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The Effect of Drying Temperature on Functional/baking Properties of Flour Produced from fresh Orange-Fleshed Sweet Potato Tubers (OFSPT)

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ABSTRACT: *This paper evaluated the effect of drying temperature on the functional/baking properties of flour processed from matured fresh orange –fleshed sweet potato tubers, in bid to add value to its utilization for baking of confectionaries singly or in composite forms. 6kg of freshly harvested orange–fleshed potato tubers (Mexican cultivar), was washed thoroughly with tap water, drained, peeled and sliced into 5mm thickness. The sliced OFSP were soaked in 2.5% sodium Metabisulphate for 30 minutes, to forestall browning. The treated potato slice were drained and divided into samples A, B, C, D, and E, and dried in a hot air oven at 40 ^oC, 45 ^oC, 50 ^oC, 55 ^oC and 60 ^oC, until a constant weight was obtained. The dried slices were crushed and milled into flour using a mini hammer mill, and sieved using 75µm micro industrial sieve. The milled samples were analyses for functional/baking properties. Statistical analysis was carried out on the data generated, using analysis of variance (ANOVA). The result shows that within the 40-60 ^oC drying temperature, the solubility (SOL) of the flour decreased progressively from 42.2%-38.0%, moisture content (MC) 6.2%-3.3%, viscosity, (V) 16.5%- 5.0%. The water absorption capacity (WAC) increased from 360%-380%, oil absorption capacity (OAC) 190%-210%, gelatinization temperature (GEL) 81^{o}C-90^{o}C, swelling capacity (SC) 7.95%-12.6%, and bulk density (D) remains constant. Drying temperature significantly ($p<0.05$) affects the baking properties of OFSP flour. The drying temperature with best matrix for baking and functional properties is 45^{o}C, thus recommended for processing of fresh orange-fleshed sweet potato tuber to flour.*
KEYWORDS: *Drying temperature, orange-fleshed sweet potato flour, functional/baking properties.*

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I. INTRODUCTION

Sweet potato is a genera name for some species of genus Ipomoea family. It is an annual or perennial tuber crop with creeping plant. The most popular type is the Ipomoea batatas. Sweet potato (Ipomoea batatas) is one of the world's most important food security crops [1]. It is easy to plant and adapted to regions with adverse weather and poor soil conditions, thus peasant farmers friendly, but among the under-utilized and exploited food crops especially in developing countries [2]. Sweet potato is a staple in Nigeria and other developing countries and over 100 species and cultivars of sweet potato exists all over the world. It could be classified based on the colour of the tubers namely white fleshed, purple fleshed and orange fleshed [3]. Sweet potato contains carbohydrates, beta-carotene (pro-vitamin A), vitamin C, vitamin B_6, minerals such as calcium, phosphorus, iron, potassium, magnesium and zinc depending on specie [4]. In other to add value, enhance storability, and diversity of use, fresh sweet potato tubers are usually processed into flour for production of secondary products. Sweet potato flour have been reported to improve colour, flavour and dietary fibre of processed food products such as bread, and these qualities could enhance its use in other food preparations [5]. In the recent years the development of processed products from composite flour of sweet potatoes had play a major role in raising awareness on the potential of the crop. The beta carotene content would be very useful in alleviating vitamin A deficiency among children below six years, pregnant women and adults, since the prevalence of vitamin A deficiency in Nigeria and other developing countries has been alledged to be high. The use of sweet potatoes as substitute for sugar would reduce the quantity of sugar needed for bread production leading to lower cost of production as well as price of bread, and enhance health benefits for the consumers [4]. Sweet potato is a low input crop used as vegetable, desert, source of starch and animal feed [1]. In Nigeria, sweet potato is mostly consumed as snack (Asondo), roasted, boiled and eaten with sauce, used with fresh yams in pounded yam and as sweetener in beverage production, thus every part of the crop is useful as well as edible [4]. It could also be commonly consumed fried, grilled, baked, and the manufacture of sweet potato purees, flours and starches, thus broadens its possibilities for utilization. Proximate composition, granular characteristics, and viscoelastic, pasting and other functional/baking properties have been studied in sweet potato to enhance use and storability [6]. Sweet potato (Ipomoea batatas L.) ranks third in world root and tuber crop production after potato and cassava. Total global production amounts to 140 million metric tons in 2016, with 90 of the production mainly from over 100 developing countries [7]. It is generally recognized as being an underutilized nutritious food [8]; [9]. Amidst its underutilization, processing sweet potato into flour will increase its marketing, potentials, utilization, as a cash crop. Nigeria is the third largest producer of sweet potato in the world after China and Uganda, with the annual production of 39 million tonnes in 2016, with per capita annual consumption of 22.3kg [7]. Sweet potato is probably the only crop that thrives in all the states of Nigeria with 1-3 months maturity period and can be grown all round the year.

