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IMPACTS OF PRETREATMENTS AND DRYING TECHNIQUES ON THE PHYSIOCHEMICAL, MICROBIAL, AND SENSORY PROPERTIES OF WHITE YAM (*Dioscorea Rotundata*) FLOUR

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ABSTRACT

The impacts of pretreatments and drying techniques on the physicochemical, microbial, and sensory properties of white yam are examined in this study. Fresh tubers were cleaned, pretreated, uniformly sliced, dried, and turned into flour. Physicochemical, microbial, and sensory attributes of the flours were assessed using accepted techniques. The findings demonstrated that, with the exception of the gelatinization temperature, all physicochemical parameters under investigation were significantly ($p<0.05$) influenced by the pretreatments and drying techniques. The moisture ranged from 3.00 to 11.50%, the bulk density was 0.67 to 0.71 g/mL, the water absorption capacity was 1.80 to 2.47 g/g, the swelling capacity was 27.30 to 70.00%, the gelatinization temperature was 74.00 to 80.00°C, and the least gelation capacity was 8.00 to 14.00%. Compared to solar and oven drying, the total viable bacterial count in open sun dried yam flour was significantly higher ($p<0.05$). *Alternaria* was isolated with using open sun and solar drying, *Aspergillus niger* and *Aspergillus flavus* were isolated using open sun drying, *Candida albicans* was isolated with using open sun and oven drying, *Rhizopus sp*. was isolated using all drying techniques taken into account. The *amala* produced from yam flour pretreated with blanching and 0.1 percent sodium metabisulphite along with oven and solar drying was preferred by the panellists to untreated and open sun-dried ones, according to the sensory analysis of the *amala*. The extensive variation in the physicochemical characteristics of the flour samples could be used as a database to enhance the processing of yam flour.

1. Introduction

The term "yam" refers to a number of plant species in the family Dioscoreaceae that produce edible tubers that are a staple crop in West Africa (Asiedu, 1992). It is a multi-species crop that was primarily developed in Africa and Asia before being introduced to other regions of the world (Hahn, 1995). Perennial herbaceous vines known as yams are grown for their starchy tubers throughout many temperate and subtropical areas. There are up to 600 species of yam tubers, some of which are crucial for the economy. *Dioscorea rotundata* (white yam), *Dioscorea cayenensis* (yellow yam), *Dioscorea alata* (water yam), *Dioscorea bulbifera* (aerial yam), and *Dioscorea esculenta* (Chinese yam) are among them. *Dioscorea rotundata* (white yam) and *Dioscorea alata* (water yam) are the two species that are most prevalent in Nigeria. *Dioscorea dumetorum*, *Dioscorea opposita*, *Dioscorea japonica*, *Dioscorea hispida*, and *Dioscorea transversa* are additional yam species with minor economic importance in some tropical areas (Asiedu *et al*., 1997).

Yams can be eaten in a variety of ways, including boiled, pounded, fried, or baked. It is frequently dried and ground into flour for a variety of products, including *amala* and other products made from composite flour. Like other tubers, yams have a number of limitations, including high production costs and post-harvest losses. Yam falls under the category of semi-perishable foods because of its relative high moisture content and susceptibility to physiological deterioration over time after harvest (Jimoh and Olatidoye, 2009). Thus, to make it available all year long, processing it into less perishable products like yam flour through a drying process is required (Ogunlakin *et al.*, 2012; Abiodun and Akinoso, 2014). The oldest method of food preservation is food drying, which is used to preserve agricultural produce to make it available all year long, lower post-harvest losses, and achieve food security (Hussein and Filli, 2018; Hussein *et al.*, 2021).

Dried yam (*gbodo*) and its flour (*elubo*) are traditional transformation methods for processing and storing yam. This yam flour is the primary ingredient in making *kokonte* in Ghana, and *amala* is eaten mainly by ethnic Yorubas of the southwestern part of Nigeria when reconstituted (Abiodun and Akinoso, 2014). Numerous people in the yam zone of West Africa depend on these products as their primary source of carbohydrates. They are renowned for feeding both adults and children (Mestres *et al.*, 2004). The appearance and taste are permanent features of *amala*. However, drying causes deterioration of both the eating quality and the nutritional value of *amala*. The colour is thus a significant attribute of *amala* and predominantly affects its acceptability by consumers. The changes in the shade are thought to be linked to browning caused by the polyphenol content of tubers and bad drying conditions (Chilaka *et al.*, 2002).

