Received: 15 June 2020 | Revised: 15 January 2021 | Accepted: 21 January 2021

DOI: 10.1111/jfpp.15324

ORIGINAL ARTICLE

Journal of Food Processing and Preservation | Institute of Food Science + Technology ifst | WILEY

Effects of incorporation of orange-fleshed sweet potato flour on physicochemical, nutritional, functional, microbial, and sensory characteristics of gluten-free cookies

Namrata Ankush Giri[1] | Bhagwan Kashiram Sakhale[2]

[1]Division of Crop Utilization, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India

[2]University Department of Chemical Technology, Dr. Babasaheb Ambedkar Marathwada University, Aurangabad, India

Correspondence
Namrata Ankush Giri, Division of Crop Utilization, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram 695017, Kerala, India.

Abstract

Cookies were formulated with orange-fleshed sweet potato (OFSP) flour, amaranth flour (AF), and cassava starch powder (CSP) in the ratio of 0:50:50 (control), 40:30:30 (T_1), 50:25:25 (T_2), 60:20:20 (T_3), 70:15:15 (T_4), 80:10:10 (T_5), 90:05:05 (T_6), and 100:0:0 (T_7), respectively. The cookies were prepared and evaluated for physicochemical, nutritional, and sensory characteristics. Significant decrease in water absorption, oil absorption, increase in spread ratio, spread factor, and hardness of gluten-free (GF) cookies with an increase in the incorporation of OFSP flour. The dough stability, consistency, and farinograph quality number were increase. The OFSP cookies were superior to control for bioactive components and antioxidant activity. The cookies containing 70% OFSP flour with 15% AF and CSP found organoleptically acceptable and safe for 90 days of storage period.

Practical applications

The orange-fleshed sweet potato tubers are rich in health benefit components such as β-carotene, phenolic acids, carbohydrates, fibers, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, and vitamins A content. The potential of orange-fleshed sweet potato flour was utilized for the development of gluten-free (GF) cookies enriched in carotenoids content. The in-depth study of various functional, nutritional, and rheological properties of orange-fleshed sweet potato flour with amaranth flour and cassava starch powder represents its suitability for the preparation of functional GF cookies enriched in micronutrients. The additional benefits of combinations of these ingredients in GF cookies can be used for celiac patients, fasting purpose, and to combat the deficiency of vitamin A.

1 | INTRODUCTION

Sweet potato (*Ipomoea batatas* L.) is an important crop and grown in the tropical region of the world. China is leading country in the production of sweet potato and alone producing about 80 to 85%, followed by other countries in Asia and then by Africa and Latin America (Centro Internacional de la Papa, 2009). It is referred to as "food security" or "famine relief" crop, particularly in developing countries (Grant, 2003) due to drought resistance and climate-resilient. It is a storehouse of energy and micronutrients such as vitamins and minerals. There are different varieties of sweet potato, based on the flesh color, such as orange-fleshed, purple-fleshed, and pale cream fleshed. The different colored varieties have health promoting nutrients, and their natural color is an excellent alternative to artificial colors and used as colorant in food and pharmaceutical industries (Truong & Avula, 2010). Sweet potato tubers are not only nutritionally dense, but also gluten-free (GF) and suitable to produce products for gluten-sensitive people (Giri & Sakhale, 2019).

The orange-fleshed sweet potato (OFSP) tubers rich in health benefit components such as β-carotene, phenolic acids, carbohydrates, fibers, thiamine, riboflavin, niacin, potassium, zinc, calcium, iron, vitamins A and C, and high-quality protein (Grace et al., 2014). The potential of this variety was utilized for the preparation of different value-added products to combat vitamin A deficiency. In many regions of the country, especially in Africa, where orange-fleshed sweet potato food products helped to reduce the incidence of vitamin A deficiency (van Jaarsveld et al., 2005). Frances et al. (2017) formulated an improved and nutritious GF biscuit suitable for celiac disease using OFSP puree along with cowpea flour, cassava starch, and coconut milk. Biscuits with 80% cassava starch, 5% orange-fleshed sweet potato puree, and 15% cowpea flour were most acceptable. This biscuit was rich in potassium and β-carotene. Celiac disease is a chronic disease that occurred in 1%–2% of the world's population (Reilly & Green, 2012). The ingestion of gluten present in wheat, rye, and barley caused severe damage to microvillus of the small intestine and led to no absorption of micronutrients, which caused micronutrient deficiency in celiac patients. The remedy to prevent symptoms of celiac disease is to stick to a GF diet for life long time (Rubio-Tapia & Murray, 2010). Sweet potato tubers can be utilized to develop GF products like cookies for celiac disease (Giri et al., 2016).

Sweet potato tubers were mainly consumed for fasting purposes in the northern part of India as a source of energy. Other ingredients, such as proso millet, sago, amaranth, and potato, were also used during fasting days (Rathod & Annapure, 2016). Among the other ingredients which are allowed to consume on fasting days, amaranth flour was selected for the present study because of its nutraceutical relevance. It is considered as a "super food" because it counts with high nutraceutical values such as: high-quality protein including several essential amino acids, unsaturated oils as omega-3 and omega-6, dietary fiber, squalene, tocopherols, phenolic compounds, flavonoids, phytates, vitamins, and minerals (Manuel et al., 2018). It is also a GF ingredient, suitable for preparation of GF products.

The snacks food items are in high demand by consumers due to their convenience and taste. Cookies are mostly liked as a snack food and could acts best vehicle for nutritional supplements.GF cookies were attempted by different researchers using nonwheat flours such as buckwheat flour, cassava flour, quinoa flour, etc. (Brito et al., 2015; Jisha & Padmaja, 2011; Mishra et al., 2015). Cookies suitable for person suffering from gluten sensitivity with additional health benefits are not much focused and there is need to develop GF cookies using ingredients having functional characteristics. However, GF ingredients especially orange-fleshed sweet potato, amaranth flour, and cassava could also be consumed on fasting days in Northern India which will not only provide energy, but also micronutrients. In the present investigation, an attempt was made to develop functional GF cookies incorporated with OFSP flour suitable for celiac patients, fasting purpose as well as to combat vitamin A deficiency.

2 | MATERIALS AND METHODS

2.1 | Materials

Orange-fleshed sweet potato (OFSP) tubers, amaranth flour (AF), cassava starch powder (CSP), refined sugar, vegetable fat, baking powder, vanilla essence, water, etc. The essential ingredients except OFSP flour and CSP were procured from the local market of Aurangabad city.

