

Table 4: Antioxidant Properties of Bitter Yam Flour Samples

Samples	TP (mg/100%)	TF (mg/100%)	NSA (mg/100%)	RPA (mg/100%)	FRAP (mg/100%)
BYM[1]	11.46[f]±0.01	8.00[d]±0.20	60.23[f]±0.01	43.12[f]±0.01	68.46[f]±0.01
BYM[2]	12.96[e]±0.01	8.45[c]±0.05	70.06[e]±0.02	44.23[e]±0.01	69.05[e]±0.01
BYM[3]	10.23[g]±0.01	7.50[e]±0.10	58.57[g]±0.01	42.68[g]±0.01	68.24[g]±0.01
BYM[4]	19.65[b]±0.01	9.73[a]±0.01	70.77[b]±0.07	67.06[b]±0.01	69.94[c]±0.01
BYM[5]	19.57[c]±0.01	9.68[a]±0.01	70.51[c]±0.03	64.95[c]±0.01	69.74[c]±0.01
BYM[6]	19.13[d]±0.01	9.06[b]±0.02	70.24[d]±0.02	64.75[d]±0.02	69.56[d]±0.01
BYM[7]	19.84[a]±0.01	9.83[a]±0.01	70.86[a]±0.01	68.06[a]±0.01	70.96[a]±0.02

Results are expressed as mean value s± S.D of duplicate determination. The level of significance is set at P≤0.05. Key: TPC (Total Phenolic Content); TFC (Total Flavonoid Content); NSA (Nitric Oxide Scavenging Activity); RPA (Reducing Power Assay); FRAP (Ferric Reducing Antioxidant Power).

KEY

BYM[1]: Bitter yam sample soaked for 6 hrs

BYM[2]: Bitter yam sample soaked for 12 hrs

BYM[3]: Bitter yam sample soaked for 18 hrs

BYM[4]: Bitter yam sample blanched for 5 mins

BYM[5]: Bitter yam sample blanched for 10 mins

BYM[6]: Bitter yam sample blanched for 15 mins

BYM[7]: Untreated control (neither soaked or blanched)

The RPA values indicated a pronounced increase in blanched and control samples (64.75–68.06%), while soaked samples recorded much lower values (42.68–44.23%). The reducing power reflects the electron-donating ability of antioxidants; therefore, higher RPA in BYM7 and BYM4-BYM6 indicated stronger antioxidant potential. The decrease observed in soaked samples further supported the loss of redox-active compounds during soaking. Heat processing, when moderate, can enhance reducing power by releasing bound phenolic compounds (Oluwole *et al.,* 2017a; Olapade *et al.,* 2017).).

The FRAP values were highest in the control (70.96 μmol Fe^{2+}/g) and least in soaked samples, especially BYM3 (68.24 μmol Fe^{2+}/g). The blanching retained relatively high FRAP values, though slightly lower than the control sample. The minimal reduction in FRAP for blanched samples suggested that blanching did not significantly ($p > 0.0$) impair ferric-reducing antioxidants. The strong similarity between FRAP and RPA trends confirms consistency in antioxidant behaviour. The antioxidant was such that the untreated sample (control) had more activity followed by the blanched samples, while the soaked samples had the least antioxidant activity (Oluwole *et al.,* 2017b). Thus, among soaked samples, increased soaking duration progressively reduced antioxidant activity, while among blanched samples, reduced blanching time (5 min) better preserved antioxidants than longer durations. The antioxidant properties are important in preventing oxidative damage caused by free radicals.

The results therefore indicated that blanching appears preferable to soaking when developing bitter yam flour with high antioxidant functionality. Also, since phenolics contribute to oxidative stability and potential health benefits, minimally processed or mildly blanched bitter yam flour could be more suitable for functional food formulations. Moreover, excessive soaking should be avoided in product development where antioxidant retention is a priority.

