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Biochemical and Antioxidant Constituents of Raw and Heat Processed Orange Fleshed Sweet Potato Flour and its Shelf-Life Study *(Ipomoea batatas)*

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ABSTRACT

Orange fleshed sweet potato (OFSP) has emerged as promising plant source with a high β-carotene content that can make a significant contribution of the vitamin A intate of individual of risk of vitamin A deficiency. This crop is used to overcome vitamin A deficiency in South Asia and Sub-Saharan region. The present study is conducted to highlight the biochemical composition, antinutrients, and β-carotene contents of Gauri variety of OFSP and its flour. The proximate and mineral composition and some anti-nutritional factors of flour and raw tubers were determined using standard methods. The nutritional compositions of OFSP flour were found as moisture (5.80 ± 0.35 g/100g), crude protein (6.33 ± 0.05 %), fat (1.41 ± 0.03 %), ash (4.64 ± 0.05 %), crude fiber (4.43 ± 0.08 %), total sugar (14.43 ± 0.17 g/100g), reducing sugar (6.57 ± 0.18 g/100g) and non reducing sugar (7.86 ± 0.02 g/100g), carbohydrate (77.38 ± 0.50 %) and energy (347.55 ± 1.70 Kcal). The minerals content i.e., calcium, iron, and phosphorous content of OFSP flour were quantified as 126.59 ± 1.90 mg, 2.14 ± 0.06 mg, and 115.00 ± 2.10 mg/100g respectively. OFSP flour was significantly higher in terms of β-carotene, total carotenoids, and antioxidant activity. Sensory evaluation of OFSP flour was carried out for 90 days at an interval of 30 days. The results revealed that there was a declining trend in the scores of sensory attributes during storage, but it was well accepted and liked by the panelists over 90 days of storage period. Thus, it was found that OFSP flour have and excellent nutritional profile from the nutritional point of view the flour is rich in β-carotene and total carotenoid content and safe for human consumption at least for 90 days of storage period. Result of this study suggest that increased consumption of OFSP incorporated products can contribute considerably in alleviating dietary deficiency of vitamin-A a major public health concern of developing countries.

Keywords: *Orange fleshed sweet potato, beta carotene, antioxidant activity, total carotenoid, proximate composition.*

Introduction

Sweet potato (*Ipomoea batatas* L. Lam) is a perennial tuber crop of the *Convolulaceae* family widely produced in different agro-climatic regions of the world. It is the second most important root and tuber crop in Asia and the sixth most important world crop after rice, wheat, potato, corn, and cassava [1]. Orange Fleshed Sweet Potato (OFSP) is a good source of energy 293 to 460KJ/100g and it is easy to propagate vegetatively in marginal fields [2]. Apart from being a cheap source of energy, it is an excellent source of β-carotene and is generally well-accepted by the people [3]. The OFSP genotypes that are cultivated in India are Kamala Sundari, Gouri, Sankar, Sree Kanaka, ST14, etc.

The poor people have limited access to expensive vitamin A-rich animal foods like fish oil, egg, milk and butter. The OFSP can meet the daily requirement of vitamin A along with some other essential nutrients, through increased consumption of OFSP [4]. Regardless of its high carbohydrate content, it has a low glycemic index, indicating low digestibility of the starch [5] thus, suitable as a food, for diabetics [6]. Just a small tuber (100 to 125g) of medium-sized, OFSP variety can meet the daily vitamin A needs of children under five years of age and protect them from night blindness [7, 8, 9].

Nutritionally, vitamin A deficiency is one of the most prevalent problems in developing countries including India, and the most common cause of childhood blindness, in the world [7]. Globally, 190 million preschool children and 19 million pregnant women are affected by vitamin A deficiency, and a leading cause of preventable blindness in the world. In Sub-Saharan Africa and South East Asia, where more than 40% of preschool children are at risk, have the highest burden of vitamin A deficiency. About,140 million children of below 5 years aged, who nearly 100 million live in South Asia or Sub Saharan Africa have serum retinol level below 0.70μmol/liter. In 2013, about 45 % of children's deaths were linked with malnutrition in the world [10].

Strategies to control vitamin A deficiency include vitamin A supplementation, food fortification and dietary diversification. The third strategy i.e., food-based intervention, which improves dietary quality and quantity through diversification of crops, is the safest and the most sustainable way of combating vitamin A deficiency. Fortunately, in low-income countries, about 82% of the total vitamin A intake is from carotenoids in plants. The most common vitamin A-forming carotenoids are β-carotene, α-carotene and β-cryptoxanthin, amongst which, β-carotene is the most common pro-vitamin A carotenoid in the food supply. It is found in many green or orange-colored vegetables and fruits such as carrots, OFSPs, mangoes, spinach and pumpkin. It has

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been documented that maceration and heat processing improve β-carotene bio-accessibility from OFSP, which is probably due to the rupture of the microstructure of plant tissue and subsequent release of nutrients from the complex food matrix [3, 11].