2.2 | Preparation of OFSP flour and CSP

Orange-fleshed sweet potato tubers (Cv. *Bhu Sona*) of 3 months maturity having moisture (69.93%), starch (20.03%), sugar (2.2%), fat (1.6%), fiber (2.29%), protein (0.4%), and carotenoid (8.89 mg/100 g) were obtained from ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, Kerala. The tubers were washed, peeled, sliced (5 mm thickness), and cabinet tray dried at 70–75°C for 8–10 hr followed by pulverization in a hammer mill into fine flour with a particle size of 0.177 mm. The dry flour was packed and stored in airtight containers at room temperature till the end-use. The method described by Giri et al. (2016) was employed for processing sweet potato tubers to flour.

Cassava starch was extracted from cassava tubers (cv. Sree Pavitra) harvested at nine-month maturity from the experimental field of ICAR-CTCRI, Trivandrum. Tubers were peeled and crushed with plenty of water. The extract was filtered through a muslin cloth and kept at undisturbed conditions for 2 days, and the supernatant was discarded, and starch particles settled down were then dried at 70–80°C and converted into powder (Krishnakumar & Sajeev, 2018).

The level of OFSP flour was optimized by mixing with AF and CSP at the level of 40% to 100%. The formulation for the preparation of OFSP GF cookies is given in Table 1.Gluten-free (GF) cookies prepared from 50% AF and CSP were treated as control.

2.3 | Preparation method of OFSP-incorporated GF cookies

The traditional creaming method was used for the preparation of GF cookies, and the process was standardized. The formulation used for the preparation of cookies as GF flour blend (100 g), refined sugar (30%), vegetable fat (40%), sodium bicarbonate (1%), vanilla essence (0.25 ml), and water added as per requirement for preparation of the dough.

Fat and sugar were creamed until light and fluffy. Flour was sieved with sodium bicarbonate. The cream was mixed with flour, and a sufficient quantity of water was added with vanilla essence to form dough. Then a sheet of dough was prepared to have thickness of 0.5 cm, and the pieces were cut using a cookie cutter. The pieces were placed in the baking tray smeared with fat and baked

Journal of Food Processing and Preservation Institute of Food Science +Technology ifst

TABLE 1 Formulation of GF cookies incorporated with OFSP flour

Treatments	Orange-fleshed sweet potato (OFSP) flour (%)	Amaranth flour (AF) (%)	Cassava starch powder (CSP) (%)
Control	0	50	50
T_1	40	30	30
T_2	50	25	25
T_3	60	20	20
T_4	70	15	15
T_5	80	10	10
T_6	90	05	05
T_7	100	0	0

at 180–200°C for 15 min. Baked cookies cooled for sufficient time, packed in HDPE, and stored at room temperature for further analysis (Kure et al., 1998).

2.4 | Functional properties

2.4.1 | Water absorption capacity (WAC)

The method described by Onwuka (2005) was used for the determination of WAC. Flour blends containing OFSP flour, AF, and CSP (1 g) was weighed into a 15 ml centrifuge tube and suspended in 10 ml of water. It was shaken on a platform tube rocker for 1 min at room temperature. The sample was allowed to stand for 30 min and centrifuged at 1,200 rpm for 30 min. The volume of free water was read directly from the centrifuge tube.

$$\text{WAC} = \frac{(\text{Amount of water added} - \text{Free water}) \times \text{Density of water}}{\text{Weight of sample}} \times 100 \quad (1)$$

2.4.2 | Oil absorption capacity (OAC)

The method of Onwuka (2005) was used for the determination of OAC by mixing flour blends (1 g) with 10 ml refined corn oil in a centrifuge tube and allowed to stand at room temperature for 1 hr. It was centrifuged at 1,500 rpm for 20 min. The volume of free oil was recorded and decanted. OAC was expressed as ml of oil bound by100 g dried flour.

$$\text{OAC} = \frac{(\text{Amount of oil added} - \text{Free oil}) \times \text{Density of corn oil}}{\text{Weight of sample}} \times 100 \quad (2)$$

2.4.3 | Bulk density (BD)

The BD of the flour blends was determined using the method described by Onwuka (2005). About 10 g of the sample was weighed into a 50 ml graduated measuring cylinder. The sample was packed by gently tapping the cylinder on the bench top 10× from a height in ml. The volume of the sample was recorded.

$$\text{BD (g/ml)} = \frac{\text{Weight of sample}}{\text{Volume of sample after tapping}} \quad (3)$$

2.4.4 | Foaming capacity and stability

Foaming capacity (FC) was determined according to the method described by Onwuka (2005). Flour blends (2 g) was weighed and added to 50 ml distilled water in a 100 ml measuring cylinder. The suspension was mixed and shaken adequately to foam, and the total volume after 30 s was recorded. The percentage increase in volume after 30 s is expressed as foaming capacity. The volume of foam was recorded 1 hr after whipping to determine foam stability as per the percent of initial foam volume.

2.4.5 | Emulsification capacity

Emulsification capacity (EC) was determined using the method as described by Kaushal et al. (2012). Flour blend sample (2 g) was blended with 25 ml distilled water at room temperature for the 30 s. After that, 10 ml of refined corn oil was added, and the blending continued for another 30 s before transferring into a centrifuging tube. Centrifugation was done at 1,500 rpm for 5 min. The volume of oil separated from the sample after centrifuging was read directly from the tube. Emulsification capacity was expressed as the amount of oil emulsified and held per gram of sample.

$$\text{Emulsification capacity} = \frac{\text{Height of emulsified layer} \times 100}{\text{Height of whole solution in centrifuge tube}} \quad (4)$$

2.4.6 | Swelling capacity

The swelling capacity of flour blends was determined using a graduated cylinder of 100 ml filled with the sample to 10 ml mark. The distilled water was added to give a total volume of 50 ml. The top of the graduated cylinder was tightly covered and mixed by inverting the cylinder. After 2 min, inverted suspension left to stand for a further 8 min, and the volume occupied by the sample was taken after the 8th min (Okaka & Potter, 1977).

2.4.7 | Dispersibility

It was determined by the method described by Kulkarni et al. (1991). Sample (10 g) was suspended in 200 ml measuring cylinder, and distilled water was added to reach the 100 ml mark. The set-up was stirred vigorously and allowed to settle for 3 hr. The volume of settled particles was recorded and subtracted from 100. The difference was reported as percentage dispersibility.

$$\text{Dispersibility} = 100 - \text{Volume of the settled particle} \tag{5}$$

2.5 | Rheological characteristics

Rheological characteristics reflect the dough properties during the processing and quality of the final product. Rheological characteristics of GF dough added with OFSP flour were determined using Brabender farinograph, extensograph, and amylograph (Make Brabender GMBH, Germany and Model T-150E) according to the method No. 54-21 as described in (AACC, 2000).