Orange- fleshed sweet potato (OFSP) (Ipomoea batatas (L) is specie of sweet potato characterized by its orange or yellow coloured tubers. It is strongly emerging as the most popular, commonly cultivated and demanded specie, due to its unique properties/health benefits such as vitamin A, C, minerals and beta carotene content (a carotenoids plant pigment responsible for the yellow/orange tuber colouration) [10]. Due to its intrinsic nutritive content OFSP became an important staple for the poor and less privileged considering its relative ease of cultivation, and poor utilization and numerous health benefits [11]. The orange flesh sweet potato (OFSP) contain up to 4,000 µ/mg fresh weight basis of beta carotene [8]. The carotenoids content of OFSP has been found to range from 0 to 20 > 20mg /100g of fresh weight, which would be equivalent to 0.60mg/100g weight [11]. It is likely that cultivars with medium to high levels colours contain most of their carotenoids in form of beta carotene [9]. Orange flesh sweet potato tubers can be processed into flour which is less bulky and more stable than the highly perishable fresh root thereby reducing losses. Drying of fresh orange flesh sweet potato tubers into flour at the appropriate drying temperature, will solve the problem of discoloration and enhance the production of high quality orange flesh sweet potato flour [12]. The Orange flesh sweet potato flour (OFSPF) can be used as thickener in soup; could be used singly or in composite form for baking numerous confectionary/ bakery products and as substitute for cereal flours. The use of orange flesh sweet potato flour can enhance food product through colour, flavor, natural sweetener and supplemented nutrients. The common method of drying to allow massive and rapid processing of fresh to dried products is the hot air drying [1]. However, hot air drying temperature greatly affects the functional/baking properties of end products (flour). Based on this, the need to determine the most suitable drying temperature that will guarantee production of quality OFSPF with high functional/baking properties becomes imperative.

II. MATERIALS AND METHODS

10kg of freshly harvested orange–fleshed potato tubers (Mexican cultivar), was washed thoroughly with tap water, drained, peeled and sliced into 5mm thickness. The sliced OFSP were soaked in 2.5% sodium Metabisulphate for 30 minutes, to forestall browning. The treated potato slices were drained and divided into samples A, B, C, D, and E. the samples were dried in a hot air oven at 40 ^{o}C, 45 ^{o}C, 50 ^{o}C, 55 ^{o}C and 60 ^{o}C respectively, until a constant weight was obtained. Each of the dried samples were allowed to cool, crushed and milled into flour separately, using a mini hammer mill. The milled flour was further sieved individually using 75µm micro industrial sieve, to obtain fine flour of uniform particle size. The functional/baking properties of the sweet potato flour dried at different temperature were determined using [13]. Statistical analysis was carried out on the data generated, using analysis of variance (ANOVA) while the level of significance was determined using Duncan's multivariate test.

Determination of functional properties

The functional properties of the OFSPF dried at different temperature was determined using [13] methods. The functional/baking properties analysed are as follows, water absorption capacity (WAC), oil absorption capacity (OAC), gelatinization temperature, viscosity, solubility, swelling capacity (SC), and density (DM).

