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RESEARCH ARTICLE

Impact of Tuber Section, Steeping Solution, and Concentration on Physicochemical Properties of Yam *(Dioscorea rotundata)* Flour

Iheagwara Marcquin Chibuzo

Department of Food Science and Technology, Federal University of Technology, Owerri, P.M.B. 1526 Owerri, Imo State, Nigeria.

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Corresponding Author: Iheagwara Marcquin Chibuzo, Department of Food Science and Technology, Federal University of Technology, Owerri, P.M.B. 1526 Owerri, Imo State, Nigeria.

Abstract

This study examined various factors such as tuber cutting (TC), tuber processing method and tuber processing duration (TPM and TPD), soaking solution type and soaking solution concentration (SST and SSC), as well as parameter analytical temperature (PAT) on flour samples prepared from different parts of yam tubers. Proximate composition analysis showed significant differences ($p < 0.05$) in carbohydrate, protein, fat, ash, fiber, and moisture content. In particular, the middle part had the highest protein content ($5.49 \pm 0.71\%$), while the main part had the highest carbohydrate content ($72.62 \pm 2.83\%$). Physicochemical properties varied significantly ($p < 0.05$) between treatment methods, including pH, gel and boiling points, total soluble solids, swelling index, and water absorption. TPM significantly affected pH, and boiled yam flour had the highest pH (8.01 ± 0.76). TPD also affected properties such as gel point temperature, with longer holding times decreasing the temperature. SST and SSC had significant effects on pH, gel point temperature, and total soluble solids. Yam flour soaked with sodium carbonate had the highest pH (12.02 ± 0.87), while increasing the concentration of the soaking solution resulted in higher pH values. PAT significantly affected pH and water absorption capacity, with higher temperatures leading to higher values.

Keywords: Yam, Physicochemical, Flour, Tuber Sections, Steeping Solution.

1. Introduction

Yams (Dioscorea species) are a significant food crop in tropical countries, ranking third after cassava and sweet potato. Particularly important in West Africa, yams hold cultural and economic importance (Adepoju et al., 2018; Kanu et al., 2018). They are highly nutritious and have medicinal value, playing a crucial role in the human diet. Yams are deeply integrated into the community's social, cultural, economic, and religious aspects, making them a key staple crop in many regions (Ike and Inoni, 2006). Nigeria is the top global yam producer, contributing 65.5% of the world's output. Yam is a vital staple for over 300 million in West Africa (FAO, 2018; Alabi et al., 2019). About six hundred yam species have been identified, of which twelve are edible yam species, with six being economically important. These include yellow yam (Dioscorea cayenensis), aerial yam (Dioscorea bulbifera), white yam (Dioscorea rotundata), Chinese yam (Dioscorea esculenta), water yam (Dioscorea alata), and three-leafed yam (Dioscorea dumetorum) (Chair et al. 2016; Quintana et al., 2023). White yam species are the most popular and widely cultivated species in West Africa, as it has many cultivars that are generally considered top quality food with good market value. Yam is high in starch, contains essential nutrients like proteins, lipids, fiber, and vitamins such as B, E, and K. It also contains minerals like manganese, sodium, and potassium, as well as essential amino acids, making it a valuable

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source of nutrients (Padhan and Panda, 2020). The proximate composition of yams varies from species to species, but usually fresh yams contain a lot of moisture ranging from 50 to 65%, ash (0.5 - 1.2%), protein (3.4 - 6.0%), fat (0.1- 0.3%). %), starch (75 - 84%), and fiber (1.5-6.2%). Yam with high humidity is susceptible to spoilage, so it is processed into dry flour for a longer shelf life. This yam flour is utilized in various dishes and is a common food item in many nations (Dereje et al., 2020). Yam flour is a versatile raw material for various food applications, prized for its extended shelf life and ease of storage and transport (Aprianita et al., 2014; Setyawan et al., 2021; Zou et al., 2021). It is used in industrial baking for producing top-quality bread and baked goods (Nindjina et al., 2011; Sobukola et al., 2013), as well as in making ice cream and thickening soups (Iwuoha, 2004). Research has shown that tuber cutting, soaking/processing chemicals, and their concentrations have a significant impact on the physicochemical properties of yam flour. While there have been numerous studies on yams, the effects of yam tuber cutting have been overlooked. This research aims to fill this gap by exploring the impact of these factors on yam flour properties.

2. Materials and Methods

2.1 Materials

2.1.1 Plant Materials

Improved white yam (Dioscorea spp) variety from FUTO farms harvested after eight months were utilized for the research.

2.1.2 Chemicals

Analytical grade chemicals sourced from the FUTO chemical store were utilized for the study.

2.2 Methods

2.2.1 Generation of Samples

The yam tubers were processed into raw flour by cutting into sections and drying, then milled and sieved to obtain fresh flour. Another batch was boiled and sliced into chips, dried, and milled to obtain boiled yam flour, while a third batch was steamed and sliced into chips, dried, and milled to obtain steamed yam flour. Whole yam flour was also obtained and processed in the same way as the sections. Samples were taken at different time (0, 30, 60 min) intervals during the boiling and steaming processes. The proportions of the head, middle, and tail sections were 30%, 40%, and 30% respectively. The sections were cut into 2cm chips for processing. The boiling was done submerged in water, while the steaming was done on a wire mesh suspended over boiling water. All samples were cooled, sliced, dried, and finished as fresh flour. The experiment aimed to compare the different processing methods and their effects on the final product.