2.5.1 | Farinograph characteristics

The farinograph characteristics of GF dough-incorporated with OFSP were evaluated by weighing a flour blend of 300 g on a 14% moisture basis and placed into the corresponding farinograph mixing bowl. Water from a burette was added to the flour and mixed to form dough. The mixing characteristics of dough were recorded in the form of farinograph curve on graph paper. The amount of water added (absorption) which affected the position of the curve on the graph paper. Less water increased dough consistency and moved the curve upward. The curve was centered on the 500 Brabender unit (BU) line ± 20 BU by adding the appropriate amount of water, and it ran until the curve leaves the 500 BU line. Dough characteristics such as water absorption (%), dough development time (min), dough stability (min), mixing tolerance index (MTI) (BU), time to break down (min), farinograph quality number, and consistency (BU) were interpreted from farinogram.

2.5.2 | Amylograph characteristics

It was determined using a sample of 65 g of flour blend to combine with 450 ml of distilled water and mixed to make slurry. The slurry was stirred when heated in the amylograph, beginning at 30°C and increased at a constant rate of 1.5°C per minute until the slurry reached 95°C. The resistance offered by the sample during stirring was recorded as a viscosity curve. The observations were recorded like the beginning of gelatinization (°C), gelatinization temperature (°C), and gelatinization maximum (AU).

2.6 | Physical properties

2.6.1 | Diameter (D) and thickness (T)

The diameter and thickness of GF cookies were calculated as per AACC (2000) methods. Diameter (D) and thickness (T) of GF cookies in terms of a millimeter (mm) were measured with the help of vernier caliper having at least count 0.01.

2.6.2 | Spread ratio (D/T)

Spread ratio of GF cookies was calculated as per AACC (2000) method. It was estimated as the ratio of diameter to thickness of cookies.

2.6.3 | Spread factor (%)

As per the AACC (2000) method, the spread ratio of the control sample was considered to be standard (100%) and the spread factor of other samples of cookies was determined in comparison with the standard value. It was expressed in terms of percentage.

2.6.4 | Texture

The hardness of GF cookies was measured using Instron Universal Texturometer (TMS-Pro, FTC, USA). A compression test was employed. The conditions employed were as follows: Pretest speed: 1.0 mm/s, test speed: 3.0 mm/s, posttest speed: 10 mm/s distance: 5 mm, and trigger force: Auto 50 g. The probe used for measurement of hardness was knife-edge with slotted insert (HDP/ BS). The maximum force required just to break the cookies is the hardness. It was expressed in terms of Newton (N).

2.7 | Nutritional composition

The proximate components of GF cookies-incorporated with OFSP flour such as percent moisture, protein, fat, ash, and crude fiber were determined according to the methods of AOAC (2011). Total carbohydrates were calculated by difference method, and total calories were calculated by multiplying protein, carbohydrates, and fat content by factors 4, 4, and 9, respectively (Gopalan et al., 2007). Minerals content including potassium, magnesium, copper, zinc, and iron were determined using atomic absorption spectroscopy, whereas phosphorus was spectrophotometrically determined according to the method of Rangana (1979).

The energy value of samples was calculated by using following formula.

$$\text{Energy value (kcal/100g)} = (\%\text{Carbohydrate} \times 4) + (\%\text{Protein} \times 4) + (\%\text{Fat} \times 9) \quad (6)$$

2.8 | Bioactive components

2.8.1 | Total phenols

The total phenolic content of cookies sample was determined using Folin–Ciocalteu (FC) reagent as the method described by Singleton and Rossi (1965) with some modifications. Cookie sample (1 g) was kept overnight for extraction with 10 ml of 50% aqueous methanol. The mixture was centrifuged at 10,000 rpm for 15 min. The 0.5 ml of centrifuged supernatant was added to a test tube containing 5 ml FC reagent (10% aqueous solution) and 4 ml aq. Sodium carbonate. The tubes were held for 15 min and measured an absorbance at 765 nm using a UV-Vis spectrophotometer (3,000 + model, Lab India). Results were then expressed as mg gallic acid equivalents (GAE)/100 g of sample.

2.8.2 | Total flavonoids

Total flavonoids content in sample was estimated using aluminum chloride colorimetric method (Rawat et al., 2011). Briefly, 0.5 ml of methanolic extract of the sample was diluted with 1.50 ml of distilled water, and 0.5 ml of aluminum chloride added along with 0.1 ml of 1 M potassium acetate and 2.80 ml of distilled water. This mixture was incubated at room temperature for 30 min. The absorbance of the resulting reaction mixture was measured at 415 nm on a spectrophotometer using a UV-Vis spectrophotometer. Quantification of flavonoids was done based on the standard curve of quercetin prepared in methanol, and results were expressed in mg quercetin equivalent (QE) / 100 g of sample.

2.8.3 | Total carotenoids

Total carotenoids content of sample was determined by taking the ground sample (5 g) and homogenized with the extraction solvent (hexane: acetone: methanol = 2:1:1). The centrifugation step was repeated until the supernatant became colorless at 10,000 rpm for 10 min and collected the supernatant. The supernatant is pooled together and transferred into a separating funnel. Carotene was extracted by using the solvent hexane. The absorbance was measured at 450 nm with hexane as blank. An absorbance was scanned between 200 and 700 nm and also read the peak absorbance at 450 nm (Giri & Sakhale, 2020). The total carotenoids were calculated using the formula:

$$\text{Total carotenoids (mg/100 g)} = \frac{A_{50} \times 0.386 \times \text{made up of final volume in ml}}{\text{Fresh weight of the sample taken}} \quad (7)$$

2.9 | In vitro antioxidant activity

The in vitro antioxidant property of GF cookies was estimated according to the standard method (Reddy et al., 2010). Determination of the antioxidant activity of the samples was carried out by 2,2-diphenyl-2-picryl-hydrazyl (DPPH) inhibition method. Sample (1 g) was added in 10 ml ethanol and kept overnight for extraction. The eluted extract was taken (0.2 ml), and to it, 1 ml of DPPH solution (80 μg/ml ethanol) was then added. The sample sets were centrifuged at 3,000 rpm for 15 min (Sigma laboratory centrifuge 3 K 18, Germany). In cuvette, 0.5 ml of centrifuged solution was taken, and 1 ml of ethanol was added to it. Absorbance was measured at 517 nm separately for blank and samples with pure ethanol as reference using a UV-Vis spectrophotometer (Lab UV-Vis 3,000^{+}, Lab India).

$$\%\,\text{DPPH inhibition } \left(A_B - A_s / A_B\right) \times 100 \quad (8)$$

where, A_B = OD for blank; A_S = OD for sample.