In developing countries like India, sweet potato tubers are mostly consumed in boiled, steamed or fried forms at the household level. Fresh tubers are bulky and perishable which limits its utilization. These tubers can be processed into flour, a shelf-stable product, which remains in good condition for a long time. Sweet potato flour can be used to substitute part of cereal flour which are used to make different value-added products. Keeping these points in view, the present investigation was undertaken to analyze the physico-chemical properties and shelf life of OFSP flour.

Methodology

Preparation of flour

Orange Fleshed Sweet Potato (OFSP) flour was prepared by the method according to Gitanjali and Lakhawat [12]. The fresh OFSP tuber (Gauri variety) were sorted and thoroughly washed, trimmed, peeled and sliced into thin slices of 0.5mm thickness. The cut slices were soaked in 0.5% potassium metabisulphite (KMS) solution for 15 minutes to prevent browning reactions. They were further blanched for 3 minutes and dried overnight in hot air oven at 60°C. The dried slices were ground in a mixer grinder and sieved through 70 mesh size. The prepared flour was packaged in an air-tight container.

Nutritional Analysis of OFSP Flour

Proximate composition

Proximate compositions of OFSP flour were determined according to the AOAC methods [13]. Total nitrogen content was determined by using the micro-kjeldahl method. The crude protein content of flour was obtained by multiplying total nitrogen by the conversion factor of 6.25 (% Protein = TN x 6.25), and the crude fat, crude fiber, ash content and moisture content of the sample were determined by using AOAC methods [13]. The total available carbohydrate content was determined by difference methods as follows: 100 – [ash (g%) + protein (g%) + fiber (g%) + fat (g%) + moisture (g%)]. Where (g%) = gram per 100grames OFSP. The energy content in Kcal/100g was determined by adding percentages of crude fat, crude protein, and carbohydrate after multiplying by factors of 9.0, 4.0, and 4.0 respectively according to Shrestha and Noomhorm [14].

Estimation of sugar content

The estimation of the total and reducing sugar content of OFSP flour was estimated by Sadasivam and Manickam [15]. The amount of non-reducing sugar was calculated by subtracting the amount of reducing sugar from total sugar of the flour.

Estimation of Mineral profile

Mineral solutions of flour were prepared by the wet ashing method. An aliquot of minerals solution was used for determination of the amount of minerals by Atomic Absorption Spectrophotometer (ECIL, model AAS 4141), and concentrations of minerals were determined.

Estimation of β-carotene

The β-carotene content was estimated through the High Pressure Liquid Chromatography (HPLC) as suggested by Chiosa *et al.* [16]. In, order to avoid possible degradation of β-carotene, the OFSP and flour were extracted directly with solvent without saponification. Five gram of samples was extracted with acetone: hexane (4:6). Then, the solvent was evaporated to dryness under the stream of nitrogen and the residue was reconstituted with 1ml of eluent solution (acetonitrile-tetrahydrofuran-methanol-ammonium acetate (68.4% (v:v): 2.0% (v:v): 6.8%(v:v): 2.8% (v:v) 1%(w:v). The reconstituted extracted sample was collected in a screw cap vial for HPLC analysis. The flow rate of the mobile phase at 1.5ml/minutes and detection was at 460nm by diode array method for 15 minutes. The peak area for β-carotene was identified by taking the reference sample peak.

Estimation of total carotenoid

The total carotenoid was estimated by acetone-petroleum ether extraction followed by spectrophotometric measurement with little modification as suggested by Rodrigues-Amaya *et al.* [17]. All procedures were carried out under the normal working conditions of the laboratory without incurring too much carotenoid loss. The solutions of carotenoids were kept under dim light and at low temperatures as much as possible. A 100mg of moisture-free samples were taken in a mortar and pestle. Thirty ml of cold acetone was added to it and mixed well. The mixture was homogenized for one minute using a vortex mixture. The homogenized mixture was transferred into a sintered funnel coupled with 250ml Buchner flask and filtered under vacuum. The carotenoid extraction procedure was repeated 3-4 times or until the sample became colorless. Fifty milliliter of petroleum ether and a small portion of acetone ether extract were taken in a separating funnel. Distilled water was added slowly along with the wall of the separating funnel. The two phases was separated and the lower aqueous phase of the acetone extract was discarded. Another portion of the acetone extract was added in flask and the process was repeated until all the extract has been transferred to petroleum ether. The extract was washed 4-5 times with distilled water to complete removal of acetone residue. Then extract was transferred to a 50ml volumetric flask through a glass funnel containing 15g of anhydrous sodium sulfate. The volume of extract was made up to 50ml with petroleum ether. The carotenoid ether extracts were read at 450nm wavelength in a spectrophotometer and total carotenoid content was calculated using the following formula:

$$\text{Total carotenoid (mg/100g)} = \frac{\text{A x Volume of the extract (ml)}}{A^{Y} \text{ x Sample Weight X 1000}} \times 100$$

Where,

A= absorbance of extract

A^{Y} = 2592 (Absorption coefficient of β-carotene in petroleum ether).