Determination of Density (DM)

The bulk density of the flour was calculated using simple laboratory method. 10ml graduated measuring cylinder is weighed, and gently filled with the sample. The bottom of the cylinder is tapped several times until there is no further diminution of the sample level after filling to the 10ml mark. The bulk density of the sample is calculated as follows.

$$\text{DM (g/ml)} = \frac{\text{weight of the sample (g)}}{\text{volume of the sample (ml)}}$$

Determination of water absorption capacity (WAC)

One gram (1g) of the sample is weighed into a conical graduated centrifuge tube. 10ml distilled water is added into it and mixed thoroughly using a whirl mixer for about 30 seconds. The mixed sample is allowed to stand for about 30 minutes at a room temperature and then centrifuged at 5000× g for 30 minutes. The volume of the free water (the supernatant) could be read directly from the graduated centrifuge tube or could be calculated using the equation below. The value is expressed as gram of water absorbed per gram of sample as described by [14].

$$\text{WAC \%} = \frac{\text{amount of water added} - \text{free water}}{\text{weight of sample}} \times \text{density of water} \times 100$$

Determination of oil absorption capacity (OAC)

The oil absorption capacity was determined using the method described by [14] was used. One gram of the flour was mixed with 10 ml refined corn oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2°C) for 1 hr. It was centrifuged at 1600 x g for 20 min. The volume of free oil was recorded and decanted. Fat absorption capacity was expressed as ml of oil bound by 100 g dried flour**.** The volume of the free oil could be read directly from the graduated centrifuge tube or could be calculated using the equation below. The value is also expressed as gram of oil absorbed per gram of sample.

$$\text{\% AOC} = \frac{\text{amount of oil added} - \text{free oil}}{\text{weight of sample}} \times \text{density of corn oil} \times 100$$

Determination of viscosity (V)

One gram (1g) of sample was weighed into a conical flask and diluted with 10ml distilled water and mechanically stirred for 2 hours at room temperature. The viscosity is then measured using Oswald viscometer. Viscosity is expressed as % of the total volume.

Determination of gelatinization temperature (GEL)

One gram (1g) of the flour sample is weighed into a test tube diluted with 10% distilled water to make suspension. The aqueous solution is heated in a boiling water bath with continuous stirring. The gelatinization temperature is recorded after 30 seconds, when gelatinization is visually noticed in the test tube.

Determination of swelling capacity (SC)

The swelling capacity of the OFSP flour was determined the method described by [15]. 100ml graduated cylinder was filled with the sample to the 10ml mark. Distilled water was used to dilute it to 50ml volume mark. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. The suspension was also inverted again after 2 minutes and left to stand for more 8 minutes. The volume occupied by the sample was taken after 8 minutes. Swelling capacity is expressed as % of the whole.

Determination of solubility (SOL)

Swelling power and water solubility of the flour were estimated as described by [15]. Flour–water slurry was made by dissolving 0.35g of flour in 12.5 ml of distilled water. The slurry was heated in a hot water bath at 60°C for 30 min, with constant stirring. It was then centrifuged at 3000 rpm (1207g) for 15 min, and the supernatant was decanted into a weighed evaporating dish and dried at 100°C to constant weight. The solubility was determined by evaporating the supernatant in a hot air oven and the residue weighed. The difference in weight of the evaporating dish was used to calculate the water solubility. The solubility in gram per 100g of the sample on dry basis can be calculate with the below equation.

$$\text{Solubility \%} = \frac{\text{weight after drying of supernatant}}{\text{weight after drying of dried sample in (1gram)}} \times 10$$

Determination of moisture content (MC)

The moisture content of the orange-fleshed sweet potato flour was determined using oven method as described by [13]. 2g of orange-fleshed sweet potato sample was weighed into a clean and dried crucible. The crucible and the sample was transferred into an oven and dried for 24hours at 100^{O}C until a constant weight was obtained. The sample was allowed to cool in a desiccators and the dried weight of the sample plus the crucible was noted. The % moisture was calculated as follows:

% Moisture = $\frac{W2-W3}{W2-W1} \times 100$
W1=initial weight of the empty crucible
W2= weight of crucible + sample before drying
W3=final weight of crucible+ sample after drying

III. RESULT AND DISCUSSION

The statistical analysis and the graphical representation of the result are presented in Table 1 and Figure 1 respectively.