2.10 | Microbial analysis

The shelf life of OFSP flour-incorporated GF cookies and control was determined by microbial analysis and expressed in days. Microbial qualities of cookies were evaluated by measuring the total plate count (TPC) (Yusufu et al., 2016). It was determined by dissolving cookie sample (1 g) powder in 10 ml sterile saline solution and homogenate for 1 min. The serial dilution was done by 1 ml of homogenate in 9 ml sterile saline, dispensed in test tubes, and 0.1 ml of the dilution (10^{-1}, 10^{-2}, and10^{-3}) was spread on sterile Petri plates containing nutrient agar media. The numbers of microbial colonies produced on petri dish were measured using a digital colony counter. The visible colonies were counted and results expressed as cfu/g.

$$\text{CFU/g} = \frac{\text{No of colonies (Mean)} \times \text{Dilution factor}}{\text{Volume of sample used (0.1 ml)}} \quad (9)$$

2.11 | Sensory evaluation

The GF cookies-incorporated with OFSP flour were evaluated by semi-trained panels of 50 judges, using a 9 point hedonic scale system for various sensory quality attribute like color and appearance, taste, texture, flavor, and overall acceptability. Each panelist evaluated the samples as per the specified conditions of the evaluation process (Amerine et al., 2013). Samples were identified with three-digit code numbers and presented in a random sequence to panelists. The panelists were instructed to rinse their mouths with water after every sample.

2.12 | Statistical analysis

The data obtained from various experiments were statistically analyzed. Results were then expressed as means with standard deviations of analysis performed in triplicate for each parameter and sensory characteristics ($n = 50$). A one-way analysis of variance (ANOVA) and Duncan's test was used to establish the significance of differences among the mean values at the 0.05 level of significance. The statistical analyses were performed using SPSS 16.0 software (Steel et al., 1997).

3 | RESULTS AND DISCUSSION

3.1 | Functional characteristics

The OFSP flour- incorporated GF flour blends were subjected to evaluation of different functional properties, and these are presented in Table 2. The data revealed that water absorption capacity (WAC) of flour blends significantly ($p \le .05$) reduced with an increase in the level of OFSP flour and found highest in the control sample (200.17%). It could have been due to the higher amount of starch and protein in control, which includes cassava starch powder (starch) and amaranth flour (protein) as compared to flour blends with OFSP flour. Similar findings are reported by Adeleke and Odedeji (2010) that a decrease in WAC with an increase in sweet potato flour level in wheat flour blend as wheat flour is rich in protein as compared to sweet potato flour. Water absorption capacity measures the ability of the product to associates with water in the condition of water limiting (Singh, 2001).

Similar to WAC, the control sample had a higher percent oil absorption capacity (OAC) as compared to GF flour- incorporated with OFSP flour. It was decreased from 150.13% to 110.19%, with an increase in the level of OFSP flour. The significant reduction in percent OAC of treatment incorporated with OFSP flour might be due to the reduction effect of OFSP on amaranth flour and cassava starch powder, which showed higher OAC compared to sweet potato flour. The OAC also makes the flour suitable in facilitating enhancement in flavor and mouth feel when used in food preparation and depends on physical trapping of fat in the particles, and association of entrapped fat with a polar chain of protein is reported by Wang and Kinsella (1976).

Bulk density (BD) of GF flour blends with OFSP flour and control was found in the range of 0.64 to 0.72 g/ml. The increase in BD was observed in treatments with an increase in the level of OFSP flour due to higher BD of sweet potato flour as compared to control (AF and CSP). But, the opposite results are reported by Adeleke and Odedeji (2010) that decrease in BD of composite flour containing wheat flour and sweet potato flout. This contradictory result might be due to the use of GF ingredients for the present study. Generally, BD of flour depends on the particle size and density, which considered an important factor during the designing of packaging (Karuna et al., 1996).

The foaming capacity (FC) of OFSP flour-incorporated GF flour blends, and control was found in the range of 12.47 to 22.31%. The value of percent FC was observed significantly decreased with an increase in the level of OFSP flour. A control sample was recorded with the highest FC as compared to flour blends with OFSP flour. It might be due to the higher protein content of amaranth flour present in higher quantity in control, which resulted in higher foaming capacity. These results are in agreement with Adeleke and Odedeji (2010). Protein forms the air bubbles as foam in dispersion by lowering the surface tension of water and air interface (Kaushal et al., 2012). A similar trend of foaming capacity was observed in percent foaming stability (FS). Flour blends with a higher level of OFSP flour observed with a significant decrease in percent FS. Control recorded with higher (28.57%) FS than other GF flour blends. The reduction in percent FS might be due to low foaming properties of sweet potato flour due to the low solubility of their proteins and their resistance to surface denaturation (Kinsella, 1979).

Emulsion capacity (EC) of flour blends with OFSP was observed higher than control. The increase in the level of OFSP flour leads to an increase in EC. The higher EC of sweet potato flour is responsible for higher EC of flour blends as compared to control. The higher EC of sweet potato flour (25.40%), which was higher than wheat flour, is reported by Adeleke and Odedeji (2010), and these are in agreement with present findings. Emulsion properties play a significant role in the food system where the proteins can bind fat batter; dough and salad dressing are reported by Sathe and Salunkhe (1981).

TABLE 2 Functional characteristics of OFSP flour-incorporated GF flour blends

Treatments	Water absorption capacity (5)	Oil absorption capacity (%)	Bulk density (g/ml)	Foaming capacity (%)	Foaming stability (%)	Emulsification capacity (%)	Swelling capacity (ml)
Control	200.17 ± 0.01^a	150.13 ± 0.01^a	0.64 ± 0.01^f	22.31 ± 0.06^a	28.57 ± 0.01^a	43.53 ± 0.01^h	34.23 ± 0.01^b
T_1	180.21 ± 0.01^b	148.23 ± 0.01^b	0.68 ± 0.01^d	21.89 ± 0.01^b	25.85 ± 0.01^b	47.93 ± 0.06^g	36.17 ± 0.01^a
T_2	175.16 ± 0.02^c	142.15 ± 0.01^c	0.69 ± 0.01^c	17.53 ± 0.06^c	23.35 ± 0.04^c	50.13 ± 0.06^f	32.18 ± 0.01^c
T_3	170.23 ± 0.01^d	135.17 ± 0.01^d	0.70 ± 0.01^b	19.03 ± 0.06^d	22.53 ± 0.06^d	51.33 ± 0.01^e	30.21 ± 0.01^d
T_4	167.31 ± 0.01^e	128.23 ± 0.01^e	0.71 ± 0.01^a	18.42 ± 0.01^e	20.29 ± 0.01^e	52.91 ± 0.01^d	28.22 ± 0.01^f
T_5	160.93 ± 0.01^f	122.18 ± 0.29^f	0.72 ± 0.01^a	15.03 ± 0.06^f	19.89 ± 0.06^f	53.84 ± 0.01^c	26.29 ± 0.01^g
T_6	156.13 ± 0.01^h	115.57 ± 0.01^g	0.72 ± 0.01^a	13.74 ± 0.05^g	19.00 ± 0.05^g	54.63 ± 0.06^b	25.10 ± 0.01^h
T_7	160.23 ± 0.01^g	110.19 ± 0.02^h	0.66 ± 0.01^e	12.47 ± 0.05^h	18.19 ± 0.01^h	55.43 ± 0.01^a	29.33 ± 0.01^e

Note: Treatment details OFSP : AF : CSP; Control – 0:50:50, T_1 – 40:30:30, T_2 – 50:25:25, T_3 – 60:20:20, T_4 – 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0. Values are expressed as mean ± *SD* of three independent determinations. Values in column followed by the same letter are not significantly different at $p \le .05$ as measured by Duncan's test.

