Food Research 5 (3) : 315 - 320 (June 2021)
Journal homepage: http://www.myfoodresearch.com

FOOD RESEARCH

FULL PAPER

Physicochemical and microbial properties of orange-fleshed sweet potato flour produced with sun-drying and sulphiting agent

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Article history:
Received: 4 October 2020
Received in revised form: 18 November 2020
Accepted: 21 January 2021
Available Online: 13 June 2021

Keywords:
Carotene,
Sweet potato,
Flour,
Microbial quality,
Physico-chemical property

DOI:
https://doi.org/10.26656/fr.2017.5(3).561

Abstract

Many local Nigerian processors of sweet potato flour use sun-drying of the sliced roots in place of modern mechanical drying. This study used carotene-rich UMUSPO3 orange-fleshed sweet potato (OFSP) variety that was newly bred at National Root Crop Research Institute (NRCRI), Umudike, Nigeria to evaluate the possible effect of sun-drying and sulphiting on the physicochemical and microbial properties of OFSP flour samples. Data were obtained for OFSP sun-dried flour samples processed by different pretreatment methods (blanching, sulphiting with sodium metabisulphite and a control). Results showed that the bacterial and fungal load of the sulphite-flour sample was 8.5×10^4 CFU/g and 4.00×10^4 CFU/g while that of the control flour sample was 12.00×10^4 CFU/g and 6.50×10^2 CFU/g respectively. The total carotenoid content (TCC) of the flour samples ranged from 10.73 – 11.68 mg/100 g while the TCC of the fresh (unprocessed) OFSP was 40.20 mg/100 g on dry matter basis. The proximate composition of the flour samples was 10.21 – 10.95% moisture, 8.18 – 8.20% protein, 2.40 -2.55% fibre, 0.95 -1.11% fat and 1.73 – 1.85% ash. Obtained physico-functional properties were 13.17 – 13.23 g/mL swelling power, 2.70 – 3.4 g/mL oil absorption capacity, 2.65 – 2.85 g/mL water absorption capacity, 77.50 – 88.00^0C gelatinization temperature and 0.65 – 0.66 g/mL bulk density.

1. Introduction

Sweet potato *(Ipomoea batatas*) is a food crop grown in the tropics especially for its economic importance (Woolfe, 1992). Awareness of its importance and its usefulness in improving the livelihood of households and national food security has been created. Orange fleshed sweet potato (OFSP) has helped to improve the health of poor families in Sub-Saharan Africa due to its high pro-vitamin A content (Ganiyat *et al.,* 2013). Despite its versatility, dynamic nature and global annual production rate of 133 million tons (FAOSTAT, 1998), it is still among the world's most underutilized crop in many underdeveloped and developing countries; after rice, wheat, maize and cassava (Owori *et al.,* 2007; Ezeano, 2010). OFSPs are generally perishable because of their high moisture content of above 62% (Satheesh and Solomon, 2019). However, with adequate drying, their shelf lives are usually prolonged and this can be achieved by drying the slices under the sun especially for small scale sweet potato farmers that do not have mechanized drying equipment. Drying the slices takes several hours to days (based on the weather) to achieve a completely dried chip. During this period of the atmospheric drying process, microorganisms may gain entrance through the exposed surfaces of the slices. Additionally, the high moisture content may allow the proliferation of microorganisms leading to microbial contamination of the product. After the slices are dried, sweet potato flours are then produced by grinding the dried sweet potato slices which could either be used as whole flour or as composite flour in making confectionaries (Nicanuru *et al.,* 2015). However, it is of optimum importance to have adequate information and knowledge concerning the changes that may occur in the carotenoid content of OFSP as a result of the different processing and drying method used. The amount of the total carotenoid retained is very important as OFSP is used to combat Vitamin A Deficiency (VAD) syndrome. Sulphiting agents have been shown to have the potential of inhibiting or reducing microbial contamination in foods (Mohammad *et al*., 2009). Therefore, this study

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eISSN: 2550-2166

was aimed to determine the possible effect of different processing pretreatments and sun-drying on the microbial load, physicochemical properties (including total carotenoid content) of flour produced from OFSP by poor resource processors in Nigeria. Furthermore, research scientists in National Root Crops Research Institute (NRCRI) in Nigeria are working hard to release more varieties of OFSP with an appreciable amount of pro-vitamin A.

2. Materials and methods

2.1 Source of material

The experimental OFSP root variety named Umuspo 3 was harvested from the National Root Crops Research Institute Umudike experimental farm. They were harvested at 16 weeks after planting.

