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Effect of Drying Techniques, Harvest Season and Their Interaction on the Functional Properties of Instant Yam Flour

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Abstract The knowledge of the effect of drying technique and harvest season is necessary in determining the most suitable conditions for the production of instant yam flour to imitate closely the traditionally produced pounded yam. This research work examined the effects of drying technique (sun, oven, vacuum and freeze drying), harvest season (old and new) and the interaction of these factors on the functional properties of instant yam flour. Yams of the same specie (*Dioscorea rotundata*) obtained at two separate harvest seasons were purchased from Oba Market, Akure, Nigeria. Sample was processed into instant yam flour using standard method. The samples were prepared using general factorial design [2 factors: harvest (2 levels) and drying (4 levels)]. Functional characteristics were assessed. From the results obtained, it was observed that drying technique had no significant influence on the bulk density, swelling capacity, water absorption capacity, oil absorption capacity and dispersibility. However, it had influence on wettability. Sun dried instant yam flour exhibited the highest wettability while freeze drying had the least value, the difference reaching 41%. Harvest season had a significant effect on swelling capacity and water absorption capacity but no differences were observed in the bulk density, oil absorption capacity, dispersibility and wettability of the instant yam flour samples. New yam exhibited slightly higher swelling capacity translating to about 27% upturn when compared to old yam. Both old and new yam possibly will result in instant yam flour with similar instant characteristics and reconstitution ability. However, considering yield, old yam may be preferred over new yam. The interaction of drying techniques and harvest season was significant for all the parameters.

Keywords *Dioscorea rotundata*, Drying, Harvest season, Functional, Instant flour

1. Introduction

Yam (*Dioscorea* spp) is a root crop and very important source of carbohydrate for people in sub-Saharan Africa; Nigeria been one [4]. However, [28] indicated that other nutrients such as caloric proteins, minerals and vitamins are also present in yam. In terms of production, [11] reported that yam is the second most important root crop in the world while [13] reported that Nigeria cultivates annually more than 2.8 million hectares of land for yam production, thus, making her the largest producer of yam with *Dioscorea rotundata* and *Dioscorea alata* identified as popularly cultivated species. [26] itemized certain importance of yam in diet diversification, employment, household food security, income generation and poverty alleviation. In Nigeria, yam is a common staple food and has been consumed in different ways such as boiling, frying, roasting or as pounded dough meal at household levels [12]; [33]; [36]. Aside household usage, industrially, yam has been used in starch, livestock feeds, yam flour or instant-pounded yam flour production [35]. In Nigeria, there exist two marked harvest seasons for yam; “old”, also referred as “dry” (i.e., November–February) and “New”, also referred to as “wet” (i.e., March–October) yam [23]. Pounded yam happens to be a key native food in Western Nigeria and traditionally, it is prepared by cooking peeled yam pieces and then pounding using a wooden mortar and pestle until a sticky dough is obtained [7]. However, the process of yam pounding is very stressful and time-consuming; therefore, it has become less popular among the elites. The need to reduce the labour associated with the preparation of pounded yam brought about instant yam flour which can be reconstituted into dough similar to the pounded yam [7]; [3]. The instant yam flour is mixed with a stipulated proportion of hot water until a thick paste is formed. The alternative, instant yam flour, which mimics closely the properties of traditionally pounded yam, is sought after by a large number. FIIRO [10] and Aworh [7] elucidated different methods of the production of instant yam flour. Consumer perspectives on the quality properties of

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instant yam flour when reconstituted have been linked to how different the product is when compared to traditionally pounded yam. However, these differences may be somewhat due to technological variables i.e. production parameters (drying methods, time) and/or agronomical conditions (yam cultivar, genetic, harvest time). Therefore, study on the influence of two or more of these variables, for example, drying techniques and harvest season on the functional characteristics of the instant yam flour become necessary. Drying is a critical factor in the process technology for instant yam flour as physical or chemical changes may occur thus resulting in extreme changes in product quality [21]; [29]. Research have been carried out in diverse ways on Instant yam flour but there remains little or no information regarding the effect of harvest season, drying technique and the interaction of these variables on the functional properties of instant yam flour. The aim of this research is to evaluate the impact of harvest season and various drying methods on the functional properties of instant yam flour.