Swelling capacity (SC) of flour blends with OFSP ranged from 25.10 to 36.17 ml. SC was found significantly decreased with an increase in the level of OFSP in blends. The swelling capacity of flours depends on the size of particles, types of variety, and types of processing methods or unit operations.

3.2 | Rheological characteristics

3.2.1 | Farinograph characteristics

The effect of different levels of OFSP flour in GF flour blend on farinograph characteristics of dough was determined. Data pertaining to the farinograph characteristics are presented in Table 3.

It was revealed that the addition of OFSP flour to the GF flour blend had a marginal effect on the water absorption. Water absorption decreased with an increase in the addition of OFSP flour. The decreased in water absorption capacity of dough might be due to the reduction in the quantity of CSP and AF, which was replaced by OFSP flour. Therefore, it was found that the increase in the incorporation of OFSP linearly decreases the water absorption capacity of dough. These results were expected due to structural modification in dough and incorporation of OFSP, which allows less water absorption as compared to control (blend of CSP and AF). The combining effect of the high water absorption capacity of AF and CSP reduced the water absorption value with the incorporation of OFSP flour. It was pointed that there were many hydroxyl groups in fiber structures, which caused water absorption to increase with producing hydrogen bonds are reported by Adeyeye and Aye (1998).

The dough development time and dough stability were found to increase with the increased addition of OFSP flour in blends. The development time in GF dough-incorporated with OFSP flour was found with respect to 40% OFSP (2.2 min), 50% OFSP (3 min), 60% OFSP (14.3 min), 70% OFSP (17.7 min), 80% OFSP (20 min), 90% OFSP (20 min), and 100% OFSP (14.4 min) in comparison with the control dough (2.2 min). The effect of gluten on dough properties, such as consistency and strength, were determined using farinograph is also assessed by Taghinia et al. (2016). The dough is developed due to complex interactions among flour constituents during the mixing operation. The process of dough development begins with the addition of water and commencement of mixing operation, and further sticky characteristics of dough disappear, and a nonsticky mass is developed at peak consistency of the dough is revealed by Khatkar (2004).

The sharp increase in dough stability with the increasing level of OFSP flour in the GF flour blends was attributed to the strengthening of the dough structure. It was found higher (20.5 min) for dough with OFSP flour as compared to control. The contradictory findings are reported by Amal (2015), change in dough stability time in wheat-sweet potato flour blends. The present findings might be due to the addition of OFSP flour in dough containing cassava starch powder which has high elasticity as compared to OFSP flour. GF dough with OFSP flour showed maximum stability as compared to control. The higher stable dough could be utilized for the preparation of GF cookies, which would be having characteristics similar to wheat cookies. The stability value of dough is an indication of the flour strength is noted by Bloksma and Bushuk (1988).

The maximum tolerance index (MTI) to knead GF dough found decreased. The tolerance index of control found highest (250BU) and decreased linearly (22BU) with an increase in the level of OFSP flour. Similar results were published in wheat breads fortified with sweet potato flour (Amal, 2015). The higher content of fiber in OFSP flour has been responsible for the change in the rheological properties of GF dough in the present study.

Farinograph quality number of GF dough increased with an increase in the level of OFSP flour in the blend. It was increased from 23FU (control) to 210FU (T_6). It indicates poor flour quality of control as compared to GF flour with OFSP. The incorporation of OFSP flour to GF flour blends had increased the farinograph quality number. Thus, there was an improvement in the flour quality. This positive effect of OFSP flour helps to justifies its incorporation in GF flour blends. Similar findings are reported by Amal (2015). Consistency of GF flour blends was found in the range of 160 BU to 931 BU. Control treatments recorded with higher consistency due to the presence of CSP. The value of consistency decreased with an increase in the incorporation of

TABLE 3 Effect of incorporation of OFSP flour on Farinograph characteristics of GF dough

Treatments	Water absorption** (%)	Dough development time (min)	Dough stability (min)	Tolerance Index (BU)	Time to breakdown (min)	Farinograph quality number	Consistency (BU)
Control	70.8 ± 0.01^a	2.2 ± 0.01^e	2 ± 0.02^f	250 ± 0.01^a	2.3 ± 0.01^f	23 ± 0.02^h	931 ± 0.01^a
T_1	61.1 ± 0.01^b	2.2 ± 0.01^e	1 ± 0.01^g	151 ± 0.03^b	2.5 ± 0.01^f	25 ± 0.01^g	342 ± 0.01^c
T_2	59.7 ± 0.02^c	3.0 ± 0.02^d	3.5 ± 0.03^e	124 ± 0.01^c	3.1 ± 0.03^e	31 ± 0.01^f	289 ± 0.02^d
T_3	58.8 ± 0.02^d	14.3 ± 0.01^c	13.6 ± 0.01^d	96 ± 0.01^d	14.2 ± 0.01^d	142 ± 0.01^e	369 ± 0.02^b
T_4	57.1 ± 0.01^e	17.7 ± 0.03^b	17.8 ± 0.01^c	73 ± 0.02^e	17.9 ± 0.01^c	179 ± 0.02^c	253 ± 0.01^e
T_5	55 ± 0.01^g	20 ± 0.01^a	19.7 ± 0.01^b	51 ± 0.02^f	20 ± 0.02^b	200 ± 0.02^b	248 ± 0.01^f
T_6	52 ± 0.03^h	20 ± 0.01^a	20.5 ± 0.01^a	34 ± 0.01^g	21 ± 0.01^a	210 ± 0.01^a	235 ± 0.03^g
T_7	56.5 ± 0.01^f	14.4 ± 0.02^c	17.1 ± 0.03^c	22 ± 0.01^h	14.7 ± 0.02^d	147 ± 0.03^d	160 ± 0.01^h

Note: Treatment; OFSP : AF : CSP; Control – 0:50:50, T_1 – 40:30:30, T_2 – 50:25:25, T_3 – 60:20:20, T_4 – 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0. Each value is the average of three determinations. **Corrected for 500 BU.

