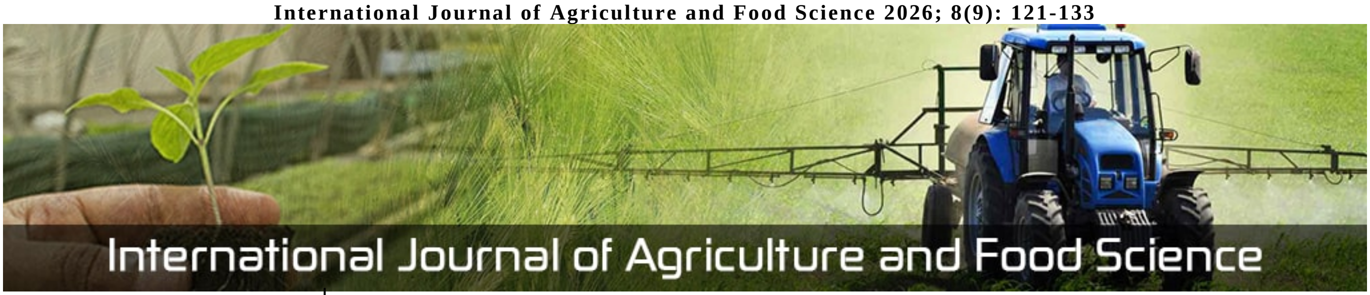

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Effect of pretreatments and drying techniques on functional and physicochemical properties of aerial yam (*Dioscorea Bulbifera*) powder

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Abstract
This research was conducted to study the effect of pretreatments and drying techniques on functional and physicochemical properties of aerial yam (*Dioscorea bulbifera*) powder. In the present study, four pre-treatments (Untreated, Cold water, Lukewarm water, Hot water blanching) were combined with three drying methods (Sun drying, Tray drying, Pyramid solar drying). The prepared aerial yam powders were evaluated for functional and physico-chemical properties. Among pretreatments hot water blanching showed superior results for bulk density (0.724 g/cm^3), oil absorption capacity (1.168 g/g), moisture (9.233%), fat (0.506%) and carbohydrate content (80.858%), while lukewarm water treatment was superior for water absorption capacity (2.630 g/g), starch content (28.733%) and fiber content (2.383 g/g). Control treatment showed higher values for ash content (3.392%), protein content (6.423%), total flavonoid content (4.403%QE), total phenol content (3.433%GAE) and total tannin content (1.529%TAE). Among the drying methods, tray drying showed superior performance for the studied parameters. Tray drying recorded minimum moisture content (9.088%) and fat content (0.533%). Tray drying recorded maximum bulk density (0.727 g/cm^3), oil absorption capacity (1.196 g/g), and water absorption capacity (2.527 g/g), ash content (3.188%), protein content (6.458%), fiber content (2.196%), carbohydrate content (80.743%), starch content (27.884%), total flavonoid content (3.549%QE), total phenol content (2.923%GAE) and total tannin content (1.328%TAE). In a combination treatments lukewarm water treatment with tray drying was found to be the most suitable treatment.

Keywords: *Dioscorea bulbifera*, aerial yam, pre-treatment, drying, tray drying

Introduction
Yams are widely cultivated and consumed by different groups of people in the tropics, among them is the *Dioscorea bulbifera*, which is also known as aerial yam. *Dioscorea bulbifera* is one of the most valuable tuber species in West Africa. It is often considered as a wild species of yam native to Africa and Asia. (FAO, 1985) [28].

The D.B.S.K.K.V., Dapoli, Dist. Ratnagiri has developed aerial yam variety in 2015, named as Konkan Kalika (KKVDb-1). It has average yield 5.3t/h and it gives high marketable yield, bulbs with pale yellowish flesh color, good taste and cooking quality, resistant to disease and pests and has been released for growing in Konkan region of Maharashtra.

It is a major edible medicinal plant employed in the treatment of diverse medical conditions. The use of *Dioscorea bulbifera* has been well documented in Chinese medicine and West and Central Africa. The plant is used in the treatment of different conditions such as ulcers, dysentery, diabetes, hyperlipidemia, and cancer (Ghosh *et al*. 2015; Ikiriza *et al*. 2019; Narzary *et al*. 2025) [30, 34, 56] The plant has bioactive compounds like flavonoids, phenols, tannins, saponins, alkaloids and terpenoids. The bioactive compounds in aerial yam showed various pharmacological properties like anti-inflammatory, antioxidant, antimicrobial, antidiabetic, and anticancer properties. The species shows a high degree of adaptability to different environments and has nutritional and medicinal versatility due to its high phytochemical content (Ghosh *et al*. 2015; Kuete *et al*. 2012) [30, 44]. The phytochemical composition of *Dioscorea* species, like other plants, may differ depending on factors such as geographical location, environment, and type of plant variety. Phytochemicals are natural bioactive compounds that occur in plants and have potential medicinal properties. *Dioscorea* species are known to produce secondary metabolites in large quantities and are widely used in the pharmaceutical industry and medicine. (Paul *et al.* 2022) [70].

Pretreatment techniques are used in a bid to reduce the effects of quality attributes degradation. They can also reduce the total drying time, which is more energy efficient and produce final products of high standards (Kucuk *et al.* 2014; Xiao *et al*. 2014) [45, 85]. pretreatments prior to the processing of agricultural products as it may destroy the enzymes responsible for degradation reactions, off-flavor, and undesirable changes in color, texture, and nutrients (Xiao *et al*. 2014) [85]. *Dioscorea bulbifera* significantly increases the value of this food crop and lowers post-harvest losses, which helps farmers make money. Overall, aerial yam is particularly vulnerable to enzymatic browning, which is brought on by polyphenol oxidases, oxidizing phenolic compounds when oxygen is present. Both enzymatic and non-enzymatic browning in powder are prevented by pretreatments (Igbokwe *et al*. 2016) [33].

Due to their high moisture content at harvest (Afoakwa and Sefa-Dedeh, 2001) [5] and susceptibility to deterioration, particularly when bruised (Fioreze and Morini, 2000) [29], yams are challenging to store. However, drying has been suggested as a viable post-harvest management option, particularly in developing nations with inadequately developed low-temperature distribution and handling facilities (Sagar and Kumar, 2010) [75]. It is possible to create a stable form of yam products to meet the demand for health foods because yams are considered health foods rather than staple foods in Oriental countries (Hsu *et al*. 2003) [32]. Dried yam powder is worth developing because powder can be conveniently used to make formulated foods or capsules for consumption and are easily stored for a long time (Akissoe *et al.* 2001) [6]. The drying conditions and techniques employed affect the final products flavor, taste, color, and nutrients. Yams may be subject to environmental contamination (Arslan and Özcan, 2010) [12]. Numerous studies have been conducted in recent years to find a substitute for the natural drying procedure, which ought to reduce the drying time, manage pests, and preserve the quality and appearance of yam powders (Jiang *et al.* 2013) [38].

The present study was undertaken to evaluate the influence of pretreatments and drying methods on the functional and physico-chemical properties of aerial yam powder.

Materials and Methods

Materials

The aerial yam tubers (variety - Kokan Kalika) procured from All India Coordinated Research Project (AICRP) on Tuber Crops, Central Experiment Station (CES), Wakavali, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. The experiment carried out in Department of Post-Harvest Management of Medicinal, Aromatic, Plantation, Spices and Forest Crops of the Post Graduate Institute of Post-Harvest Management, Killa-Roha, Dist-Raigad.

Methods

Powder Making

Fresh and mature tubers of aerial yam were washed thoroughly with clean water to remove adhering soil and other undesirable materials. The yam samples were sorted manually to remove damaged tubers, hand-peeled using stainless steel knives and sliced uniformly into 1 mm thickness to ensure uniform drying. The sliced samples were divided into four portions for different pre-treatments. One portion was kept as control without any treatment. The second portion was soaked in cold water (25°C) for 20 minutes. The third portion was soaked in lukewarm water (40 °C) for 20 minutes. The fourth portion was subjected to hot water blanching at 80°C for 2 minutes. After each treatment, excess surface water was drained and the slices were blotted gently to remove adhering moisture.