Open sun, oven, and solar drying are some of the most widely used drying techniques. However, the physicochemical characteristics of the dehydrated products are significantly impacted by these drying techniques (Ogunlakin *et al.*, 2012). Another issue that lowers the acceptability of the finished products is inadequate processing combination and microbial contamination as a result of poor processing handling. Food products are typically pretreated with hot water blanching and sulphating before drying to stop oxidative browning. According to Babajide *et al.* (2006a), blanching can be used to inhibit enzymes that might cause quality degradation and enhance the finished product. As a result, the objective of this study was to assess how pretreatments and drying techniques affected the physicochemical, microbial, and sensory properties of white yam flour.

2. Materials and methods

2.1. Materials

The Yam Market (Kasuwan Guari) at Yola Bye-Pass, Adamawa State, Nigeria, was where we bought the white yam tubers (*Dioscorea rotundata*). In order to conduct scientific identification, the samples were delivered to the Department of Crops and Horticulture. The analytical-grade chemicals and reagents that were used were obtained from the food processing laboratory of the Department of Food Science and Technology at the Modibbo Adama University, Yola, Adamawa State, Nigeria.

2.2. Methods

2.2.1. Experimental design and sample preparation

The experimental design was carried out using a completely randomised design (CRD). A total of 1 yam variety (white yam), 3 drying techniques (open sun, oven, and solar drying), 4 pretreatments (0.1% metabisulphite, blanching, blanching and soaking, and untreated), and 1 x 3 x 4 = 12 samples were used in the production of the yam flour. Three times of this were done, yielding a total of 12 x 3 = 36 samples. The yam tubers (16 tubers, each weighing about 1.5 kg) were sorted, then washed in clean tap water to remove any soil that had adhered, and finally divided into 4 portions (4 tubers each).

2.2.2. Pretreatment of the yam tubers

The first portion of the yam tubers was hand-peeled and sliced with stainless steel knife into smaller sizes of 0.5 cm thickness inside water to prevent enzymatic browning. The sliced yam was treated with 0.1% sodium metabisulphite ($Na_2S_2O_5$). Nine and a half grams (9.5 g) of sodium metabisulphite was dissolved in 5 litres of water, and the sliced yams were submerged in it for 10 minutes, drained and then set for drying. The second portion of the yam tubers was first blanched at 100^{o}C for 1 minute, after which it was immediately hand-peeled and sliced with stainless steel knife into smaller sizes of 0.5 cm thickness. It was then further blanched at 100^{o}C for 30 seconds, drained and set for drying. The third portion of the yam tubers was blanched at 75^{o}C for 5 minutes and left to soak in water overnight (12 hours) before being drained and set for drying. The yam tubers' residual portion was hand-peeled and sliced with stainless steel knife into smaller sizes of 0.5 cm thickness inside water to prevent enzymatic browning. The sliced yam was not treated with anything and served as control samples.

2.3. Drying Processes

2.3.1. Open sun drying technique

On four different wire meshes made in Nigeria, 1 kg of each pretreated yam slice and 1 kg of the control were spread out in a single layer and sun dried until equilibrium moisture content was reached. The drying period lasted for four (4) days from 8:00 am to 5:00 pm every day, with an average atmospheric temperature of about 37 to 42°C.

2.3.2. Oven drying technique

Another portion of the same pretreated samples and control were placed in a convective hot air oven (Gallenkamp plus II Oven-OPL150.TSI.B, UK) and dried to a constant weight at 50^{o}C for 36 hours.

2.3.3. Solar drying technique

The last portion of the same pretreated samples and control were dried in a constructed solar dryer by Hussein *et al.* (2017) using the principles of the greenhouse effect for 3 days to achieved equilibrium moisture content. Daily from 8:00 am to 5:00 pm, the drying process took place at an atmospheric temperature range of 37 to 42 °C. The dried yam chips were cleaned to remove dust and other impurities before being reduced in size as much as possible and pounded in a clean mortar and pestle to improve milling. To prevent mixing, each sample was carefully removed, and the mortar and pestle was thoroughly cleaned afterward. The yam pieces were ground into fine flour using a commercial mill before being allowed to pass through a sieve with a 1 mm mesh size. In order to prevent evaporation until they were used for further analysis, the acceptable yam flour samples were stored airtight at room temperature in polythene nylon.

2.4. Determination of the Physicochemical Properties of Yam Flour

The AOAC (2016) guidelines were used to determine the moisture content of the yam flour. Hussein *et al.* (2016)'s methodology was used to calculate the bulk density and water absorption index. Onwuka (2005)'s method was used to determine swelling capacity, and Msheliza *et al.* (2018a)'s was used to determine gelatinization temperature and least gelation capacity.