2.2.2 Proximate Analysis

The proximate analysis determination in the study followed methods outlined by Nielsen (2010) and AOAC (2012), including the Kjeldahl method for crude protein, incineration at 600^{o}C for ash content, Soxhlet method for crude fat, and acid/alkali digestion for crude fiber. Samples were analyzed in triplicate and carbohydrate content was calculated using a formula that subtracted the percentage of protein, moisture, fat, fiber, and ash from 100.

2.2.3 Functional Properties

The study used standard AOAC (2012) methods for pH determination and methods described by Iwuoha (2004) for SI, BVI, and solubility. Mbofung et al (2006) method was used for WAC and OAC determinations.

2.2.4 Gel Point and Boiling Point Temperatures (GPT and BPT)

The method for measuring the gelling and boiling point temperatures of flour samples outlined by Onwuka (2018) was adopted. The sample was dispersed in water and heated while stirred until it began to gel, with the temperature recorded as the onset gelling point. The mixture was then heated further until boiling, with the corresponding boiling point temperature also recorded. This process was conducted in a controlled manner using a thermometer and magnetic stirrer.

2.3 Data Analysis

The data were analyzed using statistical methods. Analysis of variance (ANOVA) was conducted to determine any significant differences, with the Duncan multiple range test (DMRT) used to confirm results at a certain confidence level.

3. Results and Discussion

3.1 Proximate Composition

The proximate composition of yam flour was influenced by the cross-section of the root tuber, as shown in Table 1. Significant differences ($p < 0.05$) were found in the composition of flour fractions from different tuber sections and whole tubers. This suggests that the distribution of components in the tuber varies significantly, contradicting previous research by Iheagwara et al. (2019a) on sweet potato flour. Regarding ash and fiber, the higher ash and fiber content of food made from the core of the yam is mainly due to the structural tissue and vascular bundles concentrated in this part of the yam. There are more of these structures in the main part, which contribute to a higher content of ash and fiber (Harijono et al., 2013). In addition, the smaller size and thinner kernel means that there is less starch content and more structural tissue, which also contributes to higher ash and fiber content. The high ash and fiber content of flour in the main part of the yam may also be due to various physiological processes occurring in that part of the yam. The main part is the last part of the yam to form and is often stressed due to lack of nutrients and low sunlight. As a result, yam plants allocate more resources to the main body, which can lead to higher levels of certain nutrients such as ash and fiber. This is consistent with a report by Asiyanbi-Hammed and Simsek (2018).On the contrary, the moisture content of the main part flour was found to be lower than that of the middle part and the tail part. This is because the head is small and thin, which means it dries faster than the middle and tail. Because of this, flour made from core parts has a lower moisture content and coarser texture than flour made from middle and tail parts (Kaushal et al., 2012). However, the protein and fat content of the flour in the middle part of the yam was usually higher than in the head and tail parts. This is because the center has more structural tissue and vascular bundles of complex proteins that help transport nutrients throughout the yam. The center is also where most of the starch stores are stored, and starches are made up of chains of glucose molecules that contain small amounts of protein and fat. Finally, the center is the widest part of the yam, meaning it has more surface area for photosynthesis and absorption of nutrients, including protein and fat. The middle part of the yam contains more carbohydrates, because most of the yam's energy reserves are stored there. Yams are a root fruit, which means that their flesh contains a large amount of starch. Starch is a carbohydrate made up of long chains of glucose molecules that give yams energy to grow and develop. As the yam matures, most of the starch accumulates in the center, which is the widest and most central part of the yam. This results in a higher carbohydrate content in the middle section compared to the head and tail section. Another reason why the carbohydrate content is higher in the middle part is because of yam growth. Yams form a central "core" as they grow, where vascular bundles, structural tissue and starch reserves are concentrated. This core is located in the center of the yam and is where most of the growth and development takes place. The head and tail are usually thinner and less developed, with fewer vascular bundles and starch stores. Therefore, their carbohydrate content is lower than in the middle region (Epping and Laibach, 2020).

Table 1. *Proximate composition of yam flour as affected by section of root tuber*

Parameter (%db)	Section of Root Tuber			
	Head	Middle	Tail	Whole
Carbohydrate *	72.57 ± 2.65^{b}	72.62 ± 2.83^{a}	71.83 ± 2.64^{c}	71.76 ± 3.05^{c}
Protein	5.24 ± 0.52^{d}	5.49 ± 0.71^{a}	5.39 ± 0.60^{c}	5.44 ± 0.85^{b}
Fat	3.80 ± 0.23^{c}	3.96 ± 0.27^{a}	3.84 ± 0.43^{b}	3.73 ± 0.44^{d}
Ash	2.51 ± 0.22^{a}	2.22 ± 0.20^{d}	2.31 ± 0.25^{c}	2.35 ± 0.33^{b}
Fiber	3.04 ± 0.18^{a}	2.56 ± 0.25^{c}	2.37 ± 0.20^{d}	2.60 ± 0.32^{b}
Moisture	12.84 ± 1.02^{c}	13.15 ± 0.98^{b}	14.24 ± 1.00^{a}	14.12 ± 1.11^{a}

** Determined by difference*

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

3.2 Physico-Chemical Properties

3.2.1 Effect of Root Tuber Cutting on the Physicochemical Properties of Yam Flour

Table 2 illustrates the impact of root tuber cutting on the physicochemical properties of yam flour. The study found no significant difference in the middle root tuber section and overall pH, SI, and WAC. However, significant differences were noted in GPT, BPT, and TSS. The pH values across all root tuber parts ranged from 7.18 to 7.24, indicating an alkaline environment. The swelling index measures the water absorption and swelling capacity of yam flour. All parts of the root tuber have similar expansion indices between 2.13 and 2.20. Water absorption is also similar in all parts of the root tuber, ranging from 2.08 to 2.17 ml/g. This suggests that different parts have similar water absorption and swelling capacity (Iheagwara, 2022).