OFSP in GF flour blends, and it might be due to the fiber content of OFSP flour. The consistency of dough reduced from 931 BU to 160 BU.

3.2.2 | Amylograph characteristics

Brabender amylograph was used to determine the beginning of gelatinization, gelatinization temperature, and gelatinization maximum. The observations for amylograph characteristics of GF dough were showed significant differences among all treatments. The effect of different levels of OFSP on amylograph characteristics of dough is presented in Table 4. In control treatment (AF and CSP) showed, the maximum gelatinization value was very high (843 AU), and the addition of OFSP reduced it from 843 to 93 AU.

The amylographic characteristics such as beginning of gelatinization, gelatinization temperature, and gelatinization maximum were observed decreased with increase in the level of OFSP flour. However, the temperature for the start of gelatinization was found higher (64.4 to 69.5°C) for OFSP-incorporated flour as compared to control (63°C). The highest value of gelatinization temperature was found 89°C for dough with 10% OFSP (T_1) and lowest (68.7°C) for dough with 90% OFSP (T_6). The higher gelatinization temperatures were observed in the dough with 40% OFSP (T_1) and 50% OFSP (T_2) as compared to control. It might be due to an increase in OFSP, increased the fiber content, which affects the gelatinization of starch. Wu et al. (2009) studied the effect of the addition of sweet potato paste on amylographic characteristics of dough. It also reported, starch gelatinization caused the breakdown of the intermolecular bonds of starch molecules in presence of water and heat, resulting in exposure of hydrogen bonds (the hydroxyl hydrogen and oxygen) resulting more absorption of water. The gelatinization temperatures of starch depend upon the amount of water present during gelatinization.

3.3 | Physical properties

The effect of incorporation of OFSP flour in GF cookies was subjected to measurement of physical properties viz. thickness (mm), diameter (mm), spread ratio, spread factor (%), and hardness (N) (Table 5).

The data on the thickness of all the cookies were found in the range of 6.43 to 9.63 mm. It was observed that the increase in the level of addition of OFSP flour resulted to a significant increase in the thickness of GF cookies from 6.43 to 9.63 mm. However, an inverse trend was observed in the diameter of GF cookies. Control treatment reported with a higher (46.83 mm) diameter and lower (44.03 mm) in 100% OFSP flour (T_7) cookies. GF cookies showed a significant ($p \le .05$) decrease in diameter with an increase in the level of OFSP flour. A similar trend is also reported by Jemziya and Mahendran (2017); Giri and Sakhale (2019); Giri et al. (2016) in sweet potato flour-based GF cookies with rice, cassava, and sorghum flour. The spread ratio was calculated by dividing diameter to thickness. It revealed from the results that the spread ratio of cookies decreased significantly ($p \le .05$) with an increase in the level of OFSP flour in GF cookies. It might be due to a decrease in diameter and an increase in the thickness of GF cookies. Reduction in the spread ratio of cookies due to the incorporation of sweet potato flour is investigated by Jemziya and Mahendran (2017); Giri and Sakhale (2019); Giri et al. (2016). The highest (7.28) spread ratio was found in control and the lowest (4.57) in 100% OFSP (T_7) cookies. Similar to the spread ratio, the percent spread factor was also found to decrease significantly to 62.53%. Similar trends are reported by Saeed et al. (2012).

The hardness of GF cookies with OFSP flour was observed in the range of 5.49 to 19.82 N. Textural properties of GF cookies was measured in terms of hardness and found significantly ($p \le .05$) increased with increase in the level of OFSP flour in GF cookies. Sweet potato flour fortified cookies were harder than unfortified one is reported by Herawati et al. (2015); Giri and Sakhale (2019); Giri et al. (2016).

3.4 | Nutritional characteristics

3.4.1 | Proximate composition

The proximate composition of OFSP flour-incorporated GF cookies were analyzed and found with respect to moisture (3.53 to 5.33%),

TABLE 4 Effect of incorporation of OFSP flour on amylograph characteristics of GF dough

Treatments	Beginning of gelatinization (°C)	Gelatinization temperature (°C)	Gelatinization maximum (AU)
Control	63 ± 0.05^{e}	77.6 ± 0.03^{c}	843 ± 0.05^{a}
T_1	69.5 ± 0.05^{a}	89 ± 0.03^{a}	170 ± 0.05^{b}
T_2	68.4 ± 0.03^{b}	87.9 ± 0.02^{b}	162 ± 0.03^{d}
T_3	66.5 ± 0.02^{c}	76.9 ± 0.05^{d}	126 ± 0.03^{g}
T_4	63.1 ± 0.05^{e}	70 ± 0.03^{f}	93 ± 0.03^{h}
T_5	61.3 ± 0.05^{f}	69.1 ± 0.05^{g}	144 ± 0.05^{e}
T_6	59.4 ± 0.03^{g}	68.7 ± 0.05^{h}	140 ± 0.05^{f}
T_7	64.4 ± 0.03^{d}	72.6 ± 0.05^{e}	167 ± 0.05^{c}

Note: Treatment details are OFSP : AF : CSP; Control – 0:50:50, T_1 – 40:30:30, T_2 – 50:25:25, T_3– 60:20:20, T_4– 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0. Each value is the average of three determinations.

Journal of Food Processing and Preservation — Institute of Food Science + Technology ifst — WILEY

TABLE 5 Effect of incorporation of OFSP flour on physical properties of GF cookies

Parameters	Treatments							
	Control	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Thickness(mm)	6.43 ± 0.06^h	8.03 ± 0.06^g	8.23 ± 0.06^f	8.77 ± 0.06^e	9.23 ± 0.06^d	9.43 ± 0.06^c	9.53 ± 0.06^b	9.63 ± 0.06^a
Diameter (mm)	46.83 ± 0.6^a	46.03 ± 0.06^b	45.97 ± 0.06^b	45.37 ± 0.06^c	44.97 ± 0.06^d	44.77 ± 0.06^e	44.33 ± 0.06^f	44.03 ± 0.12^g
Spread ratio	7.28 ± 0.06^a	5.73 ± 0.05^b	5.58 ± 0.05^c	5.18 ± 0.03^d	4.87 ± 0.04^e	4.75 ± 0.04^f	4.65 ± 0.04^g	4.57 ± 0.02^h
Spread factor (%)	100 ± 0^a	78.39 ± 0.62^b	76.38 ± 0.63^c	70.79 ± 0.38^d	66.62 ± 0.50^e	64.92 ± 0.48^f	63.62 ± 0.55^g	62.53 ± 0.29^h
Hardness(N)	5.49 ± 0.01^h	10.38 ± 0.01^g	12.32 ± 0.01^f	18.26 ± 0.01^e	18.32 ± 0.01^d	18.43 ± 0.01^c	19.28 ± 0.01^b	19.82 ± 0^a