2.5. Microbial Analysis

According to Jideani and Jideani (2006), the materials were autoclaved at a pressure of 1 kg/cm^2 (121°C) for 15 minutes to sterilise them. Petri dishes, pipettes, glass rods, measuring cylinders, beakers, and conical flasks were among the glassware that underwent detergent soaking, washing, and rinsing. They were sterilised by dry-heating them at 170°C for 60 minutes while inverted, wrapped in aluminium foil paper. Using cotton wool dipped in 70% ethanol, the working area was also cleaned and disinfected. Plate Count Agar and Sabouraud Dextrose Agar were the two media, and they were prepared in accordance with the manufacturer's instructions. Prior to use, they were sterilised for 15 minutes at 1 kg/cm^2 (121°C) and submerged in a water bath set at 100°C to prevent gelling. Additionally, a Bunsen burner was used to sterilise the wire loop, "heat fix" smears, and other tools. For culturing and sub-culturing, inoculation techniques such as streaking and pour plating were used. Secondary observations were made after preliminary tests and observations.

2.5.1. Determination of total bacterial count

To create a 10^{-1} dilution, 1 g of each sample of yam flour was added to a bottle with 9 ml of sterile distilled water and thoroughly mixed. That is, using a sterile pipette, 1 ml of the stock solution was aseptically transferred from bottle one to bottle two, bottle two to bottle three, and bottle three to bottle four, all of which contained sterile distilled water. The sample was then spread on the agar medium's surface using a sterile glass spreader. The medium's pH was modified before sterilisation. The inoculated plates were inverted and incubated at 37°C for 18–24 hours to promote bacterial growth. Utilizing a Leica Quebec dark field colony counter (Model: 3325), colonies were then counted. Using the equation in Equation 1, the counts were converted into colony-forming units per millimetre. Other samples went through the same process again.

$$Colony\ forming\ unit\ per\ gram\ \left(\frac{Cfu}{ml}\right) = \frac{NOC}{VTP} \times dilution\ blank\ factor \qquad (1)$$

Where: NOC = No of colonies

VTP = Volume transferred to plate

2.5.2. Determination of the presence of moulds and yeasts

Twelve (12) plates were prepared by dissolving 16.30 g of sabouraud dextrose agar (SDA) powder into 250 mL of distilled water. Both heating and mixing were used to make it dissolve. After autoclaving the mixture for 15 minutes at 121°C, it was cooled to 47°C to sterilise it. The agar was mixed very well, and 20 ml was poured into each Petri dish. A sterilized glass spreader was then used to spread the sample on the surface of the agar media. The SDA on the Petri dishes were allowed to solidify. The sample was inoculated at 37^oC on each Petri dish using a sterilized mountain needle. Fungal growths were observed after 3 days. The procedure was repeated for other samples (Jideani and Jideani, 2006).

2.5.3. Isolation and identification of bacterial isolates

Bacterial identification tests were conducted to differentiate and identify the various bacterial species associated with the prepared yam flour samples. The collected samples were plated onto blood, nutrient, and MacConkey agars, and then incubated for 48 hours at 37°C. Isolated colonies were further subjected to purification and subculture after the incubation period. The isolates' pure colonies were chosen using nutrient agar with 5% sheep blood. Gram stain, catalase, and oxidase tests were used to identify each isolate preliminary. If the isolates were thought to be E. coli, selective media like Eosin methylene blue agar (EMB) were then used (Bhetwal *et al.*, 2017).

2.6. Sensory Evaluation

Sensory evaluation was carried out on both the primary product (yam flour) and the secondary product (*Amala*). For each sample, 50 g of yam flour was combined with 150 ml of boiling water to create a paste known as *amala*. To prevent crowding and to allow for impartial judgement, the containers containing the samples were coded and kept far apart. A 50-member panel of judges who were familiar with the products received the samples for sensory evaluation. The panellists were chosen based on the fundamental criteria for a panellist, including availability for the entire assessment period, interest, willingness to serve, good health (not having a cold), and no allergies or sensitivities to the emulated product, as described by (Msheliza *et al.*, 2018b). Seven-point hedonic scale (7-Like extremely, 6-Like very much, 5-Like moderately, 4-Neither like nor dislike, 3-Dislike moderately, 2-Dislike very much, and 1-Dislike extremely) was used by the fifty semi-trained panellists to score the sensory attributes (Iwe, 2010). The sensory attributes evaluated for the yam flour were appearance (colour), aroma and overall acceptability. At the same time, *amala's* appearance (colour), texture, flavour and overall acceptability were evaluated.

2.7. Statistical Analysis

The results of each experiment were run in triplicate, and they were presented as means ± standard error. The graphs were plotted using the OriginPro 2021 programme, and the Duncan's Multiple Range Test was used to determine the significance of the means. The confidence level was set at p> 0.05.