For GPT, whole yam tuber flour was significantly higher than flour from other yam parts and this is due to the different starch composition of each part. Starch granules in the head, middle, and tail of the yam vary in size, shape, and amylose to amylopectin ratio. When these starch granules are mixed into yam tuber flour, they have a more complex and heterogeneous structure that requires a higher temperature for gelatinization. GPT was also affected by the crystallinity and shape of the starch granules. The main part of the jam consists of starch granules with lower crystallinity and a more irregular shape, which means that they have a lower gelation temperature. On the other hand, the middle region has starch granules with higher crystallinity and a more regular shape, which means that they have a higher gelatinization temperature. When these different types of starch granules are mixed together in yam tuber flour, the overall gelatinization temperature is higher than in individual regions. Another factor that contributed to the higher setting temperature of whole yam tuber flour is the presence of proteins and other non-starch polymers in the flour. These non-starch components form physical barriers and prevent the gelatinization of starch granules, making starch gelatinization difficult and raising the necessary temperature. This is especially true for the whole yam tuber meal, which has a higher concentration of proteins and non-starch polymers than the individual parts of the yam (Oyefeso, 2021). The boiling point of yam head flour is higher than that of middle and tail flour because of differences in starch granule size, shape, and properties. The yam head, being the thinnest part of the yam, is more exposed to environmental factors like heat and sunlight that can affect starch granule stability. This results in starch granules that are more resistant to gelatinization, requiring a higher boiling point. The high BPT of the bulk material indicates that the bulk starch molecules have less ordered and more amorphous structures, which makes them less stable and more sensitive to changes in temperature and pH, and this is consistent with Iheagwara's (2022) report. Total soluble solids content of yam tuber flour was found to be higher than flours from other parts of yam. This is due to the different concentrations of sugars and other water-soluble compounds in each part of the yam. The heads and tails of the yam contain fewer starch granules and more water-soluble components such as sugars and proteins, making them less concentrated in terms of soluble solids. The center, on the other hand, is the main storage area of the yam and contains the highest concentration of starch granules, which are insoluble in water. When the head, middle, and tail of the yam are combined into a whole yam tuber meal, different types of water-soluble compounds are mixed together, resulting in a higher total soluble solids content (Tattiyakuli et al., 2006).

Table 2. *Physicochemical properties of yam flour as affected by section of root tuber*

Properties	Section of Root Tuber			
	Head	Middle	Tail	Whole
pH	7.24 ± 0.78^{a}	7.19 ± 0.84^{a}	7.18 ± 0.65^{a}	7.21 ± 0.83^{a}
Gelling Point Temperature (°C)	60.63 ± 3.71^{c}	60.36 ± 3.82^{c}	61.29± 3.22^{b}	62.45 ± 3.87^{a}
Boiling Point Temperature (°C)	74.24 ± 2.38^{a}	73.18 ± 3.71^{b}	72.60 ± 3.35^{c}	72.84 ± 2.41^{c}
Swelling Index	2.13 ± 0.28^{a}	2.17 ± 0.27^{a}	2.16 ± 0.23^{a}	2.20 ± 0.38^{a}
Total Soluble Solids (%)	23.27 ± 2.97^{b}	23.21 ± 2.47^{b}	23.26 ± 2.46^{b}	24.39 ± 2.36^{a}
Water Absorption Capacity (ml/g)	2.08 ± 0.21^{a}	2.13 ± 0.26^{a}	2.14 ± 0.27^{a}	2.17 ± 0.32^{a}