Total antioxidant activity

The total antioxidant activity by DPPH (2,2-Diphenyl-1-pricrylhydrazyl) radical scavenging activity was assessed by the method given by Tadhani *et al.* [18] as previously described by Brand-Williams *et al.* [19]. Five grams of flour was taken in a 100ml conical flask and 15ml of 80% methanol was added in it. The sample was then acidified to pH 2.0 with 6N HCl by shaking at room temperature for 30 minutes. The supernatant was decanted and the residue was re-extracted twice for complete removal of antioxidant compounds. All collected supernatant were pooled together and centrifuged at 6000rpm for 15minutes and filtered through Whatman filter paper (No.1). The volume of filtrate was made up to 50ml with methanol. The

filtrate was then transferred to micro centrifuge tubes and stored at -20°C for determination of total antioxidant activity.
The different aliquots of filtrate were taken in test tubes and volume was made up to 1ml with methanol. The 3ml of DPPH solution was added in it and the reaction mixture was mixed properly and incubated at 37°C for 20 minutes in the dark. The absorbance of the resulting oxidized solution was read at 517nm against methanol as blank. Methanol was used as a positive control. The standard series of aliquots of known concentration of Trolox (10-40µg) were taken parallel. The antioxidant activity of the sample was calculated by using the following formula.

$$\text{AOA (Percent inhibition)} = \frac{(Ac\text{-}Ae)}{Ac} \times 100$$

Where,
Ac = Absorption of control
Ae = Absorption of extract

TAA (mgTE/100g)	=	Standard concentration	=	Sample % inhibition	=	Volume made up	=	100	=	Diluton factor
		Standard % Inhibition		Aliquot taken		Sample taken		100		

Anti nutritional factors
Phytate
Phytic acid was estimated by colorimetric determination of ferric ions according to Wheeler and Ferral [20]. Phytic acid and chelates of phytic acid reacts with ferric chloride and forms ferric phytate. The available ferric ions after the reaction is determined by developing a blood red colour with potassium thiocyanate.

Oxalate
The oxalate content was estimated as suggested by NIN [21]. The 10g of moisture-free OFSP flour was well ground in mortar and pestle along with 100ml of 2N HCl. It was shaken for about two hours in a mechanical shaker, then centrifuged and filtered. The filtrate was then transferred in the same beaker and weighed. It was then boiled for about 15 minutes and cooled. The filtrate was adjusted to the initial weight with distilled water and the volume was made up to 100ml with 2N HCl, shaken well and filtered. The filtrate (25ml) was added in 5ml phosphoric tungstate reagent, stirred well and kept overnight. The next day, it was centrifuged and filtered. Two to three drops of methyl red indicators were added in 20ml of the filtrate and neutralized with ammonia. Then, 5ml $CaCl_2$ buffer was added and stirred well. The mixture was allowed to stand overnight, next day it was filtered through Whatman filter paper (No.40 or 44) and repeatedly washed the $CaCl_2$ precipitates with distilled water till they were free from chloride. The precipitate along with the filter paper was transferred to the same beaker and some amount of distilled water was added followed by 5ml of 2N H_2SO_4. The mixture was heated to 80°C over the burner and titrated against 0.01N $KMnO_4$ to light pink colour. Blank with distilled water was also run simultaneously and proceeded the same as for the food sample. The oxalate content was calculated by using the following formula.

$$\text{Oxalate (mg/100g)} = \frac{\text{Titre value} \times \text{N of } KMnO_4 \times 0.45 \times \text{df} \times 100}{0.01 \times \text{sample weight}}$$

Where, df= dilution factor
Note:1ml of 0.1 N $KMnO_4$ = 0.045g of oxalic acid

Shelf Life Study of OFSP Flour during storage
The keeping qualities of OFSP flour were assessed by estimating the sensory quality of flour. A hundred gram of OFSP flour was packed in high-density polyethylene pouches (100g capacity) were having density of 0.65g/cm^3 and 0.1mm thickness by using heat sealing methods. Thus, all packets were stored in air tight container at room temperature for a period of 90 days. Out of this, one packet was used for organoleptic evaluation at regular intervals i.e., 0th, 30th, 60th, and 90th day for their sensory characteristics by ten panel members using nine-point hedonic scales during storage of OFSP flour. The twenty semi-trained panel members were asked to assign scores that best represented their attitude about the flour. The scores were numerical values for computation purposes, ranging from like extremely (9) to dislike extremely (1).