Each pre-treated sample was further divided into three equal portions and subjected to different drying methods. One portion was dried under direct sunlight for 3 days with an average temperature 27.33 ± 0.29°C on clean trays until constant weight was achieved. The second portion was dried in a tray dryer maintained at 40°C until constant weight was obtained. The third portion was dried in a pyramid solar dryer with an average temperature 27.33 ± 0.29°C under solar conditions until a constant weight was reached.

Thus, a total of twelve treatments (four pre-treatments × three drying methods) were employed in the study. The dried yam slices were milled using a laboratory pulverizer machine and sieved through a 1 mm mesh sieve to obtain fine aerial yam powder. The powder samples were packed in airtight zip LDPE pouches and stored at room temperature prior to further functional and physicochemical analysis. The flow chart for preparation of aerial yam powder given below.

Flow chart for preparation of aerial yam powder

Dioscorea bulbifera bulbs
↓
Washing
↓
Peeling
↓
Slicing
↓
Pretreatment
↓
Drying
↓
Milling
↓
Sieving
↓
Aerial yam powder

Methods

Functional properties of aerial yam powder

Bulk density (gm/cm^3)

Bulk density of aerial yam powder was carried out according to the procedure outlined by Onwuka (2005) [63]. Aerial yam powder sample was poured into a ten mil (10 ml) dried measuring cylinder and the bottom of the measuring cylinder was tapped repeatedly against the lab bench until the level of the sample remained constant at 10 ml. Bulk density was measured as weight per unit volume of the sample.

$$\text{Bulk density (gm/}cm^3\text{)} = \frac{Wight\ of\ sample\ (gm)}{Volume\ of\ sample\ after\ tapping\ (cm^3)}$$

Oil absorption capacity (g/g)

The oil absorption capacity of the sample was measured according to the methods of (Babu and Parimalavalli, 2014) [16] and (Bikila *et al*. 2022) [19], with slight modification. Weigh accurately 1 g of the powdered sample, put in pre-weighed centrifuge tube and add 6 ml of sunflower oil. Mix well in a vortex mixer for good contact between sample and oil. Then, centrifuged for 15 minutes. The excess oil was removed after centrifugation, and the mass of the centrifuge tube with oil absorbing sample was measured. This weight difference was taken as oil absorbed by the sample. The oil absorption capacity is expressed as grams of oil absorbed by gram of the dry sample with the formula given below:

Oil absorption capacity (g/g) = $\frac{W2-W1}{W1}$

Where:

W1: The initial weight of the dry sample (g)

W2: The weight of the sample after water absorption (g).

Water absorption capacity (g/g)

The water absorption capacity of the test sample was carried out according to the method outlined in (Babu and Parimalavalli, 2014) [16] and (Bikila *et al*. 2022) [19], but with slight modifications. First, 1 g of the ground sample was weighed and added to a pre-weighted centrifuge tube. Ten milliliters of distilled water were poured into the centrifuge tube, followed by thorough mixing of its contents using a vortex mixer. This was done to ensure that the test sample is evenly distributed in the water. Centrifugation was done for 15 minutes. The supernatant was carefully decanted without disturbing the sediment in the tube. The hydrated sample contained in the centrifuge tube was re-weighed. The water absorption capacity was measured based on the increase in the weight of the tube. Water absorption capacity is calculated in grams of water absorbed per gram of the dry test sample using the formula below:

Water absorption capacity (g/g) = = $\frac{W2-W1}{W1}$

Where:

W1: The initial weight of the dry sample (g)

W2: The weight of the sample after water absorption (g)

Physicochemical properties of aerial yam powder

Moisture (%)

The moisture content in the sample was determined by using the moisture analyzer. The moisture content of the given sample was determined by using the following formula (Ranganna, 1986) [73].

Moisture content (%) = $\frac{Ww-Wd}{Ww} \times 100$

Where,

Ww: initial weight of sample (g)

Wd: weight of dry sample (g)

Ash (%)

Ash is an inorganic residue left behind after the material is burnt to completion at a temperature of 550°C in a muffle furnace. Ash is the sum total of all the non-volatile inorganic compounds. Approximately 5 grams of the finely powdered dry sample was weighted and ash content of the paste sample determined. The tare weight of crucibles was measured and 5g of the sample put in each. The samples were then incinerated on a Bunsen burner and the material ashed at temperatures not exceeding 525 °C for 4-6 hours, in a muffle furnace. The crucibles were cooled and weighed. The difference in the weight was taken as the total ash content and expressed as a percentage (Rangana, 1986) [73]. The formula for calculating total ash (%) is as follows:

Ash (%)= $\frac{Weight\ of\ crucible\ with\ ash-Weight\ of\ the\ crucible}{Weight\ of\ sample\ (g)} \times 100$

Protein (%)

The protein content in the sample was estimated using a Micro-Kjeldahl Distillation process. The dried sample, dried at 65°C, was digested through the heating process using concentrated sulfuric acid (H2SO4), along with the digestion mixture, potassium sulphate (K2SO4), and copper sulphate (CuSO4). The resultant mixture was then made alkaline using 40% NaOH solution. Ammonium Sulphate was produced in the process. The ammonia was absorbed in 4% boric acid and titrated back with HCl. The percentage nitrogen content in the sample was estimated using the formula given below. The total protein content was determined by multiplying the nitrogen percentage with an appropriate factor (6.25) (AOAC, 2000) [10].

N% = $\frac{1.4\times\ (ml\ HCL-ml\ blank\ \times conc.of\ HCL}{weight\ of\ sample\ (g)}$

% Protein =% N × Factor (6.25)

Fat (%)

The amount of crude fat was calculated using the crude ether extract of the dried material. This was done by weighing 5g of the dry material and transferring it into a thimble, which was plugged with cotton and placed in the Soxhlet extractor, where it was extracted with anhydrous ether for 3 hours. Afterwards, the ether was evaporated, and the flask containing the residue was dried in an oven at 80oC to 100oC.

Fat% = $\frac{Weight\ of\ ether\ extract}{weight\ of\ sample\ taken} \times 100$

Fiber (%)

Approximately 2-5 g of fat-free and moisture-free sample was taken into a 500 ml beaker and then 200 ml of 0.25 N boiling sulfuric acid was added and kept boiling for 30 minutes while the volume remained constant by adding water at regular intervals. The mixture was then filtered using a muslin cloth and taken to the same beaker. Then 200 ml of boiling 0.313 N (1.25%) NaOH was added. The mixture was kept boiling for 30 minutes and then filtered using muslin cloth. The residue was washed with hot water until it became free from alkali and then with alcohol and ether. This was placed in the crucible, dried overnight at 80℃ to 100℃ and weighed. The crucible was then heated in the muffle furnace at 525℃ for 2-3 hours. It was cooled and weighed again. The difference in weights showed the weight of crude fiber (Ranganna, 1986) [73].

Fiber% = $\frac{W1-W2}{W} \times 100$

W1: weight of crucible with dried fiber residue (g)

W2: weight of crucible with ash after ignition (g)
W: weight of sample (g)

Carbohydrate (%)
Carbohydrate content of a sample dried at 65°C was determined by subtracting the total sum of protein, fiber, ash and fat from the total dry matter (Rangana, 1986) [73]. The carbohydrate was calculated by using following equation.