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

3.2.2 Effect of Processing Methods on the Physico-Chemical Properties of Yam Flour

The tuber processing method allows for the production of fresh, boiled, and steamed yam flour samples as shown in Table 3. The physicochemical properties of the flour vary depending on the treatment method used. The pH levels of the different flour samples were significantly different, with the fresh sample having the highest pH of 8.27. The gel point temperatures also varied among the samples, with the fresh sample having a gel point of 66.25 °C, while the cooked sample had a lower value of 60.27 °C. These results indicate that the processing method used can impact the physicochemical properties of yam flour (Moorthy and Ramanujam, 1996). Both boiled and steamed flour samples were found to be pre-gelled, with the harder pregelatinized sample exhibiting the lowest gelatinization temperature. This aligns with Iwuoha's (2004) findings. Flour samples with lower gel points could be beneficial for food applications that require lower temperatures. The boiling temperature behavior of the flour samples also followed similar trends, with the highest average temperature recorded for the fresh sample at 74.04 °C and 70.53 °C for the cooked sample. This reflects that hydrothermal pretreatment of a cooked sample resulted in faster-boiling reactions compared to flour samples processed using other methods. The lower boiling temperatures indicated a higher sensitivity to structural changes during heating (Iheagwara, 2022). The swelling indices of different flour samples processed using different methods were significantly different ($p < 0.05$). The boiled sample had the highest swelling index of 2.98, followed by the steamed sample with 2.56 and the fresh sample with 1.95. These data clearly show that pregelatinization changes the structure of the carbohydrate fraction of flour (Iheagwara et al., 2019a). Thermal manipulation of flour breaks weak hydrogen bonds, exposing hydrophilic ends that attract water. The extent of swelling varies based on the treatment method. Boiling results in stronger bond breaking and more hydroxyl ions than steaming. Semi-dry heat from steaming may not be as effective in promoting swelling. The swelling index of flour depends on the processing method used, with boiled flour samples expected to swell more than steamed samples. Fresh flour samples show slight swelling due to their natural state and limited water absorption. This highlights the importance of processing methods in determining the swelling index of flour. Highly swelling flours can be added to the food system to control the volume or size, texture and composition of foods (Iheagwara et al., 2019b). Total soluble solids in yam flour samples varied significantly based on processing methods. Boiled samples had the highest solubility at 21.18%, followed by steamed at 18.87%, and fresh at 15.02%. This highlights the importance of processing methods in determining solubility levels. Cooking also played a key role in enhancing solubility by imparting maturity and softness to the yam tubers and cells. The water absorption capacity of flour samples varied depending on the processing method used. The highest capacity was found in samples from the boiling process (2.43 ml/g), followed by steam processing (2.28 ml/g). These values were significantly higher than the fresh sample, which had the lowest absorption capacity. The increase in water absorption was attributed to the presence of more hydrophilic sites in the boiled and steamed samples than in the fresh ones. The heat treatment of tubers can affect their biophysical adjustments, with factors such as treatment type and duration playing a role in improving water-binding ability. Comparing processing methods, boiling is found to be more effective in manipulating physicochemical properties than steaming, with a clear sequence in tested properties observed. Boiling may be a better choice for controlling these properties. Studies by Iwuoha (2004) and Iheagwara (2013) support this idea.

Table 3. *Physicochemical properties of yam flour as affected by tuber processing method*

Properties	Tuber Processing Method		
	Boiled	Steamed	Fresh
pH	8.01 ± 0.76^{c}	8.15 ± 0.65^{b}	8.27 ± 0.83^{a}
Gelling Point Temperature (°C)	60.27 ± 2.00^{c}	62.89 ± 2.41^{b}	66.25± 2.28^{a}
Boiling Point Temperature (°C)	70.53 ± 2.03^{c}	72.26 ± 2.37^{b}	74.04 ± 3.12^{a}
Swelling Index	2.98 ± 0.32^{a}	2.56 ± 0.19^{b}	1.95 ± 0.15^{c}
Total Soluble Solids (%)	21.18 ± 1.15^{a}	18.87 ± 1.65^{b}	15.02 ± 1.42^{c}
Water Absorption Capacity (ml/g)	2.43 ± 0.21^{a}	2.28 ± 0.18^{a}	1.97 ± 0.14^{b}

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

3.2.3 Effect of Tuber Processing duration on the Physicochemical Properties of Yam Flour

Table 4 presents the impact of tuber processing duration on the physicochemical properties of yam flour. The pH of the flour samples varied significantly based on processing time, with a slight decrease as processing time increased from 0 min to 60 min. The pH of the flour samples was consistently within the alkalinity range. Longer processing times resulted in more intense heat treatment, potentially causing starch granules to tear during washing. Significant differences were observed in the fixed temperature of flours produced with varying exposure times. Iwuoha (2004) noted a similar trend in samples processed under atmospheric conditions. The same trend was observed for other physicochemical properties. The gelatinization point temperature of the yam ball flour treated at 0 min was higher than the gel point temperature of the flour treated at 30 min and 60 min. This is due to the gelatinization process that occurs during cooking. When yams are cooked, the starch granules absorb water, expand and then burst, releasing amylose and amylopectin molecules into the surrounding water. This gelatinization process breaks down the starch structure and lowers the gel point temperature compared to intact starch granules in fresh yam tubers. In addition, prolonged cooking can further degrade starch molecules, resulting in a decrease in gel point temperature as starch becomes more susceptible to gel formation, hence the low gel point temperature observed at 60 min exposure (Adebowale and Lawal, 2003). A similar trend was observed for the boiling point. This means that starch gelatinization requires more energy to raise the temperature of the water to boiling point, resulting in a higher boiling point for flour treated at 0 min compared to flour treated at 30 min and 60 min. In contrast, the swelling index and water absorption of yam tuber flour treated at 0 min were lower than the swelling index and water absorption capacity of flour treated at 30 min and 60 min due to the gelatinization process during cooking. When yams are cooked, the starch granules absorb water and expand, increasing their volume and water absorption. This expansion phenomenon results in a higher swelling index and water absorption of flour made from heat-treated yam compared to fresh yam tuber flour, which has intact starch granules that have limited water absorption and swelling capacity. In addition, prolonged cooking allows more starch granules to gelatinize, which further increases the swelling index and water absorption capacity of the flour (Falade and Ayetigbo, 2017). Similarly, total soluble solids of yam flour treated at 0 min was lower than that of flour treated at 30 min and 60 min, because soluble compounds dissolve during cooking. When yams are cooked, soluble sugars, starch balls and other compounds dissolve in the cooking water, increasing the total soluble solids content of the cooked yam flour. In contrast, fresh yam ball flour has not undergone any cooking or dissolution processes, resulting in a lower soluble solids content compared to flour made from cooked yams. Also, the longer the yam is cooked, the more extensive the dissolution process is, resulting in a higher total soluble solids content in the flour. Therefore, flour processed from yams cooked for 60 minutes would have a higher total soluble solids content compared to flour processed at 0 minutes and 30 minutes, due to the cumulative effect of dissolution during cooking (Iheagwara, 2022).