2.2 Sample preparation of orange-fleshed sweet potato flour

Figure 1 represents the flow chart for processing orange fleshed sweet potato flour samples through sun-drying. A total of 3 kg sample of the fresh experimental OFSP were washed with clean water. The sweet potatoes were divided into three portions according to the treatment that was to be given to each. The first portion was blanched as in 2.2.1 below; the second portion was treated with sodium metabisulphite (as in 2.2.2) while the third portion was given no treatment(control). The treated samples were further sun-dried. The atmospheric sun-drying was done at National Root Crop Research Institute (NRCRI) Umudike, Abia State, Nigeria (Latitude 5.489^{o}N and Longitude 7.547^{o}E) on a raised platform covered with transparent polyethylene sheet until the sample became brittle.

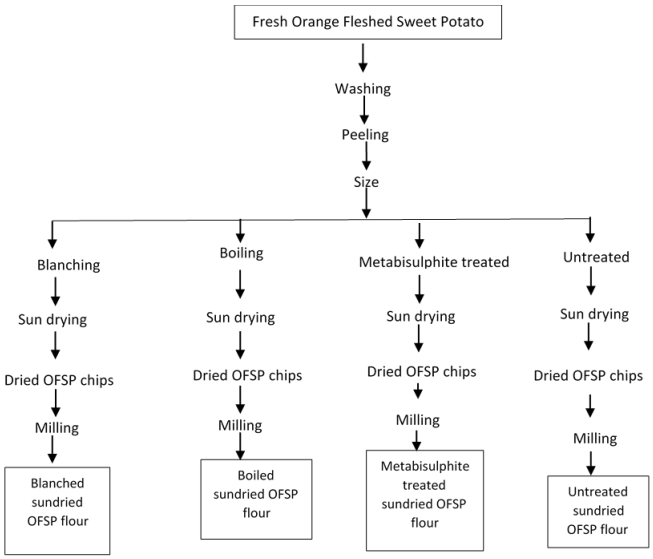

Figure 1. Flow chart for processing orange fleshed sweet potato flour samples through sun-drying

2.2.1 Blanched samples (Treatment I)

One portion of 1 kg was peeled using a sharp kitchen knife. Thereafter it was washed and cut into slices of about 2.5 mm thickness each. The diced potato roots were blanched directly by immersing them in the water bath for 5 mins at 80°C and cooled with tap water. The blanched samples were then sun-dried, milled (Moulinex Blender, Cambridge, England) and packaged.

2.2.2 Pretreatment with sodium metabisulphite (Treatment 2)

The second portion was peeled, washed with clean water, sliced into 2.5 mm thickness and soaked in 0.5% sodium metabisulphite solution for 10 mins. It was drained, sun-dried, milled (Moulinex Blender, Cambridge, England) and packaged.

2.2.3 Preparation of the control sample (Untreated sample)

The third portion was peeled, washed and sliced into 2.5 mm thickness and thereafter sun-dried. It was milled and packaged for analysis.

2.3 Pre-analysis activities

All the samples were packaged in sealed (through knotting) transparent polyethylene bags and stored on food laboratory shelf at ambient room temperature of about 29±2°C for 72 hrs.

2.4 Physico-chemical and microbial analysis

2.4.1 Proximate composition

The proximate composition (moisture, crude fibre, fat, crude protein and carbohydrate) of the fresh OFSP and OFSP flour samples were done in triplicates using the AOAC method (2002).

2.4.2 Total carotenoid content determination

The total carotenoid content of the OFSP fresh and flour samples was determined by the method described by AOAC (2000) and modified by Rodriguez-Amaya and Kimura (2004). Approximately 10 g of OFSP flour sample was added to a conical flask containing 50 mL of 95% ethanol and then placed in a water bath at 80°C and the content shaken periodically for 20 mins. A measuring cylinder was used to decant the supernatant and allowed it to cool and the initial volume was taken. Approximately 15 mL of distilled water was added to reduce the ethanol concentration to 85% and was further cooled putting it in a container with ice water. Next, 25 mL of petroleum ether was added to the mixture after it was transferred to a separating funnel. The mixture was homogenized by gently swirling the funnel and then

separated into two layers after it stood for a while. A beaker was used to collect the bottom layer while a 250 mL conical flask was used to collect the upper layer during runoff from the funnel. The bottom layer was re-extracted by adding 10 mL petroleum-ether to it and transferred back to the funnel for a runoff. This was done until the extract became light yellow. The petroleum ether was collected with a 250 mL conical flask and poured back into the separating funnel for re-extraction using 50 mL of 80% ethanol. The extract was then put in sample bottles and kept for spectrophotometer reading. The spectrophotometer (Jenway UV/VIS model United Kingdom) was set at 436 nm wavelength and the absorbance of the extract taken. The Spectrophotometer was calibrated to zero points using a 1 cm cuvette with petroleum-ether as blank. Samples of the extract were added to the cuvette. The readings of the samples were taken immediately the figure displayed on the spectrophotometer window was steady.