Carbohydrate (%) = 100 – (%Protein +%fat +%ash+%moisture)

Starch (%)
25 g weight of the sample was placed in a beaker. 15 ml of distilled water was added and a stiff paste was made that was left to settle in the beaker. This was taken out, pressed between hands and kneaded under the tap water until all the starch was washed into the collecting beaker through a 100 µm sieve. Supernatant was left to settle down while the excess water was removed. The starch was then dried in a hot air oven (Igbokwe *et al*. 2016) [33]. Dry starch was weighed and percent calculation is as follows:

$$\% \text{ Starch} = \frac{\text{Weight of starch}}{\text{Weight of sample}} \times 100$$

Total Flavonoid Content (%QE)
Methanolic extract of aerial yam powder was prepared according to the modified method. 0.5 gm of finely powdered sample was weighed accurately into a centrifuge tube and extracted with 20 ml of 80% methanol. The mixture was centrifuged at 6000 rpm for 20 min, and the supernatant was collected. The residue was re-extracted twice with 20 m of 80% methanol under the same conditions. The methanolic extract was used for the estimation of total flavonoid content. Total flavonoid content was determined by the aluminium chloride colorimetric method. An aliquot of 0.6 ml of methanolic extract was transferred into a test tube, followed by the addition of 4.4 ml distilled water and 0.3 ml of 5% sodium nitrite ($NaNO_2$) solution. The mixture was allowed to stand for 5 min, after which 0.3 ml of 10% aluminium chloride ($AlCl_3$) solution was added. After 6 min, 2.0 ml of 1 M sodium hydroxide (NaOH) was added and the final volume was made up to 10 ml with distilled water. The contents were mixed thoroughly, and the absorbance was measured at 510 nm using a UV–Visible spectrophotometer against a reagent blank. A calibration curve was prepared using quercetin as the standard, and the results were expressed as% quercetin equivalent of sample (Batuwita *et al*. 2025) [17].

Total phenol content (%GAE)
Methanolic extract of aerial yam powder was prepared according to the modified Folin–Ciocalteu method. 0.5 gm of finely powdered sample was weighed accurately into a centrifuge tube and 20 ml of 80% methanol was added. The mixture was centrifuged at 6000 rpm for 20 min, and the supernatant was collected. The residue was re-extracted twice with 20 ml of 80% methanol under the same conditions. The extract was used for the estimation of total phenolic content. Total phenolic content was determined by the Folin–Ciocalteu colorimetric method. An aliquot of 0.2 ml of methanolic extract was transferred into a test tube, followed by the addition of 0.5 mL Folin–Ciocalteu phenol reagent. After 3 min, 2.0 ml of 20% sodium carbonate (Na_2CO_3) solution was added and the volume was adjusted to 5.5 ml with distilled water. The reaction mixture was mixed thoroughly and heated in a boiling water bath for 1 min. After cooling to room temperature, the absorbance was measured at 650 nm using a UV–Visible spectrophotometer against a reagent blank. A standard calibration curve was prepared using gallic acid, and the results were expressed as% gallic acid equivalents of sample (Ghosh *et al*. 2012) [31].

Total Tannin Content (%TAE)
A water extract of aerial yam powder was prepared following the extraction procedure. About 0.5 g of finely powdered sample was weighed accurately into a 250 ml conical flask. 75 ml of distilled water was added, and the flask was placed in a boiling water bath for 30 min. The extract was then allowed to cool to room temperature and transferred into centrifuge tubes. The suspension was centrifuged at 6000 rpm for 20 min. The supernatant was collected in a 100 ml volumetric flask. The residue was re-extracted with 20 ml distilled water, centrifuged again under the same conditions, and the supernatant was combined with the first extract. Finally, the volume was made up to 100 ml with distilled water. This aqueous extract was used for the estimation of total tannin content. Total tannin content was determined using the Folin–Denis colorimetric method. An aliquot of 0.6 ml of the aqueous extract was taken in a test tube, followed by the addition of 7.9 ml distilled water, 0.5 ml Folin–Denis reagent, and 1.0 ml sodium carbonate (Na_2CO_3) solution. The reaction mixture was mixed thoroughly and allowed to stand for 30 min at room temperature for color development. The absorbance was measured at 700 nm using a UV–Visible spectrophotometer against a reagent blank. Total tannin content was calculated from a standard calibration curve prepared using tannic acid and expressed as% tannic acid equivalent of sample (Ojinnaka *et al*. 2017) [60].

Statistical analysis
The experiment was conducted the effect of different pretreatments and drying methods on the quality characteristics of aerial yam powder was studied using a Factorial Completely Randomized Design (FCRD). They were evaluated in a 4 × 3 factorial combination with four replications. The observations recorded for different quality parameters were subjected to analysis of variance (ANOVA). The statistical analysis and interpretation of the experimental data were carried out following the standard procedures described by Panse and Sukhatme (1985) [68].

Result and Discussion
Effect of different pretreatments and drying methods on the bulk density (g/cm^3) of aerial yam powder
The bulk density of aerial yam powder varied between 0.545 and 0.755 g/cm³ given in table 1. The bulk density depends on the particle size and density of the powder (Iwe *et al*. 2016) [36]. Higher bulk density and better flow properties facilitate easy handling, storage, packaging and processing of powders in nutraceutical and pharmaceutical formulations (Jallo *et al*. 2012) [37]. The maximum bulk density was observed in hot water blanching treatment (0.724 g/cm³) among pretreatments. Bulk density could be attributed to the heat treatment process applied when blanching (AACC,

2000) [1]. Similar findings were reported by Kayode *et al.* (2017) [40] who studied the bulk densities of blanched aerial yam powder. In a drying methods tray drying showing highest bulk density (0.727 g/cm^3). The bulk density of samples dried using heat consistently increased during the tray drying process (Koc *et al.* 2008) [43]. The same line of work was done by Wahab *et al.* (2016) [84] who observed variation in bulk density using different drying methods on yam four. Among interaction treatments highest bulk density was recorded in hot water blanching with tray drying (0.755 g/cm^3) which was at par with lukewarm water treatment with tray drying (0.734 g/cm^3).

Table 1: Effect of different pretreatments and drying techniques on bulk density (g/cm^3) of aerial yam powder

Treatments (Pretreatments)	Bulk density (g/cm^3) Drying methods			Mean
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	0.545	0.721	0.616	0.627
Cold water	0.662	0.696	0.684	0.681
Lukewarm water	0.667	0.734	0.697	0.699
Hot water blanching	0.709	0.755	0.708	0.724
Mean	0.646	0.727	0.676	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.005		0.013	
Drying (D)	0.004		0.012	
Factor (T X D)	0.008		0.023	

Effect of different pretreatments and drying methods on oil absorption capacity (g/g) of aerial yam powder

The oil absorption capacity ranged from 0.807 g/g to 1.325 g/g shown in table 2. Oil absorption capacity can be defined as the ability to absorb oil (Chandra and Samsher, 2013) [21]. The oil absorption capacity of the powder also makes it suitable in helping to enhance taste and texture of powder (Chandra and Singh, 2013) [21]. Among all the pretreatments studied, hot water blanching treatment showed the highest effectiveness (1.168 g/g). The impact of various processing techniques raised the value of oil absorption capacity in the powder samples. This was possibly because of the presence of more hydrophobic materials in the powder and by virtue of the heat used in processing (Kaur and Singh, 2006) [39]. Princewill-Ogbonna and Ezembaukwu, (2015) [72] showed the result of the oil absorption capacity on aerial yam flour using different pretreatments. Tray drying method demonstrated superior quality retention (1.196 g/g). Tray drying could have improved the oil binding property of the flour because of water evaporation and structural changes that resulted from heat, making more oil binding sites available (Wahab *et al.* 2016) [84]. This result was supported by Argaw *et al.* (2023) [11] on aerial yam flour. Maximum value was found in hot water blanching with tray drying (1.325 g/g) in a combination treatments.