Table 4. *Physicochemical properties of yam flour as affected by tuber processing duration*

Properties	Tuber Processing Duration		
	0	30	60
pH	8.13 ± 0.62^a	8.10 ± 0.35^b	8.08 ± 0.43^c
Gelling Point Temperature (°C)	60.85 ± 3.25^a	59.72 ± 3.53^b	57.63 ± 3.18^C
Boiling Point Temperature (°C)	72.43 ± 3.42^a	71.54 ± 3.41^b	70.68 ± 3.33^c
Swelling Index	2.43 ± 0.36^c	2.63 ± 0.45^b	2.90± 0.47^a
Total Soluble Solids (%)	22.34 ± 1.56^c	24.09 ± 1.98^b	25.09 ± 1.90^a
Water Absorption Capacity (ml/g)	2.14 ± 0.62^b	2.18 ± 0.56^b	2.24 ± 0.47^a

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

3.2.4 Effect of Steeping Solution Type on Physicochemical Properties of Yam Flour

Table 5 shows the average values of the physicochemical properties of Yam according to the type of soaking solution. The pH values of different soaking solutions vary greatly. Sodium carbonate soaking solution has the highest pH (12.02), followed by sodium citrate (7.49), sodium chloride (6.88) and sucrose (6.85). This indicates that the type of soaking solution affects the acidity or alkalinity of the yam flour solution. The wide range of pH values of the soaking solutions suggests that the choice of soaking solution can significantly change the acidity or basicity of yam flour. This has implications for food processing as pH affects enzymatic activity, gel formation and the overall structure of the product. For example, the higher pH values observed during sodium carbonate soaking can affect the functionality and stability of yam flour in various food applications (Iwuoha, 2004). The gel point temperature also varies significantly. Sodium chloride has the highest gel point temperature (64.85 °C), followed by sodium citrate (64.72 °C), sucrose (60.68 °C) and sodium carbonate (59.38 °C). Like the gel point temperature, the boiling point temperature varies between soaking solutions. Sodium chloride has the highest boiling point (73.44 °C), followed by sodium citrate (72.77 °C), sucrose (71.60 °C). and sodium carbonate (71.52 °C). This indicates that different soaking solutions can affect the gelling and ripening of yam flour. Food manufacturers can use this knowledge to tailor processing parameters for specific product applications. For example, yam flour with a higher gelation temperature, e.g. soaked in sodium chloride, may be preferred for products that require a firmer texture or heat resistance (Iheagwara, 2024). The swelling index and water absorption were fairly uniform in all soaking solutions, and no significant differences ($p < 0.05$) were observed. "Sodium carbonate soaked samples have the highest SI (2.56) and WAC (2.25 ml/g) and sucrose soaked samples have the lowest SI (2.29) and WAC (2.17 ml/g). Although water absorption indicates the consistency of soaking of solutions, this property is crucial in determining the hydration and swelling behavior of yam flour during processing. Consistent water absorption capacity means consistency in processing characteristics, which facilitates predictable results in product development and quality control (Akubor and Ukwuru, 2003). the concentration of dissolved solids in the yam flour solution. The sodium carbonate soaking solution produced the highest soluble solids (25.34%), followed by sodium citrate (24.46%), sucrose (23.46%), and sodium chloride (23.07%). Variation in total soluble solids concentration indicates differences in the extractability of compounds from yam flour to the soaking solution. This can affect the taste, color and nutritional properties of products based on yam flour. Understanding these differences enables optimization of processing conditions to achieve desired organoleptic and nutritional properties in final products (Iheagwara et al., 2019b).

Table 5. *Physicochemical properties of yam flour as affected by steeping solution type*

Properties	Steeping Solution Type			
	Sodium Carbonate	Sodium Chloride	Sodium Citrate	Sucrose
pH	12.02 ± 0.87^{a}	6.88 ± 0.52^{c}	7.49 ± 0.61^{b}	6.85 ± 0.77^{c}
Gelling Point Temperature (°C)	59.38 ± 3.55^{c}	64.85 ± 3.11^{a}	64.72 ± 3.62^{a}	60.68 ± 3.83^{b}
Boiling Point Temperature (°C)	71.52 ± 2.96^{c}	73.44 ± 2.67^{a}	72.77 ± 2.80^{b}	71.60 ± 3.40^{c}
Swelling Index	2.56 ± 0.63^{a}	2.37 ± 0.76^{a}	2.42 ± 0.61^{a}	2.29 ± 0.52^{a}
Total Soluble Solids (%)	25.34 ± 1.94^{a}	23.07 ± 1.91^{c}	24.46 ± 1.73^{b}	23.46 ± 1.57^{c}
Water Absorption Capacity (ml/g)	2.25 ± 0.77^{a}	2.18 ± 0.83^{a}	2.20 ± 0.63^{a}	2.17 ± 0.67^{a}