$$\text{Total carotenoid content } \left(\frac{\mu g}{g}\right) = \frac{A \times V \times 104}{2592 \times P}$$

Where A = Absorbance, V = Total extract volume (mL), P = Sample weight (g), and 2592 is the beta-carotene extinction co-efficient in 1 cm petroleum ether.

2.4.3 Bulk density

This was determined using the method advanced by Okaka and Potter (1979) where 10 g of the OFSP flour sample was measured into a 100 mL graduated measuring cylinder. The bottom of the cylinder was tapped repeatedly on a pad placed on a laboratory bench. Tapping was done until no further diminution or reduction in the volume occupied by the sample. The bulk density was determined as the ratio of the weight of the sample to its volume and calculated as shown below.

$$\text{Bulk density} = w/v$$

Where W = weight of the sample (g), V = volume of sample (dm^3)

2.4.4 Gelatinization temperature

Exactly 10% suspension of OFSP sample was prepared in a test tube. The aqueous suspension was heated in a boiling water bath with continuous stirring. Then, the temperature was recorded 30 s after gelatinization is visually noticed as the gelatinization temperature.

2.4.5 Swelling power determination

The swelling power was determined according to the methods described by Li and Yeh (2001). Swelling power is a measure of the hydration capacity of starch and is expressed as the weight of centrifuged swollen granules, divided by the weight of the original dry starch used to make the paste. About 2 g ground samples were suspended in 10 mL of water and incubated in a thermostatically controlled water bath at 95°C in a tarred screw cap tube of 15 mL. The suspension was stirred intermittently over 30 mins to keep the starch granules suspended. After this, the weight of the swollen sediment was determined.

Supernatant liquid (dissolved starch) was poured into a tarred evaporating dish which was then placed in an air oven and dried at 100°C for 4 hrs.

$$\text{Swelling power} = \frac{W \times 100}{W_{dm}\,(100 - \text{Solubility})}$$

$$\text{Dry matter weight} = W_s\,(1\text{-MC})$$

Where W = weight of supernatant and centrifuged swollen granules, W_s = Weight of sample, MC = Moisture content of sample dry basis (decimal), and W_{dm} = Weight of dry matter

2.4.6 Water/oil absorption capacity determinations

The method described by Onwuka (2005) was used in determining the oil and water capacity of the samples. Exactly 1.0 g of each sample was weighed into a graduated 15 mL centrifuge tube and 10 mL distilled water was added. The flour samples were mixed thoroughly and allowed to stand for 30 mins at room temperature and centrifuged at 2000 - 5000 rpm for 30 mins. The volume of free water or oil was then determined (the supernatant was read directly from the graduated centrifuge tube).

$$\text{Water and oil absorption capacity (mL/g)} = V_1 - V_2$$

Where V_1 = initial volume of water or oil before centrifugation and V_2 = final volume of water or oil after centrifugation.

2.4.7 Microbial load determination

Approximately 25 g of the well mixed sample was aseptically dispensed into a test tube containing 225 mL of sterile distilled water to obtain the first dilution of 1:10. Then in series, 1.0 mL was transferred from the first diluent to the second in the next test tube of 9 mL sterile distilled water, then from that to the third and continued to the sixth diluent (10^{-6}). Then, 1 mL was dispensed out of the last diluent to maintain equality in volume with the others. Inocula of 1 mL each was taken from the second and the 4th diluents (10^{-2} and 10^{-4}) and cultured for fungi and bacteria respectively using pour plate technique (Cheesbrough, 2000). Fungal culture was done on Sabouraud Dextrose Agar (SDA) while bacterial culture was done on Nutrient Agar (NA). In each case, the 1 mL, inoculum was poured into a sterile petridish

under aseptic condition and a portion of the sterile molten agar medium (about 15 mL), was carefully poured into the petri dish and swirled to mix completely with the inoculum in the plate. The inoculated plates were allowed to cool, solidify, sealed and their labels cross checked before they were incubated. The bacterial culture plates (Nutrient Agar) were incubated at 37±2.0° C for 24 to 48 hrs while the fungal plates were incubated at ambient temperature, (28-32°C) for 2 to 4 days. They were observed daily for growth and on establishment of growth, the number of colonies in each plate was counted with the aid of a colony counter. The formula below was used to calculate the microbial load (Ezeama, 2007).

$$\text{Microbial Load (CFU/g)} = \frac{1}{v} \times N \times D$$

Where v = volume of inoculum cultured, N = number of colonies counted and D = is the dilution factor.