Table 2: Effect of different pretreatments and drying methods on oil absorption capacity (g/g) of aerial yam

Treatments (Pretreatments)	Oil absorption capacity (g/g) Drying methods			Mean
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	0.807	1.132	0.952	0.964
Cold water	0.848	1.132	1.034	1.005
Lukewarm water	0.974	1.197	1.030	1.067
Hot water blanching	1.062	1.325	1.119	1.168
Mean	0.923	1.196	1.034	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.000		0.001	
Drying (D)	0.000		0.001	
Factor (T X D)	0.001		0.002	

Effect of different pretreatments and drying methods on water absorption capacity (g/g) of aerial yam powder

The water absorption capacity of aerial yam powder, as affected by various pre-treatments and drying methods, shown in table 3 ranging from 1.998 g/g to 2.887 g/g. The water absorption capacity refers to the volume occupied by the starch after hydration with excess water (Leonel *et al.* 2009) [47]. Water absorption capacity is important for food systems due to its ability to help increase yield and consistency as well as body in foods (Osundahunsi *et al.* 2003) [66]. It was observed that lukewarm water treatment showing good result (2.630%) among pretreatments. The weight and volume percentages and the dimensions of the powder samples increased with time and temperature during soaking (Sfayhi-Terras *et al.* 2021) [81]. Similarly, Igbokwe *et al.* (2016) [33] reported the water absorption capacity of pretreated aerial yam flour. Also, Princewill-Ogbonna and Ezembaukwu, (2015) [72] showed the result of the water absorption capacity on aerial yam flour using different pretreatments. Among drying methods, tray drying showed the highest water absorption capacity (2.527 g/g). It exhibited better efficiency than the other drying methods. Based on this study, continuous heat application and high temperatures in tray drying can enhance the water absorption capacity of the powder more than the use of solar and sun drying (Leonel *et al.* 2009; Osundahunsi *et al.* 2003) [47, 66]. These findings are in agreement with reports by Obadina *et al.* (2014) [58] in *Dioscorea* species. In a combination treatments highest water absorption capacity was recorded in lukewarm water treatment with tray drying (2.887 g/g).

Table 3: Effect of different pretreatments and drying methods on water absorption capacity (g/g) of aerial yam powder

Treatments (Pretreatments)	Water absorption capacity (g/g) Drying methods			Mean
	Sun drying	**Tray drying**	**Pyramid solar drying**	
Untreated	1.998	2.414	2.337	2.249
Cold water	2.047	2.099	1.986	2.044
Lukewarm water	2.317	2.887	2.686	2.630
Hot water blanching	2.015	2.710	2.495	2.406
Mean	2.094	2.527	2.376	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.021		0.060	
Drying (D)	0.018		0.052	
Factor (T X D)	0.036		0.104	

Effect of different pretreatments and drying methods on moisture (%) of aerial yam powder

Moisture values ranging from 8.400% to 12.825% of aerial yam powder under different pre-treatments and drying methods are given in table 4. Water content in the tubers is an important factor when considering their lifespan and resistance to microbial attack (Polycarp *et al*. 2012) [71]. The low levels of moisture are linked to increased shelf stability of powder as the moisture required for microorganism growth is greatly reduced (Tenyang *et al*. 2025) [82].

Among pretreatments lowest moisture content was found in hot water blanching treatment (9.233%). The process of hot water blanching treatment inhibits the browning reaction through the inactivation of polyphenol oxidases, which usually cause enzymatic browning helps in moisture removal as compared to cold water treatment and lukewarm water treatment (Li *et al*. 2019) [48]. Similar observations were reported by Falade *et al.* (2007) [27] on *Dioscorea alata* and *Dioscorea rotundata* slices. Also, Kayode *et al*. (2017) [40] reported the moisture content of blanched aerial yam flour. Among drying methods tray drying showing lowest moisture content (9.088%). In a tray dryer with thin-layer drying, the sample is dried in one layer, hence facilitating moisture removal (Kumar *et al*. 2012) [46]. Similar line of work was done by Nwadike *et al.* (2023) [57] who reported the moisture content of dried aerial yam flour. The combined effect of treatments further highlighted variation, with hot water blanching with tray drying showing minimum moisture content (8.400%) which was at par with untreated sample with tray drying (8.525%).

Table 4: Effect of different pretreatments and drying methods on moisture (%) of aerial yam powder

Treatments (Pretreatments)	Moisture (%) Drying methods			Mean
	Sun drying	**Tray drying**	**Pyramid solar drying**	
Untreated	10.175	8.525	9.300	9.333
Cold water	12.825	10.100	11.275	11.400
Lukewarm water	12.200	9.325	10.575	10.700
Hot water blanching	10.200	8.400	9.100	9.233
Mean	11.350	9.088	10.063	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.027		0.077	
Drying (D)	0.023		0.066	
Factor (T X D)	0.046		0.133	

Effect of different pretreatments and drying methods on ash (%) of aerial yam powder

The results revealed that ash content ranging from 2.575% to 3.563% showing significant differences among pre-treatments and drying methods in Table 5. The amount of ash content is used as an index for assessing mineral content in *Dioscorea.* (Tortoe *et al*. 2017) [83]. The ash content is an indication of how much minerals are packed into the cultivars of yams (Akonor *et al.* 2017) [7].

Among pretreatments control (untreated) sample showing highest mean ash content (3.392%). Pretreatments like soaking and blanching will lower ash because of the leaching of water-soluble minerals (Obadina *et al.* 2014) [58]. This result was supported by Ayo *et al.* (2018) [14] in aerial yam flour.

In drying methods tray drying showed good result (3.188%) The highest ash content in tray drying is attributable to the low moisture content of the tray dried sample and the influence of heat and air flow during drying (Mondal *et al.* 2019) [53]. Similar findings were reported by Kayode *et al.* (2023) [41] on aerial yam flour using different drying methods. Ojinnaka *et al.* (2017) [60] reported the similar range of ash content in dried aerial yam flour. The untreated sample with tray drying is most effective for achieving higher ash content (3.563%) in a combination treatments.

Table 5: Effect of different pretreatments and drying methods on ash (%) of aerial yam powder

Treatments (Pretreatments)	Ash (%) Drying methods			Mean
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	3.238	3.563	3.375	3.392
Cold water	2.575	3.000	2.925	2.833
Lukewarm water	2.638	2.975	2.700	2.771
Hot water blanching	2.850	3.213	3.150	3.071
Mean	2.825	3.188	3.038	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.021		0.060	
Drying (D)	0.018		0.052	
Factor (T X D)	0.036		0.104	

Effect of different pretreatments and drying methods on protein (%) of aerial yam powder

The protein content of aerial yam powder for different pre-treatments and drying methods ranging from 5.978% to 6.487% is summarized in table 6. Proteins are one of the major macronutrients that play vital roles in cell formation and physiology. They are also very important components of the human diet (Padhan and Panda, 2020) [67].

The highest protein value was observed in control (untreated) sample (6.423%). Pretreatments like soaking and blanching lower the protein content as a result of leaching of the soluble nitrogen compounds. Heating during blanching could denature the proteins, making them insoluble and thus easier to remove (Obadina *et al.* 2014) [58]. Similar findings were reported by Obadina *et al*. (2014) [58] in yam flour. Also, Induar *et al.* (2023) observed reduction in protein content of aerial yam flour after pretreatment.

Among drying methods, tray drying showed the highest protein content (6.458%). Uniform circulation of air is responsible during tray drying to facilitate higher soluble protein content in the powder. There was better retention of nutrient like protein and nutritional characteristics in a tray drying (Mondal *et al.* 2019) [53]. Similar work was done by Kayode *et al*. (2017) [40] who evaluated the protein content of dried aerial yam flour using different drying methods. When both factors pretreatment and drying method were considered together, the highest protein content was achieved with untreated sample with tray drying (6.592%).

Table 6: Effect of different pretreatments and drying methods on protein (%) of aerial yam powder

Treatments (Pretreatments)	Protein (%) Drying methods			Mean
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	6.189	6.592	6.487	6.423
Cold water	5.978	6.370	6.394	6.247
Lukewarm water	5.997	6.382	6.271	6.217
Hot water blanching	6.068	6.487	6.475	6.344
Mean	6.058	6.458	6.407	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.005		0.014	
Drying (D)	0.004		0.013	
Factor (T X D)	0.009		0.025	

Effect of different pretreatments and drying methods on fat (%) of aerial yam powder

The fat content of aerial yam powder as influenced by different pre-treatments and drying methods is presented in table 7 ranged from 0.467% to 0.683%. Fat is generally preferred in smaller amounts when it comes to tuber powders because it will help to increase their storage capability (Serna-Saldivar and García-Lara, 2016) [79].

Among all the pretreatments studied, blanching showed the lowest fat content (0.506%). Fat content reduction can be associated with heat disruption of cellular components through blanching, which facilitates lipid loss from the membrane during further processing (Melese and Keyata, 2022) [52]. Due to the low amount of fat in the blanched samples, there was a high likelihood of a prolonged shelf life in relation to rancidity (Oluwalana and Oluwamukomi, 2011) [62]. Similar findings were reported by Orhevba and Ajiboye, (2020) [64] in yam (*Dioscorea rotundata*) flour, where blanching time and slice thickness significantly affected the fat content.