3. Results and discussions

3.1. Physicochemical properties of Yam Flour Samples

Table 1 displays the findings of the physicochemical characteristics of yam flour samples. The moisture content ranged from 3.00 to 11.50%. The sample that had been pretreated with sodium metabisulphite had the lowest moisture content. In contrast, the samples that were dried after being soaked in water for a night had the highest values. This demonstrates that the samples' high water absorption during soaking is what caused their higher moisture content. The low moisture content in those samples of pretreated sodium metabisulphite, on the other hand, is a reflection of the significant impact of the sulphating pretreatment on the drying kinetics. According to Orikasa *et al.* (2018), physical damage to the sample causes sodium metabisulphite to inhibit the hardness surface, destroy cell membrane stability, and change the resistance to internal moisture diffusion. All of the values found in this study, however, were within the permitted range of not more than 10% for long-term storage of flour (Polycarp *et al.*, 2012).

Bulk densities varied between 0.63 and 0.71 g/mL. These values are comparable to the range of 0.64 to 0.76 g/cm^3 reported by Udensi *et al.* (2008) for various water yam flour varieties. The outcome revealed no distinction between the pretreatments used for each drying technique ($p > 0.05$). However, the solar drying technique had the highest bulk density, followed by the oven and open sun drying techniques. Because of its high bulk density, yam flour has the potential to be used as a thickener in the food industry to give yoghurt and other foods more body and mouthfeel (Adepeju *et al.*, 2011). Additionally, Hussein *et al.* (2016) noted that the bulk density of the flour has an impact on its packaging situation; the greater the bulk density, the more convenient the packaging will be. Therefore, it is preferable to have a high bulk density, which provides a more significant packaging advantage by allowing for the packing of a larger volume with a smaller amount of material (Adepeju *et al.*, 2011).

The range of the water absorption capacity (WAC) was 1.80 to 2.47 g/g. Sample with pretreatment of sodium metabisulphite has the highest value. For the three drying techniques taken into consideration, the control sample had the lowest values. According to the results, there was no discernible difference between the pretreatments used for each drying technique; however, oven-dried samples had the highest WAC, followed by solar and open sun drying techniques. The outcome also demonstrated that higher bulk density was caused by lower water absorption capacity. This implies that more shrunk products will have a higher bulk density and be more capable of absorbing moisture. This will be significant when cooking because it is predicted that the mixture's yield will increase (Hussein *et al.*, 2016). Water absorption capacity is a crucial factor in the development of ready-to-eat foods; a high WAC may ensure the cohesiveness of the flour product (Housson and Ayenor, 2002), while a low WAC product ensures the flour's easy digestibility (Bolarinwa *et al.*, 2015).

The ability of flour to swell when combined with water is indicated by the swelling index, which is a crucial functional characteristic. Additionally, it denotes the presence of amylase, which affects how much amylose and amylopectin are present in the yam flour (Oke *et al.*, 2013). The yam flour's swelling index ranged from 27.30 to 70.00 %. The results were significantly different ($p<0.05$); the sodium metabisulphite pretreated sample had the lowest swelling index while the untreated sample had a higher value. The outcome also revealed that oven-dried yam flour came in second place to sun-dried yam flour in terms of swelling index. This suggests that different pretreatments and drying techniques have an impact on the swelling index, which could account for the variation in the swelling capacity of yam flour. However, the relatively higher swelling capacity found in this study suggests that the starch granules in yam flour likely contain a high amount of amylose. Oke *et al.* (2013) reported a similar finding for water yam flour.