2. Materials and Methods

2.1. Source of Materials

Yams of the same specie (*Dioscorea rotundata*) obtained at two separate harvest seasons (old and new) were obtained from Oba Market, Akure, Ondo state, Nigeria. All the chemicals used were of analytical grade.

2.2. Preparation of Instant Yam Flour Samples

A modified version of the production of instant yam flour as described by [10] was carried out using vacuum drying, oven drying, freeze drying and sun-drying methods of drying. The yam tuber was peeled, washed and sliced, sodium metabisulphate was added, cooked (100°C for 15 minutes), dried (70°C for 10 hours), milled, packaged and stored at room temperature until further analysis.

2.3. Instrumental Analyses

2.3.1. Determination of Functional Properties

The Bulk density was determined as described by [1]. The swelling capacity of the samples was determined by the method described by [16] as reported by [25]. Water absorption capacity was determined according to the method described by [22]. Oil absorption capacity was determined as described by [1]. Wettability was determined according to the method of [27] was adopted as described by [22]. Dispersibility was determined as described by [14].

2.4. Statistical Analysis

Data was reported as mean ± standard error of triplicate readings and analyzed using one-way analysis of variance (ANOVA) with significant differences between means determined at p< 0.05 and measured with Duncan's multiple range tests using the Statistical Package for Social Science Research version 17 (SPSS).

3. Results and Discussion

3.1. Influence of Drying Technique

The result obtained for the effect of drying technique on the functional properties of instant yam flour is presented in Table 1. As shown in table 1, there were no significant differences ($p \geq 0.05$) among the drying techniques considering the bulk density, swelling capacity, oil absorption capacity and dispersibility of the instant yam flour samples. The bulk density of the samples ranged from 0.68 g/ml of oven drying to 0.72 g/ml of vacuum drying. Bulk density is a function of ease of dispersibility [34]. The result obtained for instant yam flour dried using the aforementioned drying techniques are comparable to values (0.65- 0.78 g/ml, 0.68-1.07 g/cm^3) reported by [50] and [39] for cabinet dried yam flours and oven dried yellow trifoliate yam flour respectively. Also, current results are higher than values (0.55 g/ml, 0.57 g/cm^3) reported by [46] and [40] for cabinet dried water yam flour and cabinet oven dried white aerial yam flour respectively. Comparing data obtained for instant yam flour with other carbohydrate-based instant flours, current bulk density is lower but close to values (0.86-0.88 g/ml) reported by [6] for unripe plantain flour while obtained data is comparable to values reported by [5] for cocoyam flour samples. All instant yam flours studied show comparable bulk density which suggests that their starch polymers showed same stable structure considering the different drying methods. This is important in determining package requirement, material handling, transportation and storability [15]; [2], therefore, a high bulk density is desirable [9]. The bulk density of flour, affected by particle size, also plays important roles during mixing, amidst other parameters, of particulate foods [38].

Besides, the swelling capacity values ranged between 18.50 and 24.33. All instant yam flours studied show comparable swelling capacity. The result obtained for instant yam flour is higher than values (2.68-2.69, 10.48-13.33, 7.47) reported by [47], [45] and [39] for oven dried yam flour, thermostat controlled mechanically dried yam flours and oven dried white trifoliate yam flour respectively. Also, current results are higher than values (3.89-4.86) reported by [54] for sun and oven dried *D. rotundata* and *D. alata* yam flour. [20] as cited by [19] reported that the swelling power of flours indicates the level of associative forces within the granule. Thus, [30] stated that the higher the swelling power, the higher the associate forces. Previous research showed that the larger the particle size, the faster the granules will swell and the higher the viscosity [18].

Further, the water absorption capacity of the instant yam flour ranged between 2.82-3.11 g/ml. Result obtained for the instant yam flour samples was slightly higher than values (1.44 - 1.93 g/ml, 2.45-2.91 g/ml) reported by [52] and [50] for oven dried stored trifoliate yam flour and cabinet dried yam flours respectively. Comparing data obtained for instant yam flour with similar carbohydrate-based instant flours, current data is comparable to values reported by [5] for cocoyam flour samples but higher than that reported by [6] for unripe plantain flour. Water absorption capacity represents the ability of the flour to associate with water under limited supply and shows the strength of the starch in aqueous dispersion [17]. All the instant yam flour studied are not significantly different, therefore, they will display comparative associative tendencies to water.