Note: Treatment details are OFSP flour : AF : CSP; Control – 0:50:50, T_1 – 40:30:30, T_2 – 50:25:25, T_3 – 60:20:20, T_4– 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0.Values are expressed as mean ± *SD* of three independent determinations. Values in row followed by the same letter are not significantly different at $p \leq .05$ as measured by Duncan's test.

fat (16.85 to 21.73%), protein (6.34 to 8.92%), ash (1.56 to 3.16%), crude fiber (2.30 to 3.60%), carbohydrate (61.95 to 64.71%), and energy value (435.88 to 479.08 kcal/100 g) and presented in Table 6. The moisture, ash, crude fiber, and carbohydrate content of GF cookies were found significantly increased whereas, fat, protein, and calorie content found decreased with an increase in the level of incorporation of OFSP flour in GF cookies. Srivastava et al. (2012) observed that moisture content of biscuits increased with increased concentration of sweet potato flour, whereas Dako et al. (2016) reported the negligible or no fat in sweet potato flour. Control treatment recorded with higher (8.92%) protein content, and it might be due to the presence of amaranth flour, which had higher protein as compared to sweet potato flour. Reduction in protein and increase in ash and fiber content of sweet potato flour-based GF cookies are also reported by Giri et al. (2016); Giri and Sakhale (2019). The higher fiber content in sweet potato flour-incorporated GF bread, considered as functional cookies suitable for constipation and cardiovascular diseases (Dako et al., 2016).

The increased level of sweet potato flour, a significant increase in carbohydrate content were observed, and it might be due to the presence of higher carbohydrate in sweet potato flour. A significant reduction in the calorie content of cookies was recorded with an increased level of OFSP flour. It could have been due to the higher fiber and lower fat content of OFSP, which indirectly lowered the calorie content. Similar research findings are noted by Giri et al. (2016).

3.4.2 | Minerals content

The minerals content of GF cookies were analyzed and the results with respects to potassium (K, 135.53 to 597.43 mg/100 g), phosphorus (P, 1.23 to 2.12 mg/100 g), magnesium (Mg, 1.23 to 2.12 mg/100 g), copper (Cu, 0.57 to 0.86 mg/100 g), zinc (Zn, 0.33 to 4.26 mg/10 g), and iron (Fe, 18.07 to 29.04 mg/100 g) are presented in Table 6.

It was analyzed that the mineral content of GF cookies except phosphorus was significantly increased with an increase in the level of incorporation of OFSP flour. The phosphorus content of OFSP cookies found lower as compared to control and it might be due to the lower content of phosphorus in sweet potato. The present findings were also in agreement with results reported on the increase in K, Mg, Cu, Zn, and Fe on the incorporation of OFSP in GF cookies by Giri et al. (2016).

3.5 | Bioactive components and in vitro antioxidant activity

The bioactive components of OFSP flour-incorporated GF cookies were subjected to evaluation of total phenols, total flavonoids, and total carotenoids and in vitro antioxidant activity in terms of percent DPPH inhibition (Table 7).

TABLE 6 Effect of incorporation of OFSP flour on nutritional characteristics of GF cookies

Parameters	Treatments							
	Control	T_1	T_2	T_3	T_4	T_5	T_6	T_7
Moisture (%)	3.53 ± 0.06^h	3.73 ± 0.06^g	4.03 ± 0.06^f	4.33 ± 0.06^e	4.63 ± 0.06^d	4.87 ± 0.06^c	5.03 ± 0.06^b	5.33 ± 0.06^a
Fat (%)	21.73 ± 0.06^a	20.63 ± 0.06^b	19.45 ± 0.04^c	18.97 ± 0.06^d	18.64 ± 0.55^d	17.58 ± 0.01^e	17.17 ± 0.29^f	16.85 ± 0.04^f
Protein (%)	8.92 ± 0.01^a	8.76 ± 0.01^a	8.44 ± 0.05^b	8.27 ± 0.03^{bc}	8.05 ± 0.02^c	7.30 ± 0.44^d	7.50 ± 0.03^d	6.34 ± 0.10^e
Ash (%)	1.56 ± 0.04^h	2.17 ± 0.01^g	2.27 ± 0.06^f	2.51 ± 0.01^e	2.71 ± 0.01^d	2.96 ± 0.01^c	3.01 ± 0.01^b	3.16 ± 0.01^a
Crude fiber (%)	2.30 ± 0.20^f	2.75 ± 0.05^e	2.91 ± 0.01^d	3.05 ± 0.05^c	3.30 ± 0.05^b	3.53 ± 0.02^a	3.61 ± 0.01^a	3.60 ± 0.00^a
Carbohydrates (%)	61.95 ± 0.34^d	61.95 ± 0.16^d	62.90 ± 0.18^c	62.87 ± 0.03^c	62.67 ± 0.43^c	63.76 ± 0.44^b	63.68 ± 0.31^b	64.71 ± 0.19^a
Calories (kcal/100g)	479.08 ± 0.88^a	468.54 ± 0.13^b	460.41 ± 0.26^c	455.29 ± 0.69^d	450.63 ± 3.21^e	442.50 ± 0.19^f	439.22 ± 1.21^g	435.88 ± 0.07^h
K (mg/100 g)	135.33 ± 0.58^h	180.36 ± 0.01^g	250.51 ± 0.01^f	346.73 ± 0.06^e	458.53 ± 0.06^d	501.33 ± 0.06^c	553.63 ± 0.06^b	597.43 ± 0.06^a
P (mg/100 g)	2.12 ± 0.01^a	2.03 ± 0.01^b	1.94 ± 0.01^c	1.72 ± 0.01^d	1.53 ± 0.01^e	1.43 ± 0.06^f	1.38 ± 0.01^g	1.23 ± 0.01^h
Mg (mg/100 g)	53.43 ± 0.06^h	57.13 ± 0.06^g	59.08 ± 0.01^f	61.53 ± 0.06^e	63.86 ± 0.01^d	65.21 ± 0.01^c	67.29 ± 0.01^b	69.08 ± 0.01^a
Cu (mg/100 g)	0.57 ± 0.01^e	0.59 ± 0.01^e	0.62 ± 0.06^d	0.63 ± 0.01^d	0.64 ± 0.01^d	0.68 ± 0.01^c	0.73 ± 0.01^b	0.86 ± 0.01^a
Zn (mg/100 g)	0.33 ± 0.06^h	0.52 ± 0.01^g	0.84 ± 0.01^f	1.25 ± 0.01^e	1.73 ± 0.01^d	2.83 ± 0.01^c	3.69 ± 0.01^b	4.26 ± 0.01^a
Fe (mg/100 g)	18.07 ± 0.01^h	19.07 ± 0.01^g	20.43 ± 0.01^f	22.06 ± 0.01^e	23.87 ± 0.01^d	25.43 ± 0.01^c	27.16 ± 0.01^b	29.04 ± 0.01^a

Note: Treatment details OFSP flour : AF : CSP; Control – 0:50:50, T_1 – 40:30:30, T_2 – 50:25:25, T_3 – 60:20:20, T_4– 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0.