Table 1: The effect of drying temperature to the functional properties of OFSPF

Drying temp (^{0}C)	SC (%)	Solubility SOL (%)	MC (%)	DM (g/cm3))	Viscosity (%)	WAC (%)	OAC (%)	Gel Temp (^{0}C)
40	7.95a	42.4e	6.2d	0.19a	16.5e	360a	190a	81a
45	10.12c	42.0d	4.9c	0.19a	12.5d	390c	170a	83b
50	9.79b	39.90b	4.8b	0.19a	8.0c	380b	190a	83b
55	7.81a	40.3c	4.8b	0.19a	5.5b	380b	170a	88e
60	12.6d	38.0a	3.3a	0.19a	5.0a	380b	210a	90d

Mean on the same column with different superscripts are significantly different ($p \leq 0.05$)

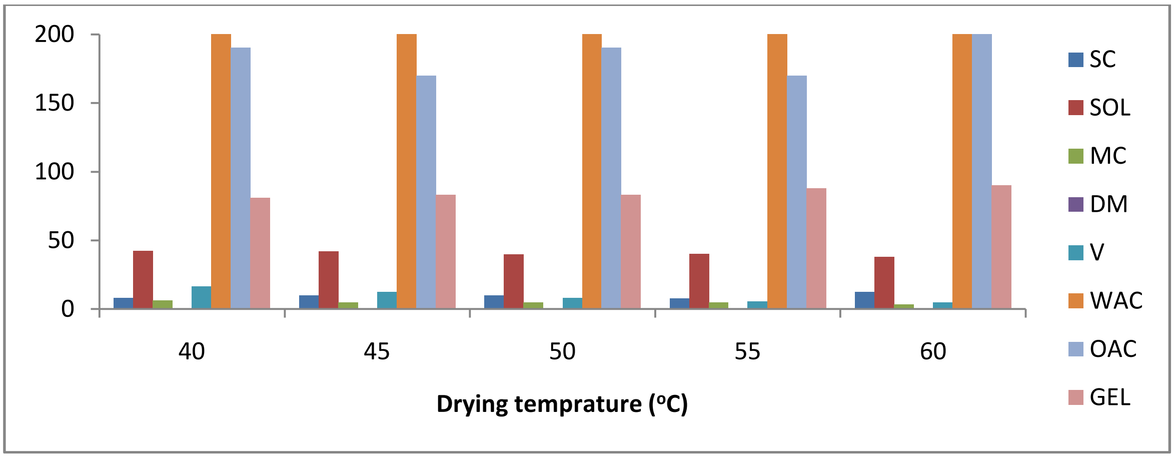

Figure1. Functional properties at different drying temperature

Solubility (SOL)

The statistical analysis shows that the solubility was significantly ($p \leq 0.05$) affected by drying temperature. Within the range of 40^{o}C to 60^{o}C drying temperature range, the solubility decreased progressively from 42.4% to 38.0%as presented in Table 4.11. The result is in agreement with the report of [1] where decrease in solubility was also reported. Significant loss of solubility at extremely high temperature was also reported by [16] and [17]. The decrease in solubility with increase in drying temperature may be attributed to critical loss of moisture and progression from fine flour into ashing [1].

Viscosity (V)

The statistical analysis shows that the viscosity was significantly ($p \leq 0.05$) affected by drying temperature. Within the range of 40^{o}C to 60^{o}C drying temperature range, the viscosity decreased progressively from 16.5 to 5.00as presented in Table 4.11. The result is in agreement with the report of [1]; [18] where decrease in viscosity with increase in drying temperature, though higher values were reported. Significant loss of viscosity and solubility at extremely high temperature was also reported by [16]. The decrease in viscosity with increase in drying temperature may be due to critical loss of moisture and the breaking down of oxygen/hydrogen molecular bonds as OFSPF as it progresses into fine flour. Among the variables evaluated, viscosity is the one of the most critically affected functional characteristics with it's decreased from 16.5 - 5.0 %.

Water absorption capacity (WAC)

The statistical analysis shows that the WAC was not significantly ($p > 0.05$) affected by drying temperature. Within the range of 40^{o}C to 60^{o}C drying temperature range, the WAC increased progressively from 360% to 380% (Table 4.11). The result is in agreement with the report of [11], where increase in WAC with increase in drying temperature, was reported though for different crops. Rohant and Narayansamy [20] also reported 62.67% to 69.17%, for wheat-sweet potato composite flour, which is lower than the results obtained from this study, at a higher drying temperature. The increase WAC may have been attributed to the effect of critical loss of moisture which increases hygroscopic potentials of milled products if exposed to moisture.