Statistical Analysis:
All experiment was performed in six replicate for each samples of OFSP flour. The results were expressed as mean, standard deviation and percentage. Two-way analysis of variance techniques was applied in full factorial completely randomized design to determine the significant difference in the mean value of organoleptic scores of OFSP flour stored for 90 days. Difference of $P \leq 0.05$ were considered to be statistically significant.

Results and Discussion
Nutritional composition
Nutritional compositions of OFSP flour were analyzed and the results obtained have been presented in the following sections.

Proximate composition and sugar content
Moisture is one of the major constituents of root and tuber crop. The moisture content of OFSP tuber was found to be 71.84 ± 0.04g/100g. The results are in close proximity with the value reported by Ali *et al.* [22] and Longvah *et al.* [23], but higher than the finding of Rose and Vasanthakaalam [24] who observed moisture content ranged from 62.58 to 64.34% in different varieties of sweet potato. However,the result reported by Atif *et al.* [25] and Emmanuel *et al.* [26] were quite higher *i.e.,*78.70 and 80.0% respectively than the observed result.
The moisture content of OFSP flour was found to be 5.80 ± 0.53g/100g (Table 1). The results of the present finding are in conformity with an observation of Ruttarattanamongkol *et al.* [27], who reported that the moisture content of flours can ranged from 3.03 to 5.36% depending on the drying temperature of hot air oven, whereas, the results reported by Rodrigues *et al.* [17] and Kidane *et al.* [28] were quite higher i.e., 6.9 and 7.36 % respectively. The crude protein in raw OFSP tubers was found to be 1.79 ± 0.02g/100g which was higher than the value reported by Gopalan *et al.* [29] i.e.,1.2% in sweet potato. Omodarmiro *et al.* [30] found great variation in the mean crude protein content of different varieties of OFSP ranging from 3.96-6.94% while Emmanuel *et al.* [26] reported 2.5 %

protein in OFSP tubers. The crude protein content of OFSP flour was observed to be 6.33 ± 0.05g/100g (Table 1). These results are in line with the findings of Boni *et al.* [31], who reported the protein content of sweet potato flour is superior to cassava and yam flour and similar to rice.

Table 1: Proximate composition and sugar content of OFSP flour (per 100g)

S. No	Nutrients	OFSP * (Fresh weight basis)	OFSP flour (Dry weight basis)
		Mean ± SD	Mean ± SD
1	Moisture (g)	71.84 ± 0.04**	5.80 ± 0.35
2	Crude protein (g)	1.79 ± 0.02	6.33 ± 0.05
3	Fat (g)	0.41 ± 0.01	1.41 ± 0.03
4	Ash (g)	1.23 ± 0.02	4.64 ± 0.05
5	Crude fibrer (g)	0.89 ± 0.02	4.43 ± 0.08
6	Total sugar (g)	4.08 ± 0.04	14.43 ± 0.17
7	Reducing sugar (g)	1.96 ± 0.05	6.57 ± 0.18
8	Non reducing sugar (g)	2.12 ± 0.02	7.86 ± 0.02
9	Carbohydrate (g)	23.83 ± 0.04	77.38 ± 0.50
10	Energy (Kcal)	106.18 ± 0.13	347.55 ± 1.70

All the values are (Mean ± SD) of three observation, *values are based on calculations of dry weight basis; **analysis was done on fresh tuber

Results also revealed that the mean value of fat and ash content of OFSP were 0.41 ± 0.01g and 1.23 ± 0.02g/100g of fresh weight basis respectively, whereas, the mean value of crude fibre was 0.89 ± 0.02g/100g of fresh weight of OFSP. The value obtained for fat, ash and crude fibre were lower than the value mentioned by Gopalan *et al.* [29] i.e., 0.3g/100g (fat), 1.0g/100g (total ash), and 0.8g/100g (crude fiber) respectively for sweet potato. Emmanuel *et al.* [26] reported 1.15% fat in OFSP tuber in their investigation. The fat content of the studied OFSP flour was found to be 1.41 ± 0.03g/100g which is within the ranges of 0.04-1.45% as reported by Olatunde *et al.* [32] for flour obtained from ten cultivars of sweet potato.