4.0 Conclusion

Soaking and blanching caused a decrease in pH of yam flour. This may be due to the release of organic acids during the soaking and blanching process. The pH of yam flour can be used as an indicator of the freshness and quality of the product. An increase in total titratable acidity, which is a measure of the acidity of a solution. This increase in acidity may be due to the release of organic acids during the soaking and blanching process. The total titratable acidity of yam flour can also be used as an indicator of the freshness and quality of the product. Soaking and blanching can affect the ratio of amylose to amylopectin in yam flour. The amylose and amylopectin content of yam flour can

affect the texture and cooking properties of the product. Soaking and blanching can also lead to a decrease in total soluble solids, which is a measure of the amount of dissolved solids in a solution. This decrease in total soluble solids may be due to the leaching of soluble compounds during the soaking and blanching process. Phenolic compounds are known for their antioxidant properties, and a decrease in their content may reduce the antioxidant potential of the product. Flavonoids are another group of compounds with antioxidant properties, and a decrease in their content may reduce the antioxidant potential of the product. Nitric oxide is a free radical that can cause oxidative damage, and a product with a high nitric oxide scavenging power can protect against this damage. The reducing power is a measure of the ability of a product to donate electrons and reduce oxidative stress. A decrease in reducing power means reduced oxidative stress buffer. Ferric reducing antioxidant power is a measure of the ability of a product to reduce ferric ions and prevent oxidative damage.

5.0 Competing Interests

Authors have declared that no competing interests exist.

References

1. Abiodun, O. A., Adeola, O., & Bamigbola, M. A. (2014). Effect of processing on functional and pasting properties of yam flour. *Journal of Food Processing and Technology, 5*(3), 1–6.

2. Adebowale, K. O., Sanni, L. O., & Oluwamukomi, M. O. (2005). Chemical composition, functional properties and retrogradation characteristics of yam, cassava, plantain flours and their starches. *Journal of Food, Agriculture & Environment, 3*(2), 22–28.

3. Adomėnienė, A., & Venskutonis, P. R. (2022). *Dioscorea* spp.: Comprehensive Review of Antioxidant Properties and Their Relation to Phytochemicals and Health Benefits. *Molecules*, *27*(8), 2530. https://doi.org/10.3390/molecules27082530.

4. Akhlaghi, Abedfar, A., Abbaszadeh, F. and Pourvatandoust, S. (2025). A Review of the Effect of Adding Fat Substitutes on the Shelf Life and Quality Characteristics of Bakery Products. *Food Science and Engineering,* 7(1), 1-11. DOI: https://doi.org/10.37256/fse.7120268406.

5. Akinoso, R., Olatoye, K.K., Ogunyele, O. O. (2016): Potentials of trifoliate yam (*Dioscorea dumetorum*) in noodles production. *Jounal of Food Processing Technology* 7: 609.

6. Akissoe, N., Mestres, C., Hounhouigan, J., Nago, N. (2006): Prediction of the sensory texture of a yam thick paste (amala) using instrumental and physicochemical parameters. *Journal of Texture Studies* 37, 393-412.

7. Akissoe, N., Samb, A., Treche, S., & Toure, M. (2003). Some flour and starch products from yams. *Food Reviews International, 19*(2), 199–226.

8. Akpapunam MA, Sefa-Dedeh S. Traditional Lactic Acid Fermentation, Malt Addition, and Quality Development in Maize-Cowpea Weaning Blends. *Food and Nutrition Bulletin*. 1995;16(1):1-9. doi:10.1177/156482659501600113.

9. Alam, M., Hasan, M. M., Debnath, M. K., Alam, A., Zahid, M. A., Alim, M. A., Rahman, M. N., Molla, M. M., Khan, M. R. And Biswas, M. (2024). Characterization and evaluation of flour's physico-chemical, functional, and nutritional quality attributes from edible and non-edible parts of papaya. *Journal of Agriculture and Food Research,* 15: 100961. https://doi.org/10.1016/j.jafr.2023.100961.

10. AOAC (2005). *Official methods of analysis*, 12th ed. Washington DC: Association of Official and Analytical Chemists.

11. AOAC (2010). *Official Methods of Analysis* 18th ed. Association of Official Analytical Chemists, Washington, D. C., USA.

12. Awol, S. M., Kuyu, C. G., Bereka, T. Y. and Abamecha, N. (2024). Physicochemical stability, microbial growth and sensory quality of refined wheat flour as affected by packaging materials during storage. *Journal of Stored Products,* 105, 102217. https://doi.org/10.1016/j.jspr.2023.102217.