Each sample was cultured in triplicates and count was taken for each.

2.5 Statistical analysis

All data obtained from the study was subjected to analysis of variance (ANOVA) using SPSS software package version 20. Where necessary, means were separated using Duncan Multiple Range test to determine the significant difference at 5% probability.

3. Results and discussion

The result in Table 1 represents the proximate and total carotenoid content of the fresh UMUSPO 3 OFSP sample. It has a dry matter content of 30.25 g/100 g, carbohydrate and crude fibre content of 76.66 g/100 g and 6.35 g/100 g respectively on dry matter basis. It also has a crude protein, fat and ash content of 10.81 g/100 g, 1.71 g/100 g and 4.49 g/100 g. The total carotenoid content value of 12.16 mg/100 g all on fresh weight basis is up to 40 mg/100 g on dry matter basis.

Table 1. Proximate composition and total carotenoid content of the fresh OFSP roots

Proximate composition	Values
Moisture content (g/100 g)	69.75±0.15
Dry matter content (g/100 g)	30.25±0.21
Carbohydrate (g/100 g)	23.19±0.00 [76.66]
Crude fibre (g/100 g)	1.92±0.03 [6.35]
Crude protein (g/100 g)	3.27±0.01 [10.81]
Fat (g/100 g)	0.52±0.00 [1.71]
Ash (g/100 g)	1.35±1.35 [4.49]
Total carotenoid content (mg/100 g)	12.16±0.12 [40.20]

Values in parenthesis are on dry weight basis

The proximate composition of flour samples as affected by the sun-drying method are shown in Table 2. The result of the effect of sun-drying on the moisture content of the Umuspo 3 OFSP flour sample is as shown in Table 2. The blanched sundried sample had the highest moisture content of 10.95% while the sample treated with a sulphiting agent had the lowest moisture content of 10.21%. Moisture content is very critical in the storage of flours samples and if not handled properly may lead to impairment in the quality and general functionality of the product (Aguilera *et al.,* 1995). Samples treated with the sulphiting agent had the crude fibre content of 2.55% while the blanched sundried sample had the lowest crude fibre content of 2.4%. Samples treated with a sulphiting agent had the highest carbohydrate content of 79.63% while blanched sundried sample had the lowest carbohydrate content of 74.60%. Sweet potatoes contain high carbohydrate content and as such are considered a high energy source that can provide up to 450 kJ/100 g of energy (Tortoe *et al*., 2017). As shown in Tables 1 and 2, the experimental drying process in the OFSP flour production reduced the TCC content of OFSP from 40.20 mg/100 g (on dry matter basis) to 10.75-11.68 mg/100 g for the flour samples. The pretreatment method also affected the TCC of the flour samples (Table 2). Vimala *et al.* (2011) noted that processing may reduce the TCC content of OFSP. Bechoff (2010) specifically opined that the degree of carotenoid loss can be limited by blanching. It was also observed that though sulphiting helped to preserve the orange colour of the OFSP flour sample, the sulphited samples had the lowest TCC. The functional properties of the OFSP flour sample in Table 3 showed that except for bulk density, there were significant differences ($p<0.05$) in other properties determined. Swelling power ranged from 13.17 - 13.29 (g/mL) with the sample treated with a sulphiting agent having the highest while the untreated sample had the lowest. The oil absorption capacity of the samples ranged 2.70 - 3.40 g/mL with the blanched sundried sample having the highest and untreated sample having the lowest. This showed that the blanched sample will absorb more oil than other samples, especially if used in food formulations and in baking where high oil retention is needed (Adejuyitan *et al.,* 2009). The WAC ranged from 2.65-2.85% for the samples. Water absorption capacity is used to indicate the level of water the flour can absorb during processing to achieve consistency and become voluminous without affecting the nutrient and energy density of such foods (Cameron and Hofvander, 1983).