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

3.2.5 Effect of Soaking Solution Concentration on the Physicochemical Properties of Yam Four

Table 6 shows the physicochemical properties of yam flour as affected by different concentrations of the soaking solution. As the concentration of the soaking solution increases, there is a significant increase in the pH of the yam flour. The highest pH is observed at the highest concentration of the soaking solution (30% w/v), while the lowest pH is 0% w/v. This suggests that a higher concentration of the soaking solution results in a more alkaline environment. Such a change in pH can affect enzyme activity, gel formation, and overall product stability during processing. For example, higher pH can improve the gelling properties of yam flour, which can be useful in certain foods that require thickening or binding properties (Iheagwara, 2012). There are no statistically significant differences between the gel point and boiling point of all concentrations of the soaking solution. This indicates that the temperature at which gel formation occurs and the boiling point of the yam flour solution remain relatively constant regardless of the concentration of the alcohol. As the concentration of the soaking solution increases, the swelling index decreases. This indicates that higher concentrations of the soaking solution may inhibit the ability of yam flour to absorb water and swell. Such a decrease in swelling index can affect the hydration and textural properties of yam flour-based products. For example, a lower swelling index can result in products with less moisture retention and a softer texture (Nwodo and Okoye, 2023). The total soluble solids content varies with the concentration of the soaking solution. The amount of total soluble solids decreases with increasing concentration of the soaking solution. This indicates that higher concentrations may result in lower solubility of yam flour components. This indicates that the concentration of the soaking solution can affect the extraction of soluble components from yam flour. Changes in total soluble solids can affect the taste, color and nutritional value of yam flour-based products (Iheagwara et al., 2019a). The water absorption capacity decreases as the concentration of the soaking solution increases. This indicates that higher concentrations of the soaking solution may limit the ability of yam flour to absorb water. Reduced water absorption can affect the hydration kinetics and processing characteristics of yam flour, which can affect product quality and composition (Iheagwara, 2013; Iheagwara et al., 2019a).

Table 6. *Physicochemical properties of yam flour as affected by steeping solution concentration*

Properties	Steeping Solution Concentration	(%m/v)		
	0	5	10	30
pH	7.69 ± 0.25[a]	9.41 ± 0.46[b]	9.61 ± 0.37[c]	10.03 ± 0.84s[d]
Gelling Point Temperature (°C)	60.02 ± 4.46[a]	60.18 ± 4.31[a]	61.91 ± 4.18[a]	62.00 ± 3.97[a]
Boiling Point Temperature (°C)	71.82 ± 4.78[a]	72.63 ± 3.38[a]	73.11 ± 3.68[a]	73.58 ± 3.79[a]
Swelling Index	2.43 ± 0.71[a]	2.33 ± 0.65[b]	2.28± 0.77[c]	2.19 ± 0.69[d]
Total Soluble Solids (%)	25.35 ± 1.73[a]	24.36 ± 1.59[b]	23.47 ± 1.51[c]	23.14 ± 1.64[c]
Water Absorption Capacity (ml/g)	2.40 ± 0.76[a]	2.21 ± 0.74[b]	2.18 ± 0.81[b]	2.11 ± 0.83[c]

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

3.2.6 Effect of Operating Temperature Parameters on Physico-chemical Properties of Yam Flour

The physicochemical properties of yam flour affected by the operating temperatures of the parameters, which show significant differences in properties at different temperatures, are shown in Table 7. There were significant differences between the evaluated parameters. Regarding pH, which is a critical parameter affecting various aspects of food quality including taste, texture and microbial stability, the pH of yam flour at 30 °C is recorded as 7.42 ± 0.35, indicating a slightly acidic nature. As the temperature increases to 50 °C and 80 °C, the pH increases significantly to 8.31 ± 0.46 and 9.43 ± 0.55. This change in alkalinity indicates that higher temperatures lead to increased alkalinity of yam flour and such an alkaline environment can affect enzymatic reactions, protein functionality and microbial growth (Iwuoha, 2004). The swelling index showed a similar trend to pH and reflects the ability of yam flour starch granules to absorb water and swell, which is important for properties such as viscosity, gel formation and textural properties. At 30 °C, the index is 2.23 ± 0.31, indicating moderate swelling. As the temperature rises to 50 °C and 80 °C, the expansion index also increases significantly - 2.75 ± 0.39 and 2.94 ± 0.46. This suggests that higher temperature increases the swelling capacity of yam flour. A higher spreading index at high temperature indicates increased water absorption and starch gelatinization, which can contribute to improved food texture, viscosity, and mouthfeel. This finding is consistent with Singh et al. (2003), Lawal (2004) and Iheagwara (2022) that starch expansion is temperature dependent and is particularly important in applications such as thickeners, gels and pastes where optimal texture and composition are desired. Total soluble solids represent the concentration of dissolved solids in a solution, including sugars, organic acids, and other solutes. Total soluble solids at 30 °C are recorded as 20.53 ± 1.34%. A significant increase of 26.34 ± 1.57% and 28.21 ± 1.40% is observed when the temperature increases to 50 °C and 80 °C. This indicates that higher temperature leads to higher soluble solids content in yam flour. The increase in total soluble solids with temperature suggests improved solubility of compounds in yam flour at higher temperatures, possibly due to increased water activity and thermal degradation of cell wall components (Iheagwara et al., 2019b). This property affects factors such as sweetness, taste and sensory perception of food, making it important for products such as drinks, soups and sauces. Water absorption capacity reflects the ability of yam flour to absorb and retain water, which is crucial for hydration, dough development and moisture retention in foods. Water absorption shows a similar pattern. At 30 °C it recorded 2.20 ± 0.52 ml/g. As the temperature increases to 50 °C and 80 °C, the absorption capacity increases to 3.02 ± 0.63 ml/g and 3.48 ± 0.61 ml/g. This indicates that higher temperature increases the water absorption capacity of yam flour. Higher water absorption at high temperature also indicates improved hydration and expansion of starch molecules, resulting in softer textures and increased moisture in finished products. This property is important in applications such as pastas, batters and wheat analogues, where moisture content and texture are key to product quality and consumer acceptance (Meka et al., 2019).