In the present scenario, fiber is recognized as an important nutrient of healthy food. In present study, the crude fiber content was lower than the value reported by Omadamiro *et al.* [30] and Emmanuel *et al.* [26] in different varieties of OFSP. Comparing the results obtained by previous work done by Omadamiro *et al.* [30] and the present investigation, variation in fiber content can be attributed to different agro-climatic conditions and cultivation methods. The data on crude protein, crude fiber, and total ash content of OFSP tuber are almost in conformity with that reported by Sanoussi *et al.* [33] and Rodrigues *et al.* [34]. The fiber and total ash content of OFSP flour was observed to be 4.43 ± 0.08 and 4.64 ± 0.05g/100g (Table-1). The values of fibre are in agreement with Olatunde *et al.* [32], who reported that the fiber content of sweet potato flour of ten different cultivars ranged from 0.08 to 5.54%.

Estimation of total and reducing sugar of OFSP was also carried out and the results revealed that the mean of total sugar and non reducing sugar content was 4.08 ± 0.04g/100g and 2.12 ± 0.02g/100g, whereas the mean of reducing sugar content was 1.96 ± 0.05g/100g on fresh weight basis. Ali *et al.* [22] also reported the reducing sugar content varied from 2.05 to 2.18% among different varieties of OFSP tuber. The non-reducing sugars and total sugar content also varied significantly from 1.81 to 2.96% and 4.04 to 5.30% respectively, among different cultivar of OFSP. The results of the sugar content of OFSP are almost in conformity with the value reported by Mitra [7] and Olatunde *et al.* [32]. Perusal of data in the Table- 1 clearly indicates that OFSP flour was found to be consisting of total sugar 14.43 ± 0.17g, reducing sugar 6.57 ± 0.18g and non-reducing sugar 7.86 ± 0.02g/100g. The results are in conformity with the observations of Olatunde *et al.* [32] and Van Hal, [35]. Atif *et al.* [25] reported that total sugar content of flour obtained from different varieties of sweet potato ranged from 19.64 to 21.53%. The total sugar content was found to be lower in the present study.

In the present investigation, the mean carbohydrate content in OFSP was 23.83±0.04 g/100g of fresh weight basis. The value obtained was in accordance with the value mentioned in Longvah *et al.* [23] i.e., 23.93g/100g. The result is also in accordance with the results of Omodamiro *et al.* [30] who reported that the range of carbohydrates content varied from 20.28 to 31.5% in different varieties of OFSP tuber. The carbohydrate content of OFSP flour was found to be 77.38±0.50g/100g. Grace *et al.* [36] and Toan *et al.* [37] have documented a slightly higher value of 80.44 and 85.80% respectively. In sweet potato flour, carbohydrates account for the bulk mass and hence can serve as a good source of energy [32].

The difference in proximate composition and sugar content of OFSP can be attributed to varietal differences, soil type, cultivation practices, location and climate, the incidence of pests and diseases and the effect of pre-treatments during blanching and dry matter content [38, 39]. Osundahunsi *et al.* [40] also noticed that blanching and parboiling caused the leaching loss of protein, crude fiber and ash contents of sweet potato flour.

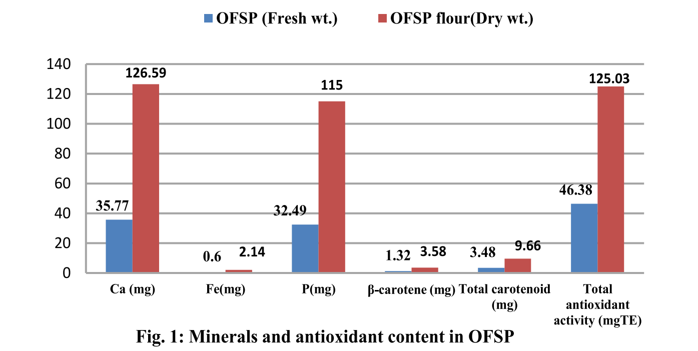

Fig. 1: Minerals and antioxidant content in OFSP

Mineral and antioxidant content

The result presented in Fig-1 revealed the mineral and antioxidant content of OFSP flour. In the present study, the results revealed that calcium and iron content in raw OFSP tuber was 35.77 ± 0.58mg and 0.60 ± 0.02mg/100g on a fresh weight basis respectively. The values obtained for calcium and iron were higher than the values reported by Longvah *et al.* [23] i.e., 28.93mg/100g and 0.35mg/100g for calcium and iron content in sweet potato. The phosphorus content of the OFSP was observed to be 32.49 ± 0.51mg/100g on a fresh weight basis (Table 2). The values obtained for phosphorus were lower than the value mentioned by Longvah *et al.* [23] i.e., 37.60mg/100 gram. Dako *et al.* [41] also reported the value of calcium content ranges between 7.42-47.04mg/100g in the unpeeled tuber and 5.28-45.54mg/100g in peeled tuber of sweet potato respectively.