13. Awoyale, W., Maziya-Dixon, B., Sanni, L. O., & Shittu, T. A. (2015). Effect of water yam (Dioscoreaalata) flour fortified with distiller's spent grain on nutritional, chemical, and functional properties. *Food science & nutrition*, *4*(1), 24–33. https://doi.org/10.1002/fsn3.254.

14. Chinma, C. E., Chang, C. Y., & Abu, J. O. (2015). Effect of processing methods on physicochemical and sensory properties of yellow maize. *Journal of Food Processing and Preservation, 39*(6), 1758–1767.

15. Chinma, C. E., Njoku, H. O., Eze, J. I. (2020): Yam (Dioscorea spp.) production, processing, and utilization in Africa and Asia: A review. *Foods* 9(12), 1898. doi: 10.3390/foods9121898

16. Colla, K., Costanzo, A., & Gamlath, S. (2018). Fat Replacers in Baked Food Products. *Foods*, *7*(12), 192. https://doi.org/10.3390/foods7120192.

17. Daley, S. F. and Shreenath, A. P. (2026). The Role of Dietary Fiber in Health Promotion and Disease Prevention: A Practical Guide for Clinicians. Treasure Island (FL): StatPearls Publishing. https://www.ncbi.nlm.nih.gov/books/NBK559033/.

18. Dehelean, A., Magdas, D-A., Cristea, G., Feher, I., Mirel, V., Covaciu, F-D. (2025). Nutritional quality of infant complementary foods from Romanian supermarkets: contribution to mineral intake. *Journal of Food Composition and Analysis*, 147: 108095.

19. Egbuonu, A. C. C, Nzewi, D. C. and Egbuonu, O. N. C. (2014). Effect of Soaking Prior to Oven-Drying on Some Nutrient and Anti Nutrient Properties of Bitter Yam (*Dioscorea dumetorum*). *Journal of Nutrition and Food Sciences,* 4(3): 1-4. DOI: 10.4172/2155-9600.1000280.

20. Ezeocha V. C., Ojimelukwe P. C. (2012): The impact of cooking on the proximate composition and anti-nutritional factors of water yam (*Dioscorea alata*). *Journal of Stored Products and Postharvest Research,* 3(13), 172 – 176.

21. Ezeonu, C. S., & Ejiofor, M. A. N. (2011). Nutritional quality and sensory evaluation of yam (Dioscorea spp.) products: A review. *African Journal of Food Science, 5*(2), 84–91.

22. FAO (2023). Yam. http://www.fao.org/potato-fruit-vegetables/crops/yam/en/. Retrieved April 29th, 2023.

23. Harijono, T.E., Saputri, D., Kusnadi, J. (2013): Effect of Blanching on Properties of Water Yam (*Dioscorea alata*) Flour. *Advanced Journal of Food Science and Technology* 5 (10):1342-1350

24. Hemery, Y., Holopainen, U., Lampi, A.-M., Lehtinen, P., Nurmi, T., Piironen, V., Edelmann, M. and Rouau, X. (2011). Potential of dry fractionation of wheat bran for the development of food ingredients, part II: Electrostatic separation of particles. *Journal of Cereal Science,* 53: 9–18. https://doi.org/10.1016/j.jcs.2010.06.014.

25. Hue, S. M., Boyce, A. N., Somasundram, C. (2012): Antioxidant activity, phenolic and flavonoid contents in the leaves of different varieties of sweet

potato (*Ipomoea batatas*). *Australian Journal of Crop Science* 6, 375–380.

26. Idowu, D. O. and Adewumi, H. O. (2021). Evaluations of some Selected Yam Flour Production Variables on Drying Time and Final Moisture Content of Sliced Dried Yam. *Direct Research Journal of Agriculture and Food Science,* 9, 344-349. DOI: https://doi.org/10.26765/DRJAFS63571652.

27. IITA (2023). Yam. International Institute of Tropical Agriculture. https://www.iita.org/crops/yam/, Retrieved April 29th, 2023.

28. Ike, P.C. and Inoni, O. E. (2006). Determinants of yam production and economic efficiency among small-holder farmers tn Southeastern Nigeria. *Journal of Central European Agriculture* 7, pp. 337-342.