The water absorption capacity is important for consideration in the preparation of mash, snack foods, extruded foods and baked products. The higher the water absorption capacity, the greater the amount of water required to make dough or batter of the predetermined consistency [15], therefore a lower water absorption capacity is desirable for dough, sausages and custards as these are supposed to incorporate water without dissolution of protein thereby attaining body thickening and viscosity [31]. On the other hand, [27] reported that high water absorption capacity improves yield, consistency and give body to food.

The oil absorption capacity of the instant yam flours ranged between 1.62-1.75 g/ml. These values are lower than those obtained for sun dried yam (aerial) flour (2.18-2.97 g/cm^3) [59]. The instant yam flour samples exhibited a very low oil absorption capacity when values (72.30- 94.80%) were compared to that reported by [41] for yam (*D. dumetorum*) flour. Also, result obtained for instant yam flour was lower than values reported by [8] for cassava and potato which was in the range 9.20-11.30 g/ml. High oil absorption capacity is desired in retention of flavor and improvement of palatability.

Considering wettability, the values ranged between 4.26-5. 99 secs. Sun dried instant yam flour exhibited the highest wettability and freeze drying the least. There were no significant differences in the wettability between oven and vacuum drying. The results obtained for instant yam flour were lower than those obtained for yam (*D. alata*) (27.00-35.00 secs) and (*D. rotundata*) (42.50 secs) by [44] and [51] respectively. The wettability for instant yam flour was considerably lower than values reported by [37] for wheat flour (52.00 secs), cassava flour (37.00 secs) and malted soybean flour (31.00 secs). The result obtained for the wettability implied that sun dried instant yam flour required longer time than the other samples before becoming completely wet. Besides, wettability will suggest to what degree the dry flour will likely possess instant characteristics [32]. This indicates a slight reduction in instant characteristics of the sun dried instant yam flour.

Further, the values obtained for dispersibility ranged between 35.12-39.88%. There was no significant difference for dispersibility amongst the drying techniques however, sun dried samples had the highest mean value. The result obtained for instant yam (*D. rotundata*) flour was lower than that reported by [48] for sun dried yam (*D. rotundata*) (69.17%), (*D. alata*) (65.67%), (D. dumetorum) (51.83%) and (*D. cayenesis*) (61.00%) flour. Also, instant yam (*D. rotundata*) flour showed low dispersibility when compared with report by [24] for unripe cooking banana, pigeon pea, and sweet potato flour blends. [14] reported that dispersibility is an index associated to the reconstitution of flour in water. It is expected that the instant yam flour samples will reconstitute somewhat easily to fine consistent dough during mixing.

3.2. Influence of Harvest Season

Table 2 shows the result obtained for the effect of harvest season on the functional properties of instant yam flour. From result obtained, the bulk density of new yam (0.71 g/ml) was slightly higher than old yam (0.69 g/ml), however, since their values were quite close, there was no significant different. Harvest season may possibly not affect bulk density of instant yam flour. In contrast, harvest season (rainy and dry season) had significant influence on bulk density of cassava gari [49]. Since observed bulk density are higher than that reported by [46] and [40], instant flour from the old and new yam (*D. rotundata*) under study are expected to offer greater packaging, handling and storage advantage.

The swelling capacity for new yam was 23.58, and 18.50 for old yam. Harvest season had significant effect on the swelling capacity of the instant yam (*D. rotundata*) flour. As observed for yam flour, it was found that harvest season (rainy and dry season) also had significant influence on swelling capacity of cassava gari [49]. Observed swelling capacity is higher than that reported by [47], [45] and [39]. The result obtained implied that instant yam flour made from new yam will possibly swell better during preparation than that made from old yam. This may be due to the influence of associative forces [30], particle size [18] or otherwise.