Oil absorption capacity (OAC)

The statistical analysis shows that the OAC was not significantly ($p > 0.05$) affected by drying temperature. Within the range of 40°C to 60°C drying temperature range, the OAC increased progressively from 190% to 210%as presented in Table 4.11. This may be due to critical loss of moisture during drying especially at higher temperature. The result is in agreement with the report of [11], where increase in OAC with increase in drying temperature, was reported with a lower value for different crops. [20]; [21] reported 168% for sweet potato flour, which is lower than the value reported by this research.

Gelatinization temperature (GEL)

The result shows that there were increases in gelatinization temperature of the OFSPF with increase in drying temperature (Table 4.11). Gelatinization temperature could be segmented into onset temperature (To), peak temperature (Tp) and conclusion temperature (Tc) but was discussed as a single unit for the purpose of this research. The statistical analysis shows that the gelatinization temperature was significantly ($p \leq 0.05$) affected by drying temperature. Within the range of 40°C to 60°C drying temperature range, the gelatinization temperature increased progressively from 81 °C to 90 °C (Table 4.11). This may be due to the fact that carbohydrate content also increases with increase in temperature, since gelatinization is largely starch related reaction. Penetration of water into flour increases the randomness in the starch granule structure, and causes swelling, thus gelatinization temperature depends on water and the magnitude of starch in the sample [22]. The result is in agreement with the report of [22] and [11] where increase in gelatinization with increase in drying temperature was reported.

Swelling capacity (SC)

From the result of the analysis, there was increase in swelling capacity of the OFSPF with increase in drying temperature. The statistical analysis shows that the swelling capacity was significantly ($p \leq 0.05$) affected by drying temperature. Within the range of 40°C to 60°C drying temperature range, the swelling capacity increased progressively from 7.95ml to 12.6mlas presented in Table 4.11. This could be attributed to critical loss of moisture during continual increase in drying temperature, since swelling capacity is the ability to absorb water and increase in size. The result is in agreement with the report of [22] and [11] who reported increase in swelling capacity with increase in drying temperature.

Density (DM)

The result shows that there was neither increase nor decrease in density DM of the OFSPF with increase in drying temperature; the values remained constant throughout the experimental period (Table 4.11). The statistical analysis shows that the DM was not affected by drying temperature. Within the range of 40°C to 60°C drying temperature range, the DM value remained constant at 0.19 as presented in Table 4.11.

Moisture content (MC)

The result of the analysis shows that the moisture content (MC) recorded for all drying temperature 40-60 °C ranges between 3.3%-6.2%. The moisture content is within the range of 2.50%-13.2% reported for sweet potato by [16] for local white flesh (LWF) and local yellow flesh (LYF) cultivars sweet potato respectively. In other similar studies, 12.55% was considered to be the critical moisture content of flour within a locality that has ambient temperature range of 27-29 °C while a value of 10% was recommended for long term storage [23]; [24]. The result of the statistical analysis shows that moisture content MC of the OFSPF decreases significantly ($p \leq 0.05$) with increase in drying temperature from 6.20% at 40°C to 3.3% at 60°C. However, it is expected, since the increase in temperature has direct effect in drying of the flour by lowering its MC. The continuous increase will lead to burning and ashing of the flour, while a decrease will lead to more moisture that will accelerate chemical and microbiological deterioration especially during storage [24]; [23].

IV. CONCLUSION AND RECOMMENDATION.

The result of this research shows that drying temperature has different effect on most of the functional/baking properties of orange-fleshed sweet potato flour. While the bulk density of the flour remain unchanged irrespective of the drying temperature, moisture content (MC), solubility (SOL), viscosity (V) decreases with increase in drying temperature. The swelling capacity (SC), water absorption capacity (WAC), oil absorption capacity (OAC), and gelatinization temperature (GEL) also increases with increase in drying temperature.

The recommended baking temperature which gave the best matrix for optimum functional /baking properties is 45^{o}C drying temperature with the following matrix, 83 % GEL, 170% OAC, 390 WAC, 10.2 SC, 42.0 SOL, 4.9% MC, 0.19g/cm3, and 12.5% viscosity.

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