29. Ikeuchi, E. O., Ogunwolu, S. O., & Ikuomola, D. S. (2017). Physicochemical and functional properties of water yam (*Dioscorea alata*) flour as influenced by variety and processing methods. *Food Science & Nutrition, 5*(4), 691–701.

30. International Potato Center. Webpage on Yam (*Dioscorea spp.*). Retrieved April 29th, 2023. The webpage can be found at https://www.cipotato.org/root-and-tuber-crops/yam/.

31. Iweala, E. E. J., Oluba, O. M., Nwachukwu, N. (2013): Effect of processing methods on the flavonoid content and antioxidant activity of yam (*Dioscorea rotundata*) tubers. *Journal of Medicinal Food* 16(10): 894-900.

32. Iweala, E. J., Soyibo, A. (2020): Nutritional and health benefits of yam (*Dioscorea spp.*) in the human diet: A review. *Critical Reviews in Food Science and Nutrition* 60(13): 2173-2193. doi: 10.1080/10408398.2019.1687503.

33. Karim, A. A., Norziah, M. H., Seow, C. C. (2000): Methods for the study of starch retrogradation. *Food Chemistry* 71(1): 9-36. dob: 10.1016/S0308-8146(00)00149-8

34. Karim, O., Kayode, R., Oyeyinka, S., Oyeyinka, A. T. (2013): Proximate, mineral and sensory qualities of "Amala" prepared from Yam flour fortified with Moringa leaf powder. *Food Science and Quality Management* 12, 10-22.

35. Kim, H. Y., & Baik, M. Y. (2021). Pressure moisture treatment and hydro-thermal treatment of starch. *Food science and biotechnology*, *31*(3), 261–274. https://doi.org/10.1007/s10068-021-01016-5.

36. Kirk, R.S., & Sawyer, R. (2016): *Pearson's Composition and Analysis of Foods* (9th Ed). Churchill Livingstone, Edinburgh.

37. Klerks, M., Bernal, M. J., Roman, S., Bodenstab, S., Gil, A., & Sanchez-Siles, L. M. (2019). Infant Cereals: Current Status, Challenges, and Future Opportunities for Whole Grains. *Nutrients*, *11*(2), 473. https://doi.org/10.3390/nu11020473.

38. Makanjuola, O. M., Coker, O. J. (2019): Assessment of sensory, functional and pasting properties of different yam cultivar flours subjected to the same processing condition. *Global Scientific Journal,* 7(10), 672-687.

39. Marc, A. R., Mureșan, C. C., Pop, A., Marțiș, S. G., Mureșan, E. A., Pușcaș, A., Postolache, N. A., Stoica, F., Crivei, C. I., Veleșcu, I.-D. and Rațu, R. N. (2025). Dietary fibers and their importance in the diet. In: Food Science and Nutrition. IntechOpen. https://doi.org/10.5772/intechopen.115461.

40. Mestres, C., Dorthe, S., Akissoé, N., Hounhouigan, J. D. (2004): Prediction of sensory properties (color and taste) of amala, a paste from yam chips flour of West Africa, through flour biochemical properties. *Plant Foods for Human Nutrition* 59, pp. 93-99. Available at: https://doi.org/10.1007/s11130-004-

41. Milkias, M., Admassu, S., and Abebe, W. (2024). Impact of variety and drying methods on the physicochemical, functional, and thermal properties of Ethiopian potato (*Plectranthus edulis*) tuber flour. *Heliyon,* 10(18): e37628. https://doi.org/10.1016/j.heliyon.2024.e37628.

42. Mugo, B. M., Kiio, J., & Munyaka, A. (2024). Effect of blanching time-temperature on potassium and vitamin retention/loss in kale and spinach. *Food science & nutrition*, *12*(8), 5403–5411. https://doi.org/10.1002/fsn3.4186.

43. Murillo, S., Mallol, A., Adot, A., Juárez, F., Coll, A., Gastaldo, I., & Roura, E. (2022). Culinary strategies to manage glycemic response in people with type 2 diabetes: A narrative review. *Frontiers in nutrition*, *9*, 1025993. https://doi.org/10.3389/fnut.2022.1025993.