Table 7. *Physicochemical properties of yam flour as affected by parameter application temperature.*

Properties		Parameter Application Temperature (°C)	
	30	50	80
pH	7.42 ± 0.35[c]	8.31 ± 0.46[b]	9.43 ± 0.55[a]
Swelling Index	2.23 ± 0.31[c]	2.75 ± 0.39[b]	2.94 ± 0.46[a]
Total Soluble Solids (%)	20.53 ± 1.34[c]	26.34 ± 1.57[b]	28.21 ± 1.40[a]
Water Absorption Capacity (ml/g)	2.20 ± 0.52[c]	3.02 ± 0.63[b]	3.48 ± 0.61[a]

Means with the same superscripts along rows are not significantly different ($p < 0.05$)

4. Conclusion

This study has demonstrated the impact of processing methods, durations, steeping solutions, concentrations, and application temperatures on yam flour characteristics. The pH remains relatively stable under different conditions, while parameters such as gel point temperature, boiling point temperature, swelling index, total soluble solids, and water absorption vary significantly. These findings suggest that careful manipulation of processing parameters can affect the functional and organoleptic properties of yam flour-based products. Therefore, to optimize the physicochemical properties of yam flour, it is important to understand the interaction of various factors such as tuber part, processing method, duration, soaking solution, concentration and application temperature. This knowledge can help manufacturers adapt production processes to specific applications, resulting in the development of high-quality yam flour-based products with improved nutritional value, organoleptic properties and functionality.

6. References

1. Adebowale, K.O. & Lawal, O.S. (2003). Microstructure, physicochemical properties and retrogradation behaviour of Mucuna bean (Mucuna pruriens) starch on heat moisture treatments. Food Hydrocoll., 17: 265-272. doi: 10.1016/S0268-005X(02)00076-0
2. Adepoju, O.T., Boyejo, O. & Adeniji, P.O. (2018). Nutrient and antinutrient composition of yellow yam (Dioscorea cayenensis) products. Food Chemistry, 238: 160-165
3. Akubor, P.I. & Ukwuru, M.U. (2003). Functional properties and biscuit making potential of soybean and cassava flour blends. Plant Foods Hum Nutr, 58: 1-12. https://doi.org/10.1023/B:QUAL.0000040344.93438.df
4. Alabi, T.R., Adebola, P.O., Asrat, A., De Koeyer, D., Lopez-Montes, A. & Asiedu, R. (2019). Spatial multivariate cluster analysis for defining target population of environments in West Africa for yam breeding. International Journal of Applied Geospatial Research, 10: 1-30. 10.4018/IJAGR.2019070104
5. AOAC (2012). Official Methods of Analysis of AOAC International. 19th edition. AOAC International, Gaithersburg, Maryland, USA
6. Aprianita, A., Vasiljevic, T., Bannikova, A. & Kasapis, S. (2014). Physicochemical properties of flours and starches derived from traditional Indonesian tubers and roots. Journal of Food Science and Technology, 51(12): 3669-3679
7. Asiyanbi-Hammed, B. and Simsek, S. (2018). Comparison of physical and chemical properties of wheat flour, fermented yam flour, and unfermented yam flour. Journal of Food Processing and Preservation, 42(12), e13844
8. Chaïr, H., Sardos, J., Supply, A., Mournet, P., Malapa, R. & Lebot, V. (2016). Plastid phylogenetics of Oceania yams (Dioscorea spp., Dioscoreaceae) reveals natural interspecific hybridization of the greater yam (D. alata). Bot J Linn Soc., 180(3): 319–33
9. Dereje, B., Girma, A., Mamo, D. & Chalchisa, T. (2020). Functional properties of sweet potato flour and its role in product development: a review. International Journal of Food Properties, 23(1): 1639-1662. http://dx.doi.org/10.1080/10942912.2020.1818776
10. Epping, J. & Laibach, N. (2020). An underutilized orphan tuber crop-Chinese yam : a review. Planta, 252(4): 58. doi: 10.1007/s00425-020-03458-3. PMID: 32959173; PMCID: PMC7505826
11. Falade, K.O. & Ayetigbo, O.E. (2017). Effects of tempering (annealing), acid hydrolysis, low-citric acid substitution on chemical and physicochemical properties of starches of four yam (Dioscorea spp.) cultivars. J Food Sci Technol., 54(6): 1455-1466. doi: 10.1007/s13197-017-2568-x
12. FAO (2018). Food and Agriculture Organization of the United Nations. Rome, Italy. Retrieved from www.fao.org/statistics/en/
13. Harijono, T., Saputri, D. & Kusnadi, J. (2013). Effect of blanching on properties of water yam (Dioscorea alata) flour. Advance Journal of Food Science and Technology, 5(10): 1342-1350. DOI: 10.19026/ajfst.5.3108
14. Hoover, R. (2001). Composition, molecular structure and physicochemical properties of tuber and root starches, A review. Carbohyrate Polymers, 45: 253 - 267
15. Iheagwara, M.C. (2024). Pasting, Physicochemical and Gel Properties of Modified Bambara Groundnut (Vigna subterranean (L.) Verdc) Starch. J Food Technol Pres., 6(1): 152
16. Iheagwara, M.C. (2012). Physicochemical and retrogradation characteristics of modified sweet potato (Ipomoea batatas L (Lam)) starch. Journal of Agriculture and Food Technology, 2: 49–55
17. Iheagwara, M.C. (2013). Isolation, modification and characterization of sweet potato (Ipomoea batatas L (Lam)) starch. Journal of Food Processing and Technology, 4(1): 1–6
18. Iheagwara, M.C., Chibuzo, I.H. & Ibeabuchi, J.C. (2019a). Effect of tuber sections and processing conditions on the physicochemical properties of sweet potato (Ipomoea batatas L (Lam)) flour. Food Quality and Safety, 3(4): 273–278