It was clearly indicated in Figure- 1 that OFSP flour was found to contain

126.59 ± 1.90mg calcium, 2.14 ± 0.06mg iron, and 115.00 ± 2.10mg phosphorus/100g, which was in line with the findings of Aywa *et al.* [42], while, relatively higher iron content of 6.03mg and 5.4mg/100g and calcium content 145.4mg/145.9mg/100g was reported by Sinha [43] for two varieties of sweet potato flour.The variation in minerals content in OFSP might be attributed due to different climate, cultivar, fertilizer applied, soil type and location of field and difference in quantification methods [32].OFSP tuber can be exploited for their calorie rich property to alleviate protein energy malnutrition, but has been majorly recommended for fighting vitamin A deficiency among nutrient deficient population [44]. In the present investigation, β-carotene of raw OFSP tuber was recorded 1.32 ± 0.02mg/100g (Fig-1). Several studies have also reported that the β-carotene content ranged between 0.03mg to 13.63mg/100g on fresh weight basis for different varieties of OFSP [45,46, 47]. Mitra [7] also reported that β-carotene content ranged between 2.58-9.74mg/100g in tubers of different OFSP cultivars.

It is apparent from the result presented in Fig-1 that the β-carotene content of OFSP flour was 3.58 ± 0.05mg/100g compared to 1.32 ± 0.02mg/100g in its raw tubers. The result further indicated that there was 81.09% retention of β-carotene in OFSP flour. The result of present study are in close proximity with Atif *et al.* [25] observed that the β-carotene content of OFSP flour ranged between 2.80-27.58mg/100g and varied significantly with different blanching treatments prior to dehydration. Ahmed *et al.* [48] also reported the β-carotene content in OFSP flour was 3.79mg/100g, which is in accordance with the present findings. Mitra [7] reported the β-carotene retention percentage ranged from 76.56 - 87.76% in cooked OFSP of different genotypes. Vimala *et al.* [11] reported a higher retention percentage of β-carotene in OFSP flour compared to its raw tubers. Several studies have shown that β-carotene retention percent ranged from 70.0-96.0% among flours obtained from different varieties of OFSP [50,51]. Nascimento *et. al.* [50] noticed that blanching of OFSP did not reduce the β-carotene content but enhanced the stability of β-carotene in flour or slices. Ahmed *et al.* [48] documented the β-carotene content ranged from 0.5-45mg/100g on dry weight basis in OFSP cultivars and varied with cultivar to cultivar.

Perusal of data in Figure-1 shows that the total carotenoid content of OFSP was recorded 3.48 ± 0.01mg/100g. The recorded value of the total carotenoid of OFSP was in accordance with the value reported by Gupta *et al.* [52] i.e., 3.45mg/100g on a fresh weight basis. The total carotenoid content of OFSP flour was found to be 9.66 ± 0.03mg/100g indicating 82.99% retention of total carotenoid in flour when compared with raw OFSP tubers. The results are in line with the finding of Kotikova *et al.* [53], who reported the total carotenoid content in a range of 1.44 - 40.13mg/100g of flour obtained from different flesh-coloured sweet potato.

The findings are in close proximity to Bengtsson *et al.* [11], Failla *et al.* [54] and Ahmed *et al.* [48], who observed the total carotenoid losses were minimal during processing and the total retention percent of carotenoid ranged between 82-95% in OFSP flour. Bechoff *et al.* [55] and Vimala *et al.* [49] reported higher retention percentage of total carotenoid in OFSP. Thus, the variation of β-carotene and total carotenoid content in OFSP flour might be due to varietal differences, variation in agro-climatic conditions, and different drying conditions also.

Antioxidants are compounds present in foods that neutralize free radicals produced by oxidation. The antioxidant activity of food depends on several factors such as antioxidant structure, availability of oxidants, the composition of lipid fraction, presence of various other promoters and inhibitors of oxidation, presence of non lipidic compounds, microstructure, moisture, temperature etc. The total antioxidant activity was dependent on the amount of β-carotene, carotenoids and flavonoids present in OFSP tubers. The antioxidant activity of food may be due to the oxygen-quenching capacity of carotenoids [56]. Maruf *et al.* [57] and Gaston *et al.* [58] stated that the carotenoids also possess good antioxidant properties and they are able to trap free radicals which are generated constantly in our body. Foods rich in carotenoids strengthen our natural body defense system against oxidative stress and thus it prevents from various chronic degenerative diseases such as cancer and cardiovascular diseases. It was also observed from Figure-1 that the total antioxidant activity of OFSP tuber on fresh weight basis was 56.38 ± 0.80 mgTE/100g.