Table 1. Physicochemical properties of the yam flour produced

Drying Techniques	PRT	Moisture Content (%)	Bulk Density (g/ml)	Water Absorption Capacity (g/g)	Swelling Capacity (%)	Gelatinization Temperature (ºC)	Least Gelation Capacity (%)
Sun dried	**MTB**	6.00 ± 0.12^{de}	0.69 ± 0.03^{ab}	2.10 ± 0.01^{bc}	45.00 ± 5.00^{d}	80.00 ± 5.00^{a}	12.00 ± 2.00^{b}
	BLC	7.50 ± 0.50^{cd}	0.68 ± 0.01^{bc}	2.30 ± 0.30^{ab}	60.00 ± 10.00^{b}	80.00 ± 5.00^{a}	10.00 ± 2.00^{c}
	SON	9.50 ± 0.50^{b}	0.66 ± 0.01^{cd}	2.30 ± 0.10^{ab}	60.00 ± 10.00^{b}	76.00 ± 4.00^{a}	12.00 ± 1.00^{b}
	CTR	8.00 ± 1.00^{bc}	0.68 ± 0.02^{bc}	2.40 ± 0.20^{a}	70.00 ± 10.00^{a}	80.00 ± 0.01^{a}	8.00 ± 1.00^{d}
Oven dried	**MTB**	4.50 ± 0.50^{ef}	0.68 ± 0.03^{bc}	2.20 ± 0.10^{abc}	40.00 ± 10.00^{e}	80.00 ± 5.00^{a}	14.00 ± 4.00^{a}
	BLC	5.00 ± 0.01^{e}	0.64 ± 0.03^{cd}	2.20 ± 0.01^{abc}	47.40 ± 2.60^{cd}	78.00 ± 3.00^{a}	12.00 ± 2.00^{b}
	SON	8.00 ± 2.00^{bc}	0.64 ± 0.02^{cd}	2.20 ± 0.20^{abc}	50.00 ± 5.00^{c}	78.00 ± 7.21^{a}	12.00 ± 4.00^{b}
	CTR	5.50 ± 0.50^{e}	0.63 ± 0.01^{d}	2.47 ± 0.12^{a}	70.00 ± 10.00^{a}	74.00 ± 4.00^{a}	8.00 ± 2.00^{d}
Solar dried	**MTB**	3.00 ± 1.00^{f}	0.69 ± 0.01^{ab}	2.30 ± 0.01^{ab}	27.30 ± 1.70^{g}	80.00 ± 0.01^{a}	10.00 ± 2.00^{c}
	BLC	6.00 ± 1.00^{de}	0.71 ± 0.02^{a}	2.00 ± 0.01^{cd}	35.00 ± 5.00^{f}	80.00 ± 5.00^{a}	14.00 ± 2.00^{a}
	SON	11.50 ± 0.50^{a}	0.69 ± 0.02^{ab}	2.10 ± 0.10^{bc}	27.30 ± 2.70^{g}	76.00 ± 2.00^{a}	12.00 ± 2.00^{b}
	CTR	8.00 ± 2.00^{bc}	0.71 ± 0.01^{a}	1.80 ± 0.20^{d}	40.00 ± 5.00^{e}	80.00 ± 5.00^{a}	8.00 ± 1.00^{d}

Mean in the same column bearing different superscript are significantly different at ($p<0.05$) for drying technique.
Where; PTR = Pretreatment, MTB = Metabisulphite, BLC = Blanching, SON = Blanching and Soak overnight, CTR = Control

The yam flour gelation temperature ranged from 74.00 to 80.00°C. The differences between the values were not statistically significant ($p>0.05$). This suggests that the pretreatments and drying procedures used had no significant impact on the yam flour's gelatinization temperature. The flour's least gelation capacity ranged from 8 to 14%. For the three drying techniques that were taken into consideration, a weak gel of 8% was noted for the untreated samples. The treated samples showed gel ranging from a strong gel at 10% to a very strong gel at 14%. This suggests that for untreated samples as opposed to treated ones, a lower flour concentration would be needed to form a gel. All of the flours' least gelation concentrations were relatively lower than the values (30–50% w/v) reported by Udensi *et al.* (2008)) for various D. alata varieties. It was, however, a little higher than the figures for cocoyam flour (6.00–8.00%) and yam flour (2.00–5.00 w/v) reported by Ogunlakin *et al.* (2012) and Wahab *et al.* (2016), respectively. The relative ratios of various constituents, such as proteins, carbohydrates, and lipids, may be the cause of the variation in this yam flour property that has been observed.

3.2. Effect of Pretreatment and Drying Method on the Microbial Composition of Yam Flour

As shown in Figure 1, the results of the microbial analysis revealed that the samples that were left untreated and dried using the open sun technique had the highest microbial loads (496×10^3 cfu/ml), while the samples that were pretreated with sodium metabisulphite and oven-dried had the lowest loads (140×10^3 cfu/ml). This demonstrated that untreated samples and samples dried in the sun had a higher overall viable count than other drying techniques. This supports the finding from Djeri *et al.* (2010) that sun-dried chips had a higher germ count than oven-dried chips. This demonstrates unequivocally how the pretreatment process and the state of the drying environment affect the microbial load of yam samples. Since the yam sample is sliced fresh until it is completely dried, airborne germs and their spores are constantly in contact with the chips during the sun-drying process at room temperature. The environment is sealed off and free from airborne bacteria during solar drying. In contrast, the higher air temperature created during oven drying prevents microbial growth. The high microbial load of untreated samples in comparison to treated samples in all drying techniques demonstrated that bacterial growth may be caused by contaminants but does not manifest after pretreatments.