The gelatinization temperature of the flour samples ranged from 77.50-88.00°C with the untreated sample having the highest value. There was no significant difference ($p>0.05$) in the gelatinization temperature of the metabisulphite treated sample and blanched. For

Table 2. Effect of sun-drying on the proximate composition of the experimental sweet potato flour samples (%)

Sample	Moisture Content	Crude Fibre	Crude Protein	Fat	Ash	CHO	TTC
USD	10.90±0.01^{b}	2.53±0.01^{b}	8.18±0.0^{b}	0.95±0.01^{b}	1.85±0.01^{a}	75.23±0.0^{b}	11.59±0.0^{b}
MSD	10.21±0.02^{c}	2.55±0.01^{a}	8.19±0.0^{b}	1.11±0.01^{a}	1.73±0.01^{c}	79.63±0.0^{a}	10.73±0.2^{c}
BSD	10.95±0.01^{a}	2.40±0.00^{c}	8.20±0.0^{a}	1.11±0.01^{a}	1.75±0.01^{b}	74.60±0.0^{c}	11.68±0.4^{a}
Means	10.69±0.03	2.49±0.01	8.19±0.03	1.06±0.01	1.78±0.01	76.49±0.00	11.33±0.08

Values are expressed as mean±SD of three determinations. Values with different superscript in the same column are significantly different ($p<0.05$). BSD = Blanched sun-dried, USD = Untreated sun-dried, MSD = Metabisulphite treated sun-dried, CHO = Carbohydrate, TCC = Total carotenoid content

Table 3. Selected physico-functional properties of experimental sweet potato flour samples

Sample	Swelling power (g/mL)	OAC (g/mL)	WAC (g/mL)	Gelatinization Temp (°C)	Bulk Density (g/mL)
USD	13.17±0.03^{c}	2.70±0.00^{c}	2.75±0.00^{b}	88.00±0.02^{a}	0.65±0.00^{a}
MSD	13.29±0.00^{a}	3.00±0.01^{b}	2.85±0.02^{a}	77.50±0.03^{b}	0.66±0.00^{a}
BSD	13.23±0.10^{b}	3.40±0.02^{a}	2.65±0.01^{c}	77.50±0.01^{b}	0.65±0.00^{a}
Means	13.23±0.04	3.03±0.01	2.75±0.01	81.00±0.02	0.64±0.00

Values are expressed as mean±SD of three determinations. Values with different superscript in the same column are significantly different ($p<0.05$). BSD = Blanched sun-dried, USD = Untreated sun-dried, MSD = Metabisulphite treated sun-dried, CHO = Carbohydrate, TCC = Total carotenoid content

foods that require gel formation, lower gelatinization temperatures are important and desirable as it helps to minimize the loss of nutrients that are heat liable in such food products (Kolawale *et al.,* 2016). The bulk density of the flour samples ranged from 0.65-0.66 g/mL and information on bulk densities are important when selecting packaging materials as the large volume of foods with high bulk density can be packed within a constant volume (Fagbemi, 1998). Table 4 represents the result obtained for the possible effect of sulphiting on the sundried flour samples. Though the bacterial and fungal load ranged from 8.5 - 12.00×10^{4} CFU/g and 4.00 - 7.00×10^{4} CFU/g respectively, the sulphited OFSP flour samples had significantly ($p = 0.5$) lower bacterial and fungal loads. The untreated sundried sample had the highest microbial load however samples treated with sulphiting agent had the lowest bacteria and fungi load as a result of the microbial inhibition effect of the potassium metabisulphite used in treating the OFSP slices before drying. Prolonged exposure to an uncontrolled environment during drying may have resulted in the increased microbial load recorded in the sundried sample. However, the range obtained in the study is within the acceptable limit of $<10^{5}$ recommended by the International Commission on Microbiological Specification for Foods (ICMSF, 1986) for local samples.

Table 4. Bacteria and Fungi load of the experimental sweet potato flour samples

Sample	Bacteria ($\times10^{4}$ CFU/g)	Fungi ($\times10^{2}$ CFU/g)
USD	12.00±0.00^{a}	6.50±0.41^{b}
MSD	8.5±0.00^{c}	4.00±0.17^{c}
BSD	10.5±0.00^{b}	7.00±0.03^{a}

Values are expressed as mean±SD of three determinations. Values with different superscript in the same column are significantly different ($p<0.05$). BSD = Blanched sun-dried, USD = Untreated sun-dried, MSD = Metabisulphite treated sun-dried, CHO = Carbohydrate, TCC = Total carotenoid content

4. Conclusion

The study shows that the physicochemical properties and total carotenoid content of sundried OFSP flour samples may be affected by the processing method utilized as was observed in this study. The available sulphiting agent can be employed by poor resource farmers who cannot afford conventional oven driers to produce flour with the reduced microbial load as samples treated with sulphiting agent had a significantly lower bacterial and fungal load.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgment

We are grateful to National Root Crops Research Institute (NRCRI), Umudike for funding this Research publication.

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