Results of the present investigation revealed that the total antioxidant activity of OFSP flour was found to be 125.03 ± 0.56 mgTE/100g. The results are in close proximity with Koala, [59] who reported that the antioxidant activity of flour obtained from eight varieties of OFSP ranged from 107- 412 mgTE/100g, which represented about four fold variations in all the cultivars. Tokusoglu and Yildirim [60] revealed that thermal processing caused damage of cell structures and resulted a more easy extraction of antioxidant constituents from sweet potatoes. Bellail *et al.* [61] also reported that the antioxidant activity of tubers was affected by different processing methods like, steaming, boiling and drying.

Anti-nutritional factors

The anti-nutritional factors viz., phytate and oxalate content of OFSP flour were analysed and the results are presented in Table-2. In the present investigation, the mean of phytate content in OFSP was found to be 64.16 ± 1.08 mg/100g, whereas the oxalate content was observed as 16.86 ± 0.58 mg/100g (Table-2). The high amount of oxalate content was also observed in sweet potatoes by Anbuselvi and Balamurugan [62]. A small amount of anti nutritional factors is present in root and tuber crops and these factors bind the essential vitamin and minerals present in diet and make them unavailable for body.

Dako *et al.* [41] reported the mean value of phytate content ranged from 93.37mg to 111.43mg/100g in unpeeled tubers and 49.35mg to 78.38mg/100g in peeled tubers of three different cultivars of sweet potato. Sinha [43] also reported that 15.36mg/100g oxalate was present in OFSP in her investigation.

Table-2 Anti nutritional factors of OFSP flour (per 100g)

S. No	Anti nutrients	OFSP* (Fresh weight basis)	OFSP flour (Dry weight basis)
		Mean ± SD	Mean ± SD
1	Phytate (mg)	64.16 ± 1.08	123.34 ± 2.75
2	Oxalate (mg)	16.86 ± 0.58	48.76 ± 1.57

All the values are (Mean ± SD) of three observation, *values are based on calculations of dry weight basis

The phytate content of OFSP flour was found to be 123.34 ± 2.75 mg/100g, which is slightly higher value reported by Endrias *et al.* [63] who observed phytate content ranged from 49.35mg-111.43mg/100g for sweet potato flour and different blend of sweet potato and corn flour respectively. The difference in phytate content of the present investigation to the other researchers can be attributed to the cultivar difference [64, 65]. It is apparent from the result presented in Table-2 that the oxalate content of OFSP flour was 48.76 ± 1.57mg/100g. The results are in line with the finding of Boni *et al.* [31] who reported the oxalate content ranged from 40.33-66.0% in the flour obtained from five different genotypes of sweet potato.

Sensory characteristic of OFSP flour during storage:

A perusal of Table-3 clearly indicates that OFSP flour was liked very much to liked moderately at all stages of the storage study for its colour scored 8.23 ±0.01 to 7.90±0.10 (control) and 8.19±0.06 to 7.80±0.10 (OFSP flour) respectively by 90th day of storage. Results demonstrate that the colour of the control and OFSP flour was liked very much and it maintained the visual appeal during the storage span in spite of the significant decrease in scores. However, no significant difference was found between control and OFSP flour for colour ($p \leq 0.05$). Scores for flavour ranged between 8.17±0.06 (initially) to 7.70 ±0.10 (90th day) for control and 8.10±0.01 to 7.43±0.06 for OFSP flour.

Taste scored 8.07±0.06 (control) and 8.07±0.06 (OFSP flour) initially portraying no significant difference between control and OFSP flour. But gradually the score of control for taste reduced to 8.03±0.06 during 30th day, followed by 7.83±0.06 during the 60th day, and finally scored 7.67±0.10 during the 90th day, whereas, OFSP flour discerned to scores slightly lower i.e., 7.97±0.06 during 30th day, followed by 7.63±0.06 during 60th day and 7.40±0.10 on 90th day of storage. A sensory study demonstrated that a significant difference in scores for taste was evident since 60th day onwards ($p \leq 0.05$) for control and OFSP flour.