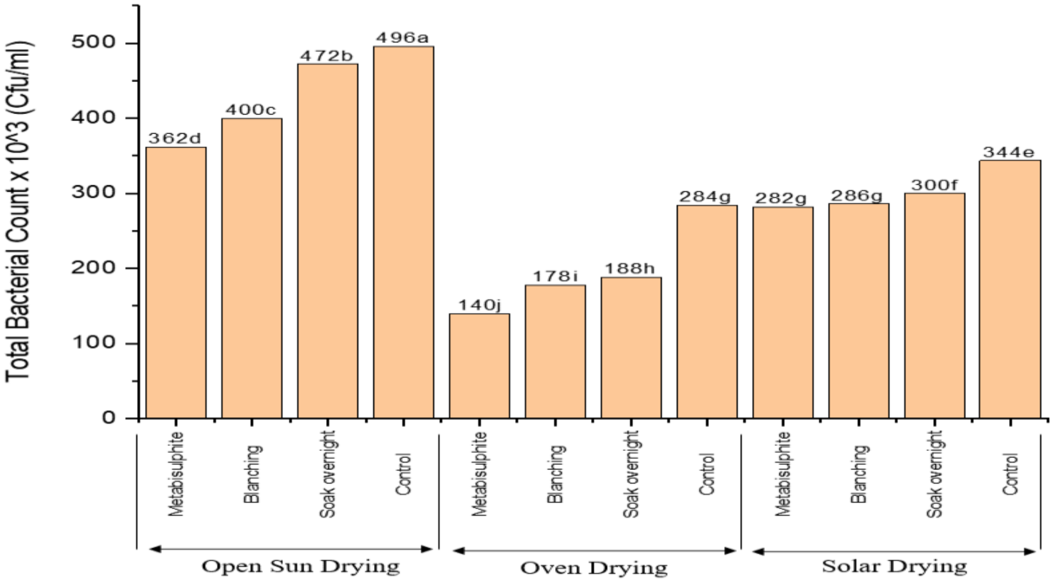

Figure 1. Total bacteria count of dried yam flour

Table 2. Morphological Characteristics of Fungi Isolates

Growth on Sabouraud Dextrose Agar (SDA)	Microscopy	Likely Organism
Black appearance on culture.	Conidial/heads are dark brown to black.	*Aspergillus niger*
Yellow green appearance on culture.	Spreading yellow green colonies, rough walled stipes, mature vesicle bearing phialides over their entire surface and conspicuously echinulate conidia.	*Aspergillus flavus*
White colonies (dense cotton) that turn yellowish brown with sporulation	Mass of non-septate hyphae bearing sporangia on sporangiospore Rhizoids present	*Rhizopus sp.*
White to cream coloured smooth, glabrous and yeast like appearance	Spherical to sub spherical budding yeast-like cell or blastoconidia	*Candida albicans*
Cottony colonies grey to olive brown on the surface with short aerial hyphae	Dark Septate hyphae Zigzag appearance, conidia are brown, ovoid with an elongated beak-like apical cell	*Alternaria*

3.3. Morphology Characteristics of Fungi Isolates

The test results for moulds and yeast in dried yam flour samples that were pretreated differently and dried using three different drying techniques are shown in Table 2. The outcome demonstrates that fungi had grown on every sample of yam flour. According to growth patterns on the media and examination, *Aspergillus niger*, *Aspergillus flavus*, *Rhizopus species*, *Candida albicans*, and *Alternaria* are among the most likely fungi isolates. The results of this study confirmed what had previously been reported for dried yam flour sold in South-West Nigeria by Bankole and Adebanjo (2003), Bankole and Mabekoje (2004), and Babajide *et al.* (2006b). Mold isolates including *Aspergillus flavus*, *Aspergillus niger*, *Penicillium spp.*, and *Rhizopus spp.* were also highlighted in the study by Djeri *et al.* (2010). According to Somorin *et al.* (2011), both white yam flour and water yam flour contained *Fusarium oxysporum*, *Aspergillus niger*, and *Rhizopus nigricans*. However, *Penicillium citrium*, *Penicillium oxalicum*, *Aspergillus fumigatus*, and *Aspergillus flavus* were also isolated from white yam flour.

Table 3 displays the percentage of each isolated fungus found in the samples of yam flour. *Aspergillus flavus* and *Aspergillus niger* are the least common, with one isolate each representing 4.2%, according to the table, which shows that *Rhizopus species* is the most common organism with nine (9) representing 75% of the isolates out of the twelve samples analysed. There are also six (6) isolates of *Alternaria* and seven (7) isolates of *Candida albicans*. Microorganisms may infect yam at any stage of its growth, from the seedling stage to postharvest (Amusa *et al.*, 2003). According to Okigbo and Ikediugwu (2000), yams are susceptible to a number of diseases; some fungi have been linked to the deterioration of yam tubers during storage. Fungal pathogens that enter wounds in the tubers brought on by insects, nematodes, and improper handling before, during, and after harvest and infect the inner tissue are to blame for this.