19. Iheagwara, M.C., Chibuzo, I.H. and Ibeabuchi, J.C. (2019b). Effect of tuber sections, heat treatment and rehydration with process chemicals on the physicochemical properties of sweet potato (Ipomoea batatas L (Lam)) flour. Journal of Food Technology Research, 6(1): 28–36

20. Iheagwara, M.C. (2022). Influence of Tuber Sections and Chemical Additives on Physicochemical Properties of Pregelatinized Cassava (Manihot esculenta Crantz) Flour. J Food Process Technol., 13: 956

21. Ike, P.C. & Inoni, O.E. (2006). Determinants of yam production and economic efficiency among small-holder farmers in South Eastern Nigeria. Journal of Central European Agriculture, 7(2): .337-342

22. Iwuoha, C.I. (2004). Comparative evaluation of physicochemical qualities of flour from steam processed yam tubers. Food Chemistry, 85, pp.541 - 551

23. Kanu, A.N., Ezeocha, C.V. & Nwamaka, P.O. (2018). A Review on Bioactive Compounds of Yam Varieties for Human Disease Management. Asian Food Science Journal, 1(4): 1-10

24. Kaushal, P., Kumar, V. & Sharma, H.K. (2012). Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (Colocasia esculenta), rice (Oryza sativa) flour, pigeonpea (Cajanus cajan) flour and their blends. LWT - Food Science and Technology, 48(1): 59-68

25. Lawal, O.S. (2004). Composition, physicochemical properties and retrogradation characteristics of native, oxidized, acetylated and acid thinned new cocoyam (Xanthosoma sagitifolium) starch. Food Chemistry, 87: .205–218

26. Mbofung, C.M.F., Abubakar, Y.N., Njintang, A. & Balaam, F. (2006). Physicochemical and functional properties of six varieties of Taro (Colocasia esculenta L. Schott) flour. Journal of Food Technology, 4: 135–142

27. Meka, E., Igbabul, B.D. & Ikya, J. (2019). Chemical and Functional Properties of Composite Flours Made from Yellow Maize, Soybeans, and Jackfruit Seed. International Journal of Research and Innovation in Applied Science (IJRIAS), 4(11): 57-63

28. Moorthy, S.N. & Ramanujan, T. (1996). Variation in properties of starch in cassava varieties in relation to age of the crop. Starch, 38(2): 58–61

29. Nielsen, S.S. (2010). Food Analysis. 4th edn., Springer Science and Business Media, New York

30. Nindjina, C., Amani, G.N. & Sindic, M. (2011). Effect of blend levels on composite wheat doughs performance made from yam and cassava native starches and bread quality. Carbohydrate Polymer, 86(4):1637–1645. https://doi.org/10.1016/j.carbpol.2011.06.076

31. Nwodo, J.I. & Okoye, J.I. (2023). Effect of Soybean Flour Addition on the Proximate Composition, Functional and Pasting Properties of Soy-Poundo Yam Flour. Research Journal of Food Science and Quality Control, 9(3):63-77

32. Onwuka, G.I. (2018). Food Analysis and Instrumentation. Naphtali Print, Surulere, Lagos, Nigeria, pp.93-140

33. Oyefeso, B.O., Ayorinde, M.O., Ogunlade, C.A., Fadele, O.K. & Akintola, A. (2021). Effect of blanching period and drying temperature on selected physicochemical properties of cocoyam (Xanthosoma sagittifolium) flour. Agricultural and Food Science Journal of Ghana, 14:1457–1467

34. Padhan, B. & Panda, D. (2020). Potential of Neglected and Underutilized Yams (Dioscorea spp.) for Improving Nutritional Security and Health Benefits. Front. Pharmacol., 11:.496. doi: 10.3389/fphar.2020.00496

35. Quintana, S.E., Mendoza, J.P. & Zapateiro, L.A.C. (2023). Physicochemical, Structural, and Rheological Properties of Hawthorn Yam (Dioscorea rotundata) Flour. Curr Res Nutr Food Sci., 11(3). doi: http://dx.doi.org/10.12944/CRNFSJ.11.3.04

36. 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, 10(6):1341. doi: 10.3390/FOODS10061341

37. Singh, N., Singh, J., Kaur, L., Sodhi, N.S., & Gill, B.S. (2003). Morphological, thermal and rheological properties of starches from different botanical sources. Food Chemistry, 81: 219-231.

38. Sobukola, O.P., Babajide, J.M. & Ogunsade, O. (2013). Effect of brewers spent grain addition and extrusion parameters on some properties of extruded yam starch-based pasta. Journal of Food Processing and Preservation, 37(5):734-743. https://doi.org/10.1111/j.1745-4549.2012.00711.x

39. Tattiyakul, J., Naksriaporn, T., Pradipasena, P. & Miyawaki, O. (2006). Effect of moisture on hydrothermal modification of yam (Dioscorea hispider) dennst starch. Starch, 58:170–176

40. Zou, J., Xu, M., Zou, Y. & Yang, B. (2021). Physicochemical properties and microstructure of Chinese yam (Dioscorea opposita Thunb.) flour. Food Hydrocoll., 113:106448. doi: 10.1016/J.FOODHYD.2020.106448