Tray drying method demonstrated superior result (0.533%) compared to the remaining drying methods. The reason behind the low fat value of tray dried samples lies in its low moisture content and high yield (Mondal *et al*. 2019) [53]. Argaw *et al*. (2023) [11] observed variation in fat content in aerial yam flour due to the effect of drying methods. Abara, (2011) [2] found similar findings in proximate of the of *Dioscorea bulbifera* tuber. The lowest fat content was recorded in hot water blanching with tray drying (0.467%) which was at par with hot water blanching with pyramid solar drying (0.483%) in a combination treatments.

Table 7: Effect of different pretreatments and drying methods on fat (%) of aerial yam powder

Treatments (Pretreatments)	Fat (%)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	0.683	0.567	0.633	0.628
Cold water	0.667	0.583	0.633	0.628
Lukewarm water	0.667	0.517	0.617	0.600
Hot water blanching	0.567	0.467	0.483	0.506
Mean	0.646	0.533	0.592	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.007		0.020	
Drying (D)	0.006		0.017	
Factor (T X D)	0.012		0.034	

Effect of different pretreatments and drying methods on fiber (%) of aerial yam powder

A significant interaction effect between pre-treatments and drying methods was observed. The fiber content ranged from 1.617% to 2.583% given in table 8. Fiber present in yams is crucial in facilitating digestive processes in humans and animals. (Dhingra *et al*. 2012; Sánchez-Zapata *et al*. 2015) [24, 77]. According to study fiber consumption decreases the risk of obesity, cardiovascular diseases, diabetes and causes soft stools (Anderson *et al*. 2009) [8].

Among all the pretreatments studied, lukewarm water treatment showed highest fiber content (2.383%). This may have been caused by the extraction of the anti-nutrient components (Adebayo, 2014) [3]. Ayo *et al*. (2018) [14] also reported a relatively high fiber content in soaked-dried aerial yam flour. In drying methods tray drying showing highest fiber content (2.196%). Variations in values could be due to differences in the methods used for drying and the extent of homogenization. Dhore *et al*. (2023) [25] similarly reported higher crude fiber content in cabinet tray-dried aerial yam flour than in sun-dried powder. Maximum value was in lukewarm water treatment with tray drying (2.583%) in a combination treatments.

Table 8: Effect of different pretreatments and drying methods on fiber (%) of aerial yam powder

Treatments (Pretreatments)	Fiber (%)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	1.817	1.933	1.767	1.839
Cold water	1.617	1.883	1.700	1.733
Lukewarm water	2.183	2.583	2.383	2.383
Hot water blanching	2.167	2.383	2.317	2.289
Mean	1.946	2.196	2.042	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.013		0.039	
Drying (D)	0.012		0.034	
Factor (T X D)	0.023		0.067	

Effect of different pretreatments and drying methods on carbohydrate (%) of aerial yam powder

The carbohydrate content of aerial yam powder, as affected by various pre-treatments and drying methods, is presented in table 9 ranged from 77.955% to 81.468%. A key proximate composition is carbohydrates, which play an important role in energy formation and cellular physiology (Baah *et al*. 2009) [15]. Hot water blanching treatment showed highest carbohydrate content (80.858%). This implies that the content of carbohydrate will be increased through blanching (Egbuonu and Nzewi, 2016) [26]. Similar findings were reported by Igbokwe *et al*. (2016) [33], who observed that blanching significantly increased the carbohydrate content of *Dioscorea bulbifera* flour.

In drying methods highest carbohydrate content found in tray drying (80.743%). This could be due to the removal of water in aerial yam which makes it concentrated in a smaller volume leading to an increase in the carbohydrate content (Ojeniran *et al*. 2025) [59]. Similar line of work was done by Nwadike *et al*. (2023) [57] who reported the carbohydrate content of dried aerial yam flour. In a interaction treatments highest value was observed in hot water blanching with tray drying (81.468%).

Table 9: Effect of different pretreatments and drying methods on carbohydrate (%) of aerial yam powder

Treatments (Pretreatments)	Carbohydrate (%)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	79.715	80.755	80.205	80.225
Cold water	77.955	79.947	78.773	78.892
Lukewarm water	78.500	80.802	79.838	79.713
Hot water blanching	80.315	81.468	80.792	80.858
Mean	79.121	80.743	79.902	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.037		0.108	
Drying (D)	0.032		0.093	
Factor (T X D)	0.065		0.186	

Effect of different pretreatments and drying methods on starch (%) of aerial yam powder

Starch content of aerial yam powder ranging from 23.630% to 29.471% under different pre-treatments and drying methods are given in table 10. Starch is a big source in our diets with many uses too. Starch are responsible for the taste and consistency of foods and therefore influence consumer choice (Sajilata *et al.* 2006) [76].

Among the pretreatments, lukewarm water treatment recorded the highest starch content (28.733%). During lukewarm water soaking, there is leaching of other nutrients, resulting in changes to the structure thereby improving the accessibility of the starch and increasing starch content of powder (Marconi *et al.* 2000) [50]. Similar variation in starch content due to different pretreatment methods was reported by Olatunde *et al.* (2016) [61], who observed a significant effect of pretreatment on the starch content of sweet potato flour. Among the drying methods, tray drying recorded the highest starch content (27.884%). Tray drying affected the starch structure by lowering its digestibility and creating resistant starch (Björck *et al.* 1984) [20]. Starch content was found low in sun dried and pyramid dried samples because starch crystallinity was decreasing with an increase in the drying temperature (Aviara *et al.* 2010) [13]. Similar effects of processing conditions on starch content of underutilized tuber flours were also reported by Orji, (2023) [65]. Olatunde *et al.* (2016) [61] also reported significant variation in starch content of sweet potato flour due to drying methods, indicating that drying conditions can influence starch retention in flour. The combined effect of treatments further highlighted variation, with lukewarm water treatment with tray drying showing maximum starch content (29.471%).

Table 10: Effect of different pretreatments and drying methods on starch (%) of aerial yam powder

Treatments (Pretreatments)	Starch (%)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	23.630	25.349	24.899	24.626
Cold water	26.766	28.044	27.482	27.431
Lukewarm water	28.229	29.471	28.499	28.733
Hot water blanching	26.777	28.674	27.142	27.531
Mean	26.350	27.884	27.005	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.006		0.018	
Drying (D)	0.005		0.015	
Factor (T X D)	0.011		0.030	

Effect of different pretreatments and drying methods on total flavonoid content (%QE) of aerial yam powder

The results revealed that total flavonoid content ranged from 0.757%QE to 4.657%QE shown in table 11. Flavonoids, the biggest group of natural phenolic compounds, appear in various parts of plants both freely and as glycosides. They've got a bunch of biological activities, like antimicrobial, mitochondrial adhesion inhibition, antiulcer, and more (Bhat *et al.* 2005) [18]. Control (untreated) sample showed superior performance with the highest flavonoid content (4.403%QE). Loss of nutrients in the process of other treatments can be attributed to the leaching effect (Mukherjee and Chattopadhyay, 2007) [55]. Similar findings were reported by Indaur *et al.* (2023),
who observed variation in flavonoid content between raw and boiled *Dioscorea bulbifera* flour. Drying method tray drying contributed to higher flavonoid content (3.549%QE). Tray drying owing to its effectiveness because of their moderate temperature in preventing the breakdown of flavonoids (Ling *et al.* 2015) [49]. The processes of sun drying depend on weather conditions and duration of daylight cause dehydration. The low level of flavonoids could be due to the long drying period (Ling *et al.* 2015) [49]. Kayode *et al.* (2017) [40] studied different drying methods for *Dioscorea bulbifera* flour and reported presence of flavonoid content. The interaction between factors was significant, suggesting that the combination of lukewarm water treatment with tray drying (4.657%QE) is most effective for achieving higher flavonoid content which
was at par with untreated sample with tray drying (4.508%).