44. Nainggolan, E. A., Banout, J., & Urbanova, K. (2024). Recent Trends in the Pre-Drying, Drying, and Post-Drying Processes for Cassava Tuber: A

Review. *Foods*, *13*(11), 1778. https://doi.org/10.3390/foods13111778.

45. Nzabuheraheza F. D., Nyiramugwera A. N., & Gustavo T. M. (2018): Yam physicochemical parameters assessment and its bread sensory attributes for corporate agribusiness boosting. *Journal of Nutritional Health and Food Engineering* 8(6): 453-458.

46. Oboh, G., Ademiluyi, A. O., & Akinrinola, B. L. (2015): Influence of blanching on the antioxidant properties and inhibition of α-amylase, α-glucosidase and angiotensin I-converting enzyme activities of white yam (*Dioscorea rotundata*) and yellow yam (*Dioscorea cayenensis*). *Journal of Food Biochemistry* 39(5): 572-582.

47. Oboh, G., Akindahunsi, A. A., & Oshodi, A. A. (2004). Changes in polyphenol content and antioxidant activities of cassava tubers (Manihot esculenta Crantz) and leaves (Manihot esculenta Crantz) at different stages of boiling. *Food Chemistry, 85*(4), 525–530.

48. Oladele, A. K., Akinoso, R. and Adeyemi, I. A. (2016). Effect of soaking on physicochemical properties and antioxidant activity of yam flour. *Journal of Food Processing and Preservation* 40(4): 762-770.

49. Olapade, A. A., Adekoya, M. A., Ade-Omowaye, B. I. O. & Adebiyi, A. P. (2017). Effect of blanching and sun-drying on the physicochemical and antioxidant properties of white yam (*Dioscorea rotundata*) flour. *Journal of Food Processing and Preservation* 41(1): e12774.

50. Oluwole, O. B., Aina, J. O., & Aina, O. S. (2018). Effect of blanching on the total phenolic content and antioxidant activity of yam flour. *Journal of Food Processing and Preservation* 42(2), e13514.

51. Oluwole, O. B., Akintayo, E. T., & Olufemi, T. A. (2017a). Effect of Soaking and Boiling on the Nutrient Composition and Antioxidant Properties of Yam Flour. *Food Science and Quality Management* 59, 15-21.

52. Oluwole, O. B., Falade, K. O., & Oyewole, O. B. (2017b). Effect of soaking and boiling on the functional and sensory properties of yam flour. *Journal of Food Measurement and Characterization* 11(2), 626-632.

53. Omohimi, C. I., Piccirillo, C., Roriz, M., Ferraro, V., Vasconcelos, M. W., Sanni, L. O., Tomlins, K., Pintado, M. M., & Abayomi, L. A. (2018). Study of the proximate and mineral composition of different Nigerian yam chips, flakes and flours. *Journal of food science and technology*, *55*(1), 42–51. https://doi.org/10.1007/s13197-017-2761-y.

54. Onwuka, G. I. (2018). *Food Analysis and Instrumentation. Theory and Practices*. Revised edition. Naphtali Prints Lagos, Nigeria, pp. 10-20.

55. Otoo, E., Mertz, O., Padoch, C., & Brink, M. (2018): Yam: A Tropical Multispecies Starchy Staple. *Frontiers in Plant Science* 9, pp. 1263. doi: 10.3389/fpls.2018.01263.

56. Padhan, B. and Panda, D. (2020) Potential of Neglected and Underutilized Yams (Dioscorea spp.) for Improving Nutritional Security and Health Benefits. *Frontiers in Pharmacology* 11:496. doi: 10.3389/fphar.2020.00496.

57. Quayson, E.T., Ayernor, G.S., Johnson, P.T., Ocloo, F. C. K. (2021): Effects of two pretreatments, blanching and soaking modulation on nonenzymatic browning developments in three yam cultivars from Ghana. *Heliyon* 7(6), e07224. https://doi.org/10.1016/j.heliyon.2021.e07224.

58. Rafiq, S., Cui, S. W., Zhang, R., Sultan, M. T., Xiao, H., & Wang, Q. (2011). An overview of the influence of processing on the nutritional properties of rice. *Critical Reviews in Food Science and Nutrition, 51*(6), 570–580.