Table 1. Effect of Drying Technique on the Functional Properties of Instant Yam Flour

Parameters	Sun Drying	Freeze Drying	Vacuum Drying	Oven Drying
Bulk Density (g/ml)	0.71 ± 0.02^a	0.71 ± 0.02^a	0.72 ± 0.02^a	0.68 ± 0.02^a
Swelling Capacity	18.50 ± 1.60^a	22.33 ± 1.60^a	19.00 ± 1.60^a	24.33 ± 1.60^a
WAC (g/ml)	3.11 ± 0.16^a	2.82 ± 0.16^a	2.82 ± 0.16^a	2.85 ± 0.16^a
OAC(g/ml)	1.75 ± 1.10^a	1.62 ± 1.10^a	1.63 ± 1.10^a	1.63 ± 1.10^a
Wettability (sec)	5.99 ± 0.21^c	4.26 ± 0.21^a	5.13 ± 0.21^b	5.67 ± 0.21^{bc}
Dispersibility (%)	39.88 ± 1.79^a	39.35 ± 1.79^a	39.27 ± 1.79^a	35.12 ± 1.79^a

Data are means ±standard error; letters denote significant differences between groups (p<0.05)
Key: WAC means water absorption capacity; OAC means oil absorption capacity

Table 2. Effect of Harvest Season on the Functional Properties of Instant Yam Flour

Parameters	New Yam	Old Yam	Remark
Bulk Density (g/ml)	0.71 ± 0.01^{a}	0.69 ± 0.01^{a}	NSD
Swelling Capacity	23.58 ± 1.04^{b}	18.50 ± 1.04^{a}	SD
Water Absorption Capacity (g/ml)	2.62 ± 0.07^{a}	3.18 ± 0.07^{b}	SD
Oil Absorption Capacity (g/ml)	1.60 ± 0.07^{a}	1.72 ± 0.07^{a}	NSD
Wettability (sec)	5.40 ± 0.24^{a}	5.12 ± 0.24^{a}	NSD
Dispersibility (%)	35.59 ± 1.01^{a}	41.32 ± 1.01^{a}	NSD

Data are means ±standard error; letters denote significant differences between groups ($p<0.05$)
Key: SD means significant difference; NSD means no significant difference.

Table 3. Effect of Interaction of Drying Technique and Season on the Functional Properties of Instant Yam Flour

Parameters	Bulk Density (g/ml)	Swelling Capacity	WAC (g/ml)	OAC (g/ml)	Wettability (sec)	Dispersibility (%)
SN	0.74 ± 0.00^{f}	19.33 ± 0.31^{c}	3.07 ± 0.05^{cd}	1.88 ± 0.03^{e}	6.69 ± 0.01^{h}	41.50 ± 0.13^{f}
FN	0.73 ± 0.00^{e}	28.33 ± 0.31^{f}	2.30 ± 0.05^{a}	1.20 ± 0.03^{a}	4.39 ± 0.01^{b}	33.30 ± 0.13^{b}
VN	0.76 ± 0.00^{g}	22.67 ± 0.31^{d}	2.70 ± 0.05^{b}	1.57 ± 0.03^{bc}	5.42 ± 0.01^{f}	36.23 ± 0.13^{c}
ON	0.62 ± 0.00^{a}	24.00 ± 0.31^{de}	2.40 ± 0.05^{a}	1.77 ± 0.03^{de}	5.12 ± 0.01^{d}	31.33 ± 0.13^{a}
SO	0.70 ± 0.00^{d}	17.67 ± 0.31^{b}	3.17 ± 0.05^{de}	1.63 ± 0.03^{bcd}	5.30 ± 0.01^{e}	38.27 ± 0.13^{d}
FO	0.68 ± 0.00^{c}	16.33 ± 0.31^{ab}	3.33 ± 0.05^{e}	2.03 ± 0.03^{f}	4.12 ± 0.01^{a}	45.40 ± 0.13^{h}
VO	0.67 ± 0.00^{b}	15.33 ± 0.31^{a}	2.93 ± 0.05^{c}	1.70 ± 0.03^{cd}	4.83 ± 0.01^{c}	42.30 ± 0.13^{g}
OO	0.74 ± 0.00^{ef}	24.67 ± 0.31^{e}	3.30 ± 0.05^{e}	1.50 ± 0.03^{b}	6.22 ± 0.01^{g}	39.30 ± 0.13^{e}

Data are means ±standard error; letters denote significant differences between groups ($p<0.05$)
Key: SN means sun drying + new season; FN means freeze drying + new season; VN means vacuum drying + new season; ON mean oven drying + new season; SO means sun drying + old season; FO means freeze drying + old season; VO means vacuum drying + old season; OO mean oven drying + old season; WAC means water absorption capacity; OAC means oil absorption capacity.