Table 11: Effect of different pretreatments and drying methods on total flavonoid content (%QE) of aerial yam powder

Treatments (Pretreatments)	Total Flavonoid Content (%QE)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	4.345	4.508	4.357	4.403
Cold water	2.970	3.487	3.216	3.226
Lukewarm water	3.165	4.657	4.018	3.947
Hot water blanching	0.757	1.542	1.010	1.103
Mean	2.809	3.549	3.151	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.039		0.111	
Drying (D)	0.034		0.097	
Factor (T X D)	0.067		0.193	

Effect of different pretreatments and drying methods on total phenol content (%GAE) of aerial yam powder

The phenol content of aerial yam powder obtained using different pretreatments and drying methods is summarized in table 12 which is ranged from 0.483%GAE to 3.749%GAE. Phenolics have various biochemical activities, including antioxidant, antimutagenic, and anticarcinogenic properties, plus they can modify gene expression (Marinova *et al*. 2005) [51].

Control (untreated) sample showed the highest phenol content (3.433%GAE). The decrease in phenol concentrations is due to their leaching from the samples into the water used in the pretreatment process (Chipurura *et al.* 2010) [23]. Setyawan *et al*. (2021) [80] reported that processing techniques influenced the total phenolic content of *Dioscorea bulbifera* flour. Similarly, Ratnaningsih *et al.* (2018) [74] reported that soaking treatments affected the phenolic content of *Dioscorea alata* flour.

Drying method tray drying contributed to higher phenol content (2.923%GAE). Tray drying generally involves convective heat transfer, in which hot air is circulated over the sample to facilitate heat transfer (Patil and Shukla, 1998). Extreme heat can cause the destruction of phytochemicals that are susceptible to high temperatures (Kerr, 2013) [42]. Adebowale *et al*. (2018) [4] reported that drying method significantly affected the phenolic content of yam flour. When both factors were considered together, they were showing significant difference. The highest phenol content was achieved with untreated sample with tray drying (3.749% GAE) which was at par with lukewarm water treatment with tray drying (3.667%).

Table 12: Effect of different pretreatments and drying methods on total phenol content (%GAE) of aerial yam powder

Treatments (Pretreatments)	Total Phenol Content (%GAE)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	3.126	3.749	3.423	3.433
Cold water	2.547	3.276	2.901	2.908
Lukewarm water	2.940	3.667	3.422	3.339
Hot water blanching	0.483	1.000	0.875	0.786
Mean	2.274	2.923	2.655	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.018		0.055	
Drying (D)	0.016		0.048	
Factor (T X D)	0.032		0.095	

Effect of different pretreatments and drying methods on total tannin content (%TAE) of aerial yam powder

The tannin content of aerial yam powder as influenced by different pre-treatments and drying methods is presented in table 13 ranged from 0.428%TAE to 1.576%TAE. Tannins have some neat therapeutic uses because of their anti-inflammatory, anti-fungal, antioxidant, and healing properties (Zuanazzi and Montanha, 2004; Santos and Mello, 2004) [86, 78].

The highest tannin content was recorded in control (untreated) sample (1.529%TAE). The reason for the low concentration of tannin in other treatments because they were leached out. (Mongwaketse *et al.* 2022) [54]. Similar findings were reported by Egbuonu and Nzewi. (2014) [26] who observed a significant and time-dependent reduction in tannin content of bitter yam flour

The highest tannin content was observed in tray drying (1.328% TAE). The type of heat transfer in tray drying is important in determining the amount of phytochemicals that remain (Patil and Shukla, 1998). Adebowale *et al.* (2018) [4] reported that drying method influenced the tannin content of yam flour. Among interaction treatments highest tannin content was recorded in lukewarm water treatment with tray drying (1.576% TAE) which was at par with untreated sample with tray drying (1.152% TAE).

Table 13: Effect of different pretreatments and drying methods on total tannin content (%TAE) of aerial yam powder

Treatments (Pretreatments)	Total Tannin Content (%TAE)			Mean
	Drying methods			
	Sun drying	Tray drying	Pyramid solar drying	
Untreated	1.486	1.552	1.548	1.529
Cold water	1.062	1.463	1.074	1.200
Lukewarm water	1.278	1.576	1.493	1.449
Hot water blanching	0.447	0.721	0.428	0.532
Mean	1.068	1.328	1.136	
Factors	S.Em (±)		CD at 5%	
Pretreatments (T)	0.018		0.049	
Drying (D)	0.016		0.042	
Factor (T X D)	0.032		0.084	

Conclusion

Based on the results of present study, it is concluded that hot water blanching treatment recorded the highest values of bulk density, oil absorption capacity and carbohydrate content and superior values of moisture content and fat content. Lukewarm water treatment recorded the highest values of water absorption capacity, fiber content and starch content whereas the control (untreated) recorded the highest values of ash content, protein content, total flavonoid content, total phenol content and total tannin content. Among the different drying methods, tray drying was found to be the best drying method for preparation of aerial yam powder based on its overall quality characteristics. Based on the comparative evaluation of different pre-treatments and drying methods, the powder prepared from aerial yam using lukewarm water treatment with tray drying was found to be the most suitable treatment.