59. Ratnaningsih, Richana, N., Suzuki, S. and Fujii, Y. (2018). Effect of Soaking Treatment on Anthocyanin, Flavonoid, Phenolic Content and Antioxidant Activities of Dioscorea alata Flour. *Indonesian Journal of Chemistry,* 18 (4), 656 – 663.

60. Rizvi, Q. U. E. H., Guiné, R. P. F., Ahmed, N., Sheikh, M. A., Sharma, P., Sheikh, I., Yadav, A. N., & Kumar, K. (2024). Effects of Soaking and Germination Treatments on the Nutritional, Anti-Nutritional, and Bioactive Characteristics of Adzuki Beans (*Vigna angularis* L.) and Lima Beans (*Phaseolus lunatus* L.). *Foods*, *13*(9), 1422. https://doi.org/10.3390/foods13091422.

61. Sanful, R. E., Oduro, I. N., Ellis, W. O (2017). Effects of pretreatment on the pasting characteristics, amylose content and colour of Aerial Yam (*Dioscorea bulbifera*) flour. *International Journal of Food Science and Nutrition* 2(4): 23-28.

62. Setyawan, N., Maninang, J. S., Suzuki, S., & Fujii, Y. (2021). Variation in the Physical and Functional Properties of Yam (*Dioscorea* spp.) Flour Produced

by Different Processing Techniques. *Foods (Basel, Switzerland)*, *10*(6), 1341. https://doi.org/10.3390/foods10061341.

63. Singleton, V. L., Orthofer, R., Lamuela-Raventós, R. M. (1999): Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods Enzymology* 299, 152–178. doi: 10.1016/S0076-6879(99)99017-1.

64. Subroto, E., Mahani, Indiarto, R., Yarlina, V. P., & Izzati, A. N. (2022). A Mini Review of Physicochemical Properties of Starch and Flour by Using Hydrothermal Treatment. *Polymers*, *14*(24), 5447. https://doi.org/10.3390/polym14245447.

65. Sudha, G., Vadivukkarasi, S., Indhu Shree, R. B., Lakshmanan, P. (2012): Antioxidant activity of various extracts from an edible mushroom *Pleurotuseous*. *Food Science Biotechnology* 21, 661–668. doi: 10.1007/s10068-012-0086-1.

66. Syan, V., Kaur, J., Sharma, K., Patni, M., Rasane, P., Singh, J. and Bhadariya, V. (2024). An overview on the types, applications and health implications of fat replacers. *Journal of food science and technology*, *61*(1), 27–38. https://doi.org/10.1007/s13197-022-05642-7.

67. Tamene, A., Fufa, D. D., Bekele, T., Bultosa, G., Kumar, A., Singh, N. (2025). Value-addition to composite soft bread wheat cookies using avocado seed and finger millet flours: assessing the nutritional, techno-functional, and sensory properties. *Measurement: Food*, 20: 100262. https://doi.org/10.1016/j.meafoo.2025.100262.

68. Ukom, A.N., Ojimelukwe, P.C., Ezeama, C.F., Ortiz, D.O. and Aragon, I.J. (2014). Phenolic content and antioxidant activity of some under-utilized Nigerian yam (Dioscorea spp.) and cocoyam (Xanthosomamaffa (scoth)) tubers. *IOSR Journal of Environmental Science, Toxicology and Food Technology,* 8(7), 104 – 111.

69. Varghese, S., Awana, M., Mondal, D., Rubiya, M. H., Melethil, K., Singh, A., Krishnan, V. and Thoma, B. (2023). Amylose–Amylopectin Ratio. In: Thomas, S., AR, A., Jose Chirayil, C., Thomas, B. (eds) Handbook of Biopolymers. Springer: Singapore. https://doi.org/10.1007/978-981-19-0710-4_48.

70. Wu, S., Jia, W., He, H., Yin, J., Xu, H., He, C., Zhang, Q., Peng, Y., & Cheng, R. (2023). A New Dietary Fiber Can Enhance Satiety and Reduce Postprandial Blood Glucose in Healthy Adults: A Randomized Cross-Over Trial. *Nutrients*, *15*(21), 4569. https://doi.org/10.3390/nu15214569.