Yam flour might also have microbial contamination from the drying environment. According to Djeri *et al.* (2010), improper drying is the root of the mould and yeast contamination. These microorganisms produce the toxins that cause food poisoning infections and are to blame for the decline in the nutritional value and flavour of food. According to a study by Somorin *et al.* (2011), some milling equipment may introduce fungi known to produce mycotoxins into the yam flour. Due to some unhygienic practises used during the milling process, they reported that milling yam chips into flour in the equipment available at markets increased the microbiological contamination of the yam chips by 10^1 to $>10^2$ folds. This has implications for the microbial quality and safety of the yam flour meal consumed.

3.4. Sensory Attributes of Yam Flour Samples (*Elubo*) and Thick Yam Dough (*Amala*)

Figure 2 displays the sensory characteristics of yam flour (Elubo) as reported by the 50 panellists. The ratings had a 95 percent probability level of statistical significance. This suggests that the test samples had a lot of variation. Based on three sensory qualities (appearance, aroma, and overall acceptability) evaluated, oven-dried yam flour samples were rated as the best drying technique, followed by solar and open sun drying. In all drying techniques taken into consideration, the samples pretreated with sodium metabisulphite and blanching received higher ratings (6.90), while the untreated samples received lower ratings (4.10).

Table 3. Percentage occurrence of each fungi isolate obtained from the yam flour samples

Fungal isolate	**Open sun drying**				**Oven drying**				**Solar drying**				**No of isolate**	**Occurrence (%)**
	MTB	BLC	SON	CTR	MTB	BLC	SON	CTR	MTB	BLC	SON	CTR		
Aspergillus niger	-	+	-	-	-	-	-	-	-	-	-	-	1	4.2
Aspergillus flavus	-	+	-	-	-	-	-	-	-	-	-	-	1	4.2
Rhizopus sp.	+	-	+	+	-	-	+	+	+	+	+	+	9	37.5
Candida albicans	+	+	-	+	+	+	+	+	-	-	-	-	7	29.1
Alternaria	+	+	-	-	-	-	-	-	+	+	+	+	6	25
Total													24	100

Where; MTB = Metabisulphite, BLC = Blanching, SON = Blanching and Soak overnight, CTR = Control, + = Present and - = Absent

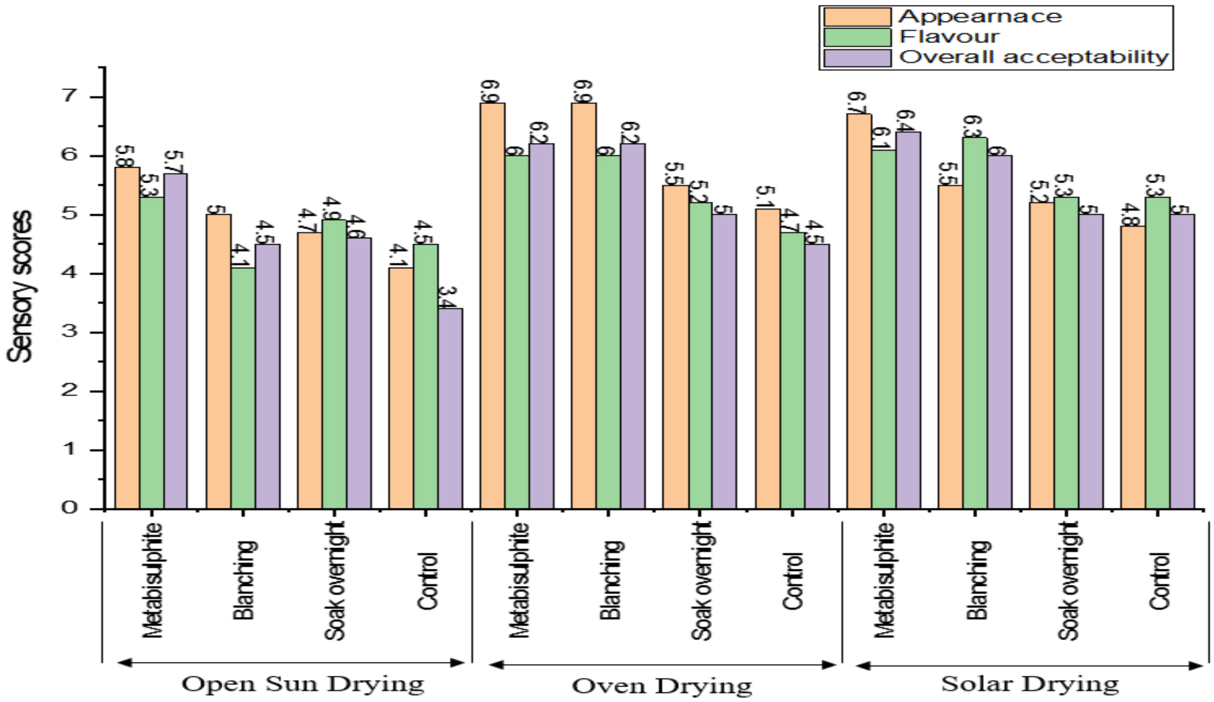

Figure 2. Sensory attributes of yam flour samples (*Elubo*)