References

1. American Association of Cereal Chemists. Approved methods of the American Association of Cereal Chemists. 10th ed. St. Paul (MN): American Association of Cereal Chemists; 2000.
2. Abara AE. Proximate and mineral elements composition of the tissue and peel of *Dioscorea bulbifera* tuber. Pakistan Journal of Nutrition. 2011;10(6):543-551.
3. Adebayo SF. Effect of soaking time on the proximate, mineral compositions and anti-nutritional factors of lima bean. Food Science and Quality Management. 2014;27(2):2224-6088.
4. Adebowale AA, Wahab AB, Sobukola PO, Obadina AO, Kajihausa EO, Adegunwa OM, *et al*. The antinutritional and vitamin composition of high-quality yam flour as affected by yam species, pretreatment, and drying method. Food Science and Nutrition. 2018;6(8):1985-1990.
5. Afoakwa EO, Sefa-Dedeh S. Chemical composition and quality changes occurring in *Dioscorea dumetorum* Pax tubers after harvest. Food Chemistry. 2001;75:85-91.
6. Akissoe N, Hounhouigan DJ, Brias N, Vernier P, Nago CM, Olorunda AO. Physical, chemical and sensory evaluation of dried yam (*Dioscorea rotundata*) tubers, flours and "amala" a flour-derived product. Tropical Science. 2001;41:151-155.
7. Akonor PT, Tortoe C, Buckman ES, Hagan L. Proximate composition and sensory evaluation of root and tuber composite flour noodles. Cogent Food & Agriculture. 2017;3(1):129158.
8. Anderson JW, Baird P, Davis RH Jr, Ferreri S, Knudtson M, Koraym A, *et al*. Health benefits of dietary fiber. Nutrition Reviews. 2009;67(4):188-205.
9. Association of Official Analytical Chemists. Official methods of analysis. 12th ed. Washington (DC): Association of Official Analytical Chemists; 1975.
10. Association of Official Analytical Collaboration. International Association of Official Analytical Chemists. Washington (DC): Association of Official Analytical Collaboration; 2000.
11. Argaw SG, Beyene TM, Woldemariam HW, Esho TB. Physico-chemical and functional characteristics of flour of Southwestern Ethiopia aerial and tuber yam (*Dioscorea*) species processed under different drying techniques. Journal of Food Composition and Analysis. 2023;119:105269.
12. Arslan D, Özcan MM. Study the effect of sun, oven and microwave drying on quality of onion slices. LWT-Food Science and Technology. 2010;43:1121-1127.
13. Aviara NA, Igbeka JC, Nwokocha LM. Effect of drying temperature on physicochemical properties of cassava starch. International Agrophysics. 2010;24(3):219-225.
14. Ayo JA, Ojo M, Obike JI. Proximate composition, functional and phytochemical properties of pre-heated aerial yam flour. Research Journal of Food Science and Nutrition. 2018;3(1):1-8.
15. Baah FD, Maziya-Dixon B, Asiedu R, Oduro I, Ellis WO. Nutritional and biochemical composition of *Dioscorea alata* (*Dioscorea* spp.) tubers. Journal of Food, Agriculture and Environment. 2009;7(2):373-378.
16. Babu AS, Parimalavalli R. Effect of starch isolation method on properties of sweet potato starch. The Annals of the University Dunarea de Jos of Galati, Fascicle VI – Food Technology. 2014;38(1):48-63.
17. Batuwita BKHH, Jayasinghe JMJMK, Perera PRD, Jayasinghe CVL. Nutritional profile and chemical properties of four accessions of hingurala (*Dioscorea alata*) as a highly nutritious starch-based functional food. Food and Humanity. 2025;4:100614.
18. Bhat SV, Nagasampagi BA, Sivakumar M. Chemistry of natural products. New Delhi: Narosa Publishing House; 2005.
19. Bikila AM, Tola YB, Esho TB, Forsido SF, Mijena DF. Starch composition and functional properties of raw and pretreated anchote (*Coccinia abyssinica* (Lam.) Cogn.) tuber flours dried at different temperatures. Food Science and Nutrition. 2022;10(3):645-660.
20. Björck I, Asp NG, Birkhed D, Eliasson AC, Sjöberg LB, Lundquist I. Effects of processing on starch availability *in vitro* and *in vivo*. II. Drum-drying of wheat flour. Journal of Cereal Science. 1984;2(3):165-178.
21. Chandra S, Samsher. Assessment of functional properties of different flours. African Journal of Agricultural Research. 2013;8(38):4849-4852.
22. Chandra S, Singh S. Assessment of functional properties of different flours. African Journal of Agricultural Research. 2013;8(38):4849-4852.
23. Chipurura B, Muchuweti M, Manditseraa F. Effects of thermal treatment on the phenolic content and antioxidant activity of some vegetables. Asian Journal of Clinical Nutrition. 2010;2:93-100.
24. Dhingra D, Michael M, Rajput H, Patil RT. Dietary fiber in foods: a review. Journal of Food Science and Technology. 2012;49(3):255-266.
25. Dhore SG, Raut VU, Thorat NR, Khan SM. Study on nutritional quality of aerial yam flour. The Pharma Innovation Journal. 2023;12(12):1699-1703.
26. Egbuonu ACC, Nzewi DC. Influence of blanching on some nutrient and anti-nutrient compositions of bitter yam (*Dioscorea dumetorum*). British Journal of Applied Science and Technology. 2016;16(2):1-8.
27. Falade KO, Olurin TO, Ike EA, Aworh OC. Effect of pretreatment and temperature on air-drying of *Dioscorea alata* and *Dioscorea rotundata* slices. Journal of Food Engineering. 2007;80:1002-1010.
28. Food and Agriculture Organization of the United Nations. FAO production yearbook 1985. Rome: Food and Agriculture Organization of the United Nations; 1985. Vol. 39.
29. Fioreze R, Morini B. Yam (*Dioscorea* sp.) drying with different cuts and temperatures: experimental and simulated results. Ciência e Tecnologia de Alimentos. 2000;20(2).
30. Ghosh S, More P, Nitnavare R, Jagtap S, Chippalkatti R, Derle A, *et al*. Antidiabetic and antioxidant properties of copper nanoparticles synthesized by medicinal plant *Dioscorea bulbifera*. Journal of Nanomedicine and Nanotechnology. 2015;(S6):007.

31. Ghosh S, Patil S, Ahire M, Kitture R, Kale S, Pardesi K, *et al*. Synthesis of silver nanoparticles using *Dioscorea bulbifera* tuber extract and evaluation of its synergistic potential in combination with antimicrobial agents. International Journal of Nanomedicine. 2012;7:483-496.
32. Hsu C, Chen W, Weng YM, Tseng CY. Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. Food Chemistry. 2003;83:85-92.
33. Igbokwe CJ, Akubor PI, Mbaeyi-Nwaoha IE. Effect of processing on the chemical composition, phytochemical contents and functional properties of yellow fleshed aerial yam (*Dioscorea bulbifera*) flour. International Journal of Pharmacy and Pharmaceutical Sciences. 2016;8(11):162-167.
34. Ikiriza H, Ogwang PE, Peter EL, Hedmon O, Tolo CU, Abubaker M, *et al*. *Dioscorea bulbifera*: highly threatened African medicinal plant, a review. Cogent Biology. 2019;5(1):1631561.
35. Induar S, Behera BC, Naik PK, Dubey D. Comparative antioxidant and phytochemical activity of raw and boiled tuber of *Dioscorea bulbifera* collected from tribal forest of Sundargarh district, Odisha, India. Carpathian Journal of Food Science and Technology. 2023;15(4):15-24.
36. Iwe MO, Onyeukwu U, Agiriga AN. Proximate, functional and pasting properties of FARO 44 rice, African yam bean and brown cowpea seeds composite flour. Cogent Food & Agriculture. 2016;2:1142409.
37. Jallo LJ, Ghoroi C, Gurumurthy L, Patel U, Davé RN. Improvement of flow and bulk density of pharmaceutical powders using surface modification. International Journal of Pharmaceutics. 2012;423(2):213-225.
38. Jiang X, Huang LF, Zheng SH, Chen SL. Sulphur fumigation, a better or worse choice in preservation of Traditional Chinese Medicine. Phytomedicine. 2013;20:97-105.
39. Kaur M, Singh N. Relationships between the selected properties of seeds, flours and starches from different chickpea cultivars. International Journal of Food Properties. 2006;9:597-608.
40. Kayode RMO, Buhari OJ, Otutu LO, Ajibola TB, Oyeyinka SA, Opaleke DO, *et al*. Physicochemical properties of processed aerial yam (*Dioscorea bulbifera*) and sensory properties of paste (amala) prepared with cassava flour. Journal of Agricultural Sciences. 2017;12(2):84-94.
41. Kayode RMO, Chia CN, Kayode BI, Olowoseye AP, Joshua VA. Quality evaluation of chin-chin produced from aerial yam (*Dioscorea bulbifera*) and wheat flour blends. Food Production, Processing and Nutrition. 2023;5(1):45.
42. Kerr WL. Food drying and evaporation processing operations. In: Handbook of farm, dairy and food machinery engineering. San Diego: Academic Press; 2013. p. 317-354.
43. Koc B, Eren I, Ertekin FK. Modelling bulk density, porosity and shrinkage of quince during drying: the effect of drying method. Journal of Food Engineering. 2008;85(3):340-349.
44. Kuete V, Betrandteponno R, Mbaveng AT, Tapondjou LA, Meyer JJ, Barboni L. Antibacterial activities of the extracts, fractions and compounds from *Dioscorea bulbifera*. BMC Complementary and Alternative Medicine. 2012;12:228.
45. Kucuk H, Midilli A, Kilic A, Dincer I. A review on thin-layer drying-curve equations. Drying Technology. 2014;32:757-773.
46. Kumar N, Sarkar BC, Sharma HK. Mathematical modelling of thin layer hot air drying of carrot pomace. Journal of Food Science and Technology. 2012;49:33-41.
47. Leonel M, Sarmento SBS, Cereda MP. New starches for the food industry: *Curcuma longa* and *Curcuma zedoaria*. Carbohydrate Polymers. 2009;54:385-388.
48. Li Y, Liu XQ, Liu SS, Liu DH, Wang X, Wang ZM. Transformation mechanisms of chemical ingredients in steaming process of *Gastrodia elata* Blume. Molecules. 2019;24(17):3159.
49. Ling ALM, Yasir S, Matanjun P, Abu Bakar MF. Effect of different drying techniques on the phytochemical content and antioxidant activity of *Kappaphycus alvarezii*. Journal of Applied Phycology. 2015;27(4):1717-1723.
50. Marconi E, Ruggeri S, Cappelloni M, Leonardi D, Carnovale E. Physicochemical, nutritional, and microstructural characteristics of chickpeas (*Cicer arietinum* L.) and common beans (*Phaseolus vulgaris* L.) following microwave cooking. Journal of Agricultural and Food Chemistry. 2000;48(12):5986-5994.
51. Marinova D, Ribarova F, Atanassova M. Total phenolics and total flavonoids in Bulgarian fruits and vegetables. Journal of the University of Chemical Technology and Metallurgy. 2005;40:255-260.
52. Melese AD, Keyata EO. Impacts of pretreatment techniques on the quality of tuber flours. The Scientific World Journal. 2022:1-10.
53. Mondal IH, Rangan L, Uppaluri RV. Effect of oven and intermittent airflow assisted tray drying methods on nutritional parameters of few leafy and non-leafy vegetables of North-East India. Heliyon. 2019;5(11).
54. Mongwaketse T, Kruger J, Lewies A, Baumgartner C, Smuts M. Minerals, antinutrients content and the bioaccessibility of iron and zinc in cooked, spontaneously fermented-dried, and blanched-dried dark green leafy vegetables commonly consumed in Sub-Saharan Africa. Food Science and Technology. 2022;154:112682.
55. Mukherjee PK, Chattopadhyay. Whirling bed blanching of potato cubes and its effects on product quality. Journal of Food Engineering. 2007;78:52-60.
56. Narzary C, Sarkar D, Das P, Papi D. Ethnobotany, phytochemistry, and pharmacological activity of *Dioscorea bulbifera*: a comprehensive review. Chemistry & Biodiversity. 2025;22(1).
57. Nwadike EC, Abonyi MN, Okafor AA, Okachi II. Sensory analysis and phytochemical characterization of aerial yam and water yam. UNIZIK Journal of Engineering and Applied Sciences. 2023;2(1):240-249.
58. Obadina AO, Babatunde BO, Olotu I. Changes in nutritional composition, functional, and sensory properties of yam flour as a result of presoaking. Food Science and Nutrition. 2014;2(6):676-681.
59. Ojeniran JI, Adejumo BA, Obasa PA. Effects of drying methods on the qualities of beetroot flour. European