The water absorption capacity of new yam (2.62 g/ml) was significantly lower than old yam (3.18 g/ml). As reported for yam flour, harvest season (rainy and dry season) also had significant influence on water absorption capacity of cassava gari [49]. Water absorption capacity of instant yam flour is higher than that reported by [52] and [50]. The result obtained implied that instant yam flour made from old yam absorbed more water which shows that the strength of the starch in aqueous dispersion may be higher. Old yam will need more water to form dough. This might be an added advantage considering economic value where yield is necessary for profitability. Thus, harvest season significantly influence yield. The result obtained showed there were no significant differences in the oil absorption capacity, wettability and dispersability of the instant yam. Both old and new yam may result in instant yam flour with similar instant characteristics and reconstitution ability.

3.3. Influence of the Interaction of Drying Technique and Harvest Season

The result of the effect of the interaction of drying technique and harvest season on the functional properties of instant yam flour is presented in table 3. It can be observed that samples showed observable differences regarding drying and seasonal differences. The bulk density of instant flour made from new yam and was vacuum dried had the highest value (0.76 g/ml) while instant flour made from new yam and oven dried had the least value (0.62 g/ml). From literature, higher bulk density has been attributed to low moisture content which is dependent on drying techniques [42]. It is expected that when new yam is used and vacuum dried, there will be packaging advantage and better ease of dispersibility.

As regard swelling capacity, instant flour made from new yam and freeze dried had the highest value (28.33) while instant flour made from old yam and vacuum dried had the least value (15.33). Swelling capacity of flours is influenced by types of processing methods or unit operations [43]. Desirable swelling yield of reconstituted flour and better viscosity may be obtained when new yam is used and freeze dried.

Water absorption capacity was highest for instant flour made from old yam and freeze-dried while least value was obtained for instant flour made from new yam and freeze dried. Similar trend was observed in result obtained for oil absorption capacity. However, there was no significant difference in water absorption capacity of instant flour made from new yam that was freeze dried or oven dried. According to literature, differences in water absorption capacity may be due to different heating process which influences the size and shape of starch granules as well as the distribution of protein clusters [53], however, in this study, the influence of harvest season on water absorption capacity is more significant. Previous report shows that water and oil binding capacity of food depend upon intrinsic factors [43]. Also, the reduction of oil absorption capacity is reported to be attributed to the denaturation of proteins during drying process [42]. Therefore, yield advantage is expected in instant flour made from old yam and freeze-dried.

With respect to wettability, instant flour made from new yam and was sun dried had the highest value (6.69 secs) while instant flour made from old yam and freeze dried had the least value (4.12 secs). It has been reported that the physical properties of flour such as porosity, particle size, densities and morphology influence wettability; higher density flour tend to sink rapidly while larger particle size flour tend to have better wetting behaviour [57]; [58]. Differences in wettability are therefore linked to impact of the variables on physical properties of the instant yam flours. Freeze dried old yam will have better instant characteristics.

Further, freeze dried instant flour made from old yam had the highest dispersibility while oven dried instant flour made from new yam had the least value. Freeze dried old yam will display better reconstitution ability than other sample. [55] and [56] reported that age, variety, growth season, maturity at harvest, the length of storage, elapsed time between harvesting and processing period, cultivar's type of root tubers affect their physico-chemical properties.

4. Conclusions

The drying technique and harvest season were identified as factors that will possibly affect the functional properties in the production of instant yam flour from white yam (*Dioscorea rotundata*). Consequently, to produce instant yam flour with high and acceptable functional properties from white yam (*Dioscorea rotundata*), old yam with freeze drying is recommended. Instant yam flour when reconstituted should have properties comparable to the traditionally prepared pounded yam as desired and savoured by consumers in Western part of Nigeria.

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