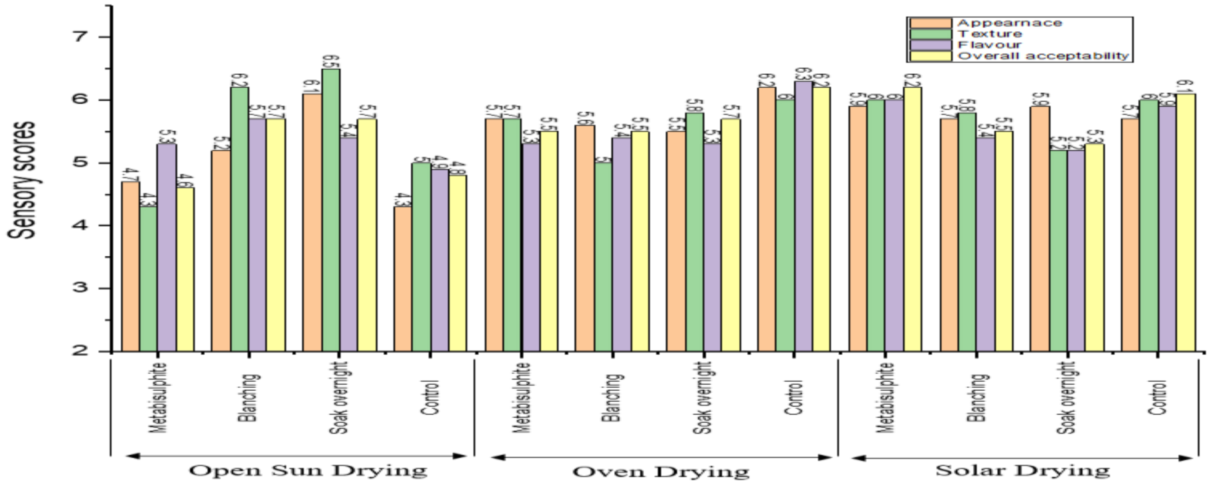

Figure 3. Sensory attributes of *amala* (Yam flour dough meal)

This might be because the pretreated samples were dried out more quickly than the untreated ones. Additionally, it might be because of the dust and other environmental toxins to which sun-dried yam flour was exposed while drying in the open sun. According to Somorin *et al.* (2011), the process of exhuming raw yam from the soil, peeling and cutting it into chips, and then sun-drying it on mats or broom-swept cement floors may expose the dried yam chips to dirt and other environmental contamination, lowering their acceptability.

Figure 3 displays the sensory assessment of yam flour-based *amala*. The flour and *amala* made from the flour sample that was blanched and oven-dried received the highest ratings for appearance (6.20 and 6.30). The sample that was left untreated but dried in the sun received the lowest rating (4.30 and 4.90). The samples that had been pretreated by soaking overnight and being sun-dried received the highest texture ratings (6.50), while the samples that had not been pretreated and been sun-dried received the lowest ratings (4.30). The samples that were pretreated with blanching, 0.1 percent sodium metabisulphite, and oven and solar dryer drying were equally rated highest for overall acceptability (6.2). The sample that wasn't pretreated and dried in the sun, on the other hand, received the lowest rating (4.6). Overall, the evaluation revealed that solar and oven-dried yam flour was preferred to open-sun-dried yam flour for making *amala*. The panellists gave the pretreated samples a higher rating than the untreated ones, but they both agreed that the *amala* made from oven- and solar-dried flour was acceptable. The untreated and dried in the open in the sun received low ratings, neither like nor dislike. The untreated and dried outdoors in the sun received a low rating, or neither like nor dislike. The negative impact of the open sun drying technique may be responsible for the poor reception of these *alama* samples. Abiodun and Akinoso (2014) noted a similar finding for yam flour in stiff dough *amala*.

4. Conclusions

The findings of this study demonstrated that the physicochemical, microbial, and sensory characteristics of white yam flour were significantly influenced by the pretreatments and drying techniques. The temperature at which gelatinization occurs was unaffected by the pretreatments or drying techniques employed. In comparison to solar and open sun drying techniques, oven drying produces the best results because it shortens drying times and minimises microbial contamination. The *amala* produced from yam flour pretreated with blanching and 0.1 percent sodium metabisulphite along with oven and solar drying was preferred by the panellists to untreated and open sun-dried ones, according to a sensory evaluation of the *amala*. The extensive variation in the physicochemical characteristics of the flour samples could be used as a database to enhance the processing of yam flour.

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