Journal of Sustainable Development Research. 2025;9(3).
60. Ojinnaka MC, Okudu H, Uzosike F. Nutrient composition and functional properties of major cultivars of aerial yam (*Dioscorea bulbifera*) in Nigeria. Food Science and Quality Management. 2017;62(1):1-2.
61. Olatunde GO, Henshaw FO, Idowu MA, Tomlins K. Quality attributes of sweet potato flour as influenced by variety, pretreatment and drying method. Food Science and Nutrition. 2016;4(4):623-635.
62. Oluwalana IB, Oluwamukomi MO. Proximate composition, rheological and sensory qualities of plantain (*Musa paradisiaca*) flour blanched under three temperature regimes. African Journal of Food Science. 2011;5(14):769-774.
63. Onwuka GI. Food analysis and instrumentation: theory and practice. Lagos, Nigeria: Naphtali Printers; 2005.
64. Orhevba BA, Ajiboye MO. Quality attributes of yam (*Dioscorea rotundata*) flour as affected by some processing parameters. Journal of Food Technology Research. 2020;7(2):171-177.
65. Orji RN. Profiling the *in vitro* starch contents of some underutilized tubers flours as affected by some pre-processing operations. World Journal of Advanced Research and Reviews. 2023;20(3):1387-1394.
66. Osundahunsi OF, Fagbeme TN, Kesselman E, Shimoni E. Comparison of the physicochemical properties and pasting characteristics of flour and starch from red and white sweet potato cultivars. Journal of Agricultural and Food Chemistry. 2003;51(8):2232-2236.
67. Padhan B, Panda D. Potential of neglected and underutilized yams (*Dioscorea* spp.) for improving nutritional security and health benefits. Frontiers in Pharmacology. 2020;11:496.
68. Panse VS, Sukhatme PV. Statistical methods for agricultural workers. New Delhi: Indian Council of Agricultural Research; 1985. p. 50-56.
69. Patil RT, Shukla BD. Natural convection cabinet tray dryer using agricultural waste fuel. Drying Technology – An International Journal. 1998;6:195-212.
70. Paul C, Chakraborty K, Bhattacharjee A, Debnath B. Gender-specific differences in micro-morphology, secondary metabolites, antioxidant and antimicrobial activity of wild *Dioscorea* species. Vegetos. 2022;35(3):698-706.
71. Polycarp D, Afoakwa EO, Budu AS, Otoo E. Characterization of chemical composition and anti-nutritional factors in seven species within the Ghanaian yam (*Dioscorea*) germplasm. International Food Research Journal. 2012;19(3):985-992.
72. Princewill-Ogbonna IL, Ezembaukwu NC. Effect of various processing methods on the pasting and functional properties of aerial yam (*Dioscorea bulbifera*) flour. British Journal of Applied Science and Technology. 2015;9(5):517-526.
73. Ranganna S. Handbook of analysis and quality control for fruit and vegetable products. 2nd ed. New Delhi: Tata McGraw-Hill Publishing Company Ltd.; 1986.
74. Ratnaningsih R, Richana N, Suzuki S, Fujii Y. Effect of soaking treatment on anthocyanin, flavonoid, phenolic content and antioxidant activities of *Dioscorea alata* flour. Indonesian Journal of Chemistry. 2018;18(4):656-663.
75. Sagar VR, Kumar PS. Recent advances in drying and dehydration of fruits and vegetables: a review. Journal of Food Science and Technology. 2010;47(1):15-26.
76. Sajilata M, Singhai R, Kulkarni P. Resistant starch: a review. Comprehensive Reviews in Food Science and Food Safety. 2006;5:1-17.
77. Sánchez-Zapata E, Pérez-Álvarez JA, Fernández-López J. Resistant starch as functional ingredient. In: Ramawat KG, Mérillon JM, editors. Polysaccharides: bioactivity and biotechnology. 2015. p. 1911-1931.
78. Santos SC, Mello JCP. Taninos. In: Simões CMO, Schenkel EP, Gosmann G, de Mello JCP, Mentz LA, Petrovick PR, editors. Farmacognosia: da planta ao medicamento. 5th ed. rev and expanded. Porto Alegre: Editora da UFRGS; Florianópolis: Editora da UFSC; 2004.
79. Serna-Saldivar SO, García-Lara S. Cereals: storage. In: Caballero B, Finglas PM, Toldrá F, editors. Encyclopedia of Food and Health. 2016. p. 748-754.
80. Setyawan N, Maninang JS, Suzuki S, Fujii Y. Variation in the physical and functional properties of yam (*Dioscorea* spp.) flour produced by different processing techniques. Foods. 2021;10(6):1341.
81. Sfayhi-Terras D, Hadjyahia N, Zarroug Y. Effect of soaking time and temperature on water absorption capacity and dimensional changes of bulgur. Cereal Chemistry. 2021;98(4):851-857.
82. Tenyang N, Zakaria HB, Mamat A, Goledefroy TZ, Galoua D, Womeni HM. Effect of oven drying, solar drying methods and traditional roasting on the proximate composition, lipid oxidation and minerals content of *Sclerocarya birrea* kernels collected in Far North Region of Cameroon. Cameroon Journal of Biological and Biochemical Sciences. 2025;33:37-51.
83. Tortoe C, Dowuona S, Akonor PT, Dziedzoave NT. Examining the physicochemical, functional and rheological properties in flours of farmers' 7 key yam (*Dioscorea* spp.) varieties in Ghana to enhance yam production. Cogent Food & Agriculture. 2017;3(1):1371564.
84. Wahab BA, Adebowale ARA, Sanni SA, Sobukola OP, Obadina AO, Kajihausa OE, *et al*. Effect of species, pretreatments, and drying methods on the functional and pasting properties of high-quality yam flour. Food Science and Nutrition. 2016;4(1):50-58.
85. Xiao HW, Bai JW, Sun DW, Gao ZJ. The application of superheated steam impingement blanching (SSIB) in agricultural products processing – a review. Journal of Food Engineering. 2014;132:39-47.
86. Zuanazzi JAS, Montanha JA. Flavonoides. In: Simões CMO, Schenkel EP, Gosmann G, de Mello JCP, Mentz LA, Petrovick PR, editors. Farmacognosia: da planta ao medicamento. 5th ed. rev and expanded. Porto Alegre: Editora da UFRGS; Florianópolis: Editora da UFSC; 2004. p. 577-614.