Table-3: Effect of storage on sensory attributes of OFSP flour

Sensory Attributes	Products	Storage Period				LSD (p≤0.05)
		0 Days	30 Days	60 Days	90 Days	
Colour	Control	8.23^{Aa}±0.01	8.13^{Aa}±0.06	7.97^{Ab}±0.12	7.90^{Ab}±0.10	0.16
	OFSP flour	8.19^{Aa}±0.06	8.00^{Ab}±0.01	7.83^{Abc}±0.06	7.80^{Ac}±0.10	0.17
	LSD (p≤0.05)	0.18	0.18	0.20	0.22	
Flavour	Control	8.17^{Aa}±0.06	8.07^{Aab}±0.15	7.90^{Abc}±0.10	7.70^{Ac}±0.10	0.20
	OFSP flour	8.10^{Aa}±0.01	7.93^{Ab}±0.06	7.60^{Bc}±0.10	7.43^{Bd}±0.06	0.15
	LSD (p≤0.05)	0.18	0.26	0.22	0.18	
Taste	Control	8.07^{Aa}±0.06	8.03^{Aa}±0.06	7.83^{Ab}±0.06	7.67^{Ac}±0.10	0.14
	OFSP flour	8.07^{Aa}±0.06	7.97^{Aa}±0.06	7.63^{Bb}±0.06	7.40^{Bc}±0.10	0.13
	LSD (p≤0.05)	0.13	0.13	0.13	0.24	
Texture	Control	8.07^{Aa}±0.06	8.03^{Aab}±0.06	7.93^{Ab}±0.06	7.77^{Ac}±0.06	0.10
	OFSP flour	8.00^{Aa}±0.01	7.90^{Aab}±0.10	7.80^{Ab}±0.10	7.50^{Bc}±0.10	0.18
	LSD (p≤0.05)	0.18	0.18	0.18	0.18	
Appearance	Control	8.03^{Aa}±0.06	8.00^{Aab}±0.10	7.90^{Aab}±0.10	7.89^{Aab}±0.06	0.15
	OFSP flour	7.97^{Aa}±0.06	7.97^{Aa}±0.06	7.83^{Aa}±0.06	7.80^{Aa}±0.17	0.18
	LSD (p≤0.05)	0.13	0.18	0.18	0.29	
Overall acceptability	Control	8.10^{Aa} ±0.10	8.07^{Aa} ±0.15	7.83^{Ab} ±0.06	7.56^{Ac}±0.06	0.18
	OFSP flour	8.07^{Aa} ±0.06	7.93^{Ab} ±0.06	7.60^{Bc}±0.10	7.33^{Bd}±0.06	0.13
	LSD (p≤0.05)	0.18	0.26	0.18	0.13	

All the values are (Mean±SD) of three observations. Mean followed with superscript with a and b in rows represent the difference between the days and superscript with A and B in column shows the difference between control and OFSP flour. Values followed with different superscripts are significant ($p \leq 0.05$).

The texture was scored 8.07±0.06 and 8.00±0.01 for control and OFSP flour initially and was liked very much by the sensory panel. Scores for texture decreased significantly during storage and finally scored for 7.77±0.06 and 7.50±0.10 for control and OFSP flour. Appearance of OFSP flour initially scored 7.97±0.06 on nine points hedonic scale and 7.80±0.17 during 90th day of storage revealing that no significant ($p \leq 0.05$) reduction in score was observed during the storage period and it was liked very much. Overall acceptability ranged between 8.10±0.10 (initially) to 7.56±0.06 (90th day) for control and 8.07±0.06 to 7.33±0.06 (90th day) for OFSP flour. On an overall basis, OFSP flour was found to be liked moderately by the sensory panel by the end of storage. On the contrary, OFSP flour was acceptable even after 90th day of storage.

Results presented in Table-3 thus clearly indicated that initially and on the 30th day of storage the control and OFSP flour did not differ from each other in all sensory attributes. In the due course of storage after the 60th day significant difference ($p \leq 0.05$) was observed between control and OFSP flour from flavour, taste, and overall acceptability points of view. Further during the 90th day of storage again a significant decrease was evident for flavour between the control and OFSP flour ($p \leq 0.05$). However, no significant difference was found between control and OFSP flour for colour and appearance by the end of the storage period. During the storage period gradual significant decrease was evident in the scores of all sensory characteristics for both control and its counterparts except appearance ($p \leq 0.05$). Despite the reduction in sensory scores for all the parameters, both control and OFSP flour were found to be acceptable by the end of the storage.

Conclusion

At the whole, it can be concluded that this OFSP variety has a good amount of carbohydrate, fiber, β-carotene, total carotenoids, and antioxidant activity. OFSP flour also possesses high potential of nutrients especially β-carotene, total carotenoid content and antioxidant activity, and can easily be stored and can be consumed up to a period of 90 days. This indicates that this sweet potato cultivar may present a potential asset for their using as natural antioxidants to prevent vitamin A deficiency and malnutrition. OFSP flour can be incorporated in the manufacturing of a variety of value-added products such as biscuits, bread, cakes, cookies, doughnuts, etc.

Future scope of study

Orange fleshed sweet potato has been attracting food technologists and nutritionists due to its high content of carotenoids and pleasant sensory characteristics. So this study will be helpful in addressing in vitamin A deficiency management. However, the utilization of OFSP based products is still low as a result of limited production. The use of OFSP flour to substitute wheat flour in preparation of various value added produts such as extruded products, baked products, confectionaries etc. will be helpful to expand its further application in the food industries.

Confliet of interest

The author (s) decleared no confliect of interest with respect to the research, authorship and/or publication of this articles.

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