Values are expressed as mean ± *SD* of three independent determinations. Values in row followed by the same letter are not significantly different at $p \le .05$ as measured by Duncan's test.

Data presented in Table 6 revealed that a significant variation ($p \le .05$) among the total phenols and flavonoids content of GF cookies were observed. The increased levels of OFSP flour in GF cookies significantly increase the total phenols and flavonoids content from 3.47 (control) to 13.07 mg GAE/100 g and 16.15 (control) to 79.94 mg QE/100 g, respectively. Sweet potato is a rich source of phenolics is reported by Islam et al. (2002).These results are in agreement with the findings reported by Hue et al. (2012).

Total carotenoids content was found a range of 2.81 to 7.48 mg/100 g. A control sample was not detected with total carotenoids due to the absence of OFSP flour. The increase in total carotenoids was reported with an increase in the level of OFSP flour in GF cookies. Mitra (2012) reported that OFSP having the potential to combat vitamin A deficiency. Sweet potato is found abundant in bioactive components that help to fight diseases and could be used as functional ingredients for the development of functional food products. Total carotenoids were found absent in control, and GF cookies with OFSP flour could be beneficial to combat vitamin A deficiency due to the presence of carotenoids.

The in vitro antioxidant activity (%) of GF cookies was found increased from 36.53% (control) to 82.47% (100% OFSP) with an increase in the level of incorporation of OFSP flour in GF cookies. It might be due to the higher radical scavenging activity of OFSP. Chan et al. (2012) reported the higher DPPH scavenging activity of OFSP.

3.6 | Sensory evaluation

The GF cookies-incorporated with OFSP flour were subjected to sensory assessment using a 9-point Hedonic scale and presented in Table 8. The score exhibited for color and appearance was found higher in GF cookies prepared from OFSP flour-incorporated up to 70%. The score for color and appearance of GF cookies were significantly reduced above the level of incorporation of 70% OFSP flour in GF cookies. The score for texture was observed higher for control as compared to OFSP flour added GF cookies. It might be due to the increase in the hardness of cookies with OFSP flour. The textural score for GF cookies with 40% (T_1) and 50% OFSP flour (T_2) were nonsignificantly different whereas, the score found reduced when the level of OFSP flour increased above 70%. GF cookies with 70% OFSP flour (T_4) received a higher score for taste and decreased significantly when the level of OFSP flour increased above 70%, which might be due to typical flavor component and caramelization of free sugar present in OFSP flour during baking. The GF cookie incorporated with 70% OFSP flour recorded with an overall acceptability score of 9.00, which was significantly superior to others. Singh et al. (2008) reported that OFSP at the rate of 40% was sensorial acceptable in the development of cookies.

3.7 | Shelf life and microbial quality

The microbial quality of GF cookie added with 70% OFSP flour and control sample was analyzed to determine the shelf life of the cookies. The microbial qualities were assessed at the interval of every 30 days during the storage period. The data about the microbial count in terms of total plate count (TPC) are presented in Table 9. The total plate count of freshly prepared cookies with 70% incorporation of OFSP flour and control were not found.

It was observed that the increase in the storage period of cookies resulted in a gradual increase in the microbial growth in terms of total plate count. The TPC of cookies with 70% OFSP flour and control was observed on 30th day (1.3×10^3 and 1.1×10^3 cfu/g) followed by on 60th day (2.2×10^3 and 1.8×10^3 cfu/g) and the highest value (4.2×10^3 and3.5×10^3 cfu/g) was observed on 90th day of storage respectively. It was noted that the microbial growth of GF cookies with 70% OFSP flour was found at par with the microbial growth of control. The total plate count of cookies with 70% OFSP flour was slightly higher as compared to control, and it might be due to higher moisture content of OFSP flour-incorporated cookies as compared to control. It meant that the incorporation of OFSP in GF cookies did not affect the microbial quality and found suitable for consumption until 90 days.

TABLE 7 Effect of OFSP flour on bioactive components and in vitro antioxidant activity of GF cookies

Treatments	In vitro antioxidant activity (%)	Total phenols (mg GAE/100 g)	Total flavonoids (mg QE/100 g)	Total carotenoids (mg/100 g)
Control	36.53 ± 0.06^h	3.47 ± 0^h	16.15 ± 0^h	Not detected
T_1	40.97 ± 0.01^g	5.20 ± 0^g	31.60 ± 0^g	2.81 ± 0.01^g
T_2	47.95 ± 0.01^f	6.50 ± 0^f	39.50 ± 0^f	3.75 ± 0.01^f
T_3	53.93 ± 0.01^e	7.80 ± 0^e	47.40 ± 0^e	4.49 ± 0.01^e
T_4	62.53 ± 0.06^d	9.10 ± 0^d	55.50 ± 0^d	5.25 ± 0.06^d
T_5	70.26 ± 0.01^c	10.23 ± 0^c	63.25 ± 0^c	6.0 ± 0.05^c
T_6	77.97 ± 0.01^b	11.56 ± 0^b	70.82 ± 0.01^b	6.71 ± 0.02^b
T_7	82.47 ± 0.01^a	13.07 ± 0^a	79.94 ± 0.01^a	7.48 ± 0.02^a

Note: Treatment details OFSP flour: AF: CSP; Control – 0:50:50,T_1 – 40:30:30, T_2 – 50:25:25, T_3 – 60:20:20, T_4 – 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0. Values are expressed as mean ± *SD* of three independent determinations. Values in column followed by the same letter are not significantly different at $p \le .05$ as measured by Duncan's test.

TABLE 8 Effect of OFSP flour on sensory characteristics of GF cookies

Treatments	Color and Appearance	Texture	Flavor	Taste	Overall acceptability
Control	9.0 ± 0.06^a	9.0 ± 0.06^a	8.53 ± 0.06^b	8.03 ± 0.06^e	8.53 ± 0.06^c
T_1	9.0 ± 0.06^a	8.80 ± 0.06^b	9.0 ± 0.06^a	8.23 ± 0.06^d	8.53 ± 0.06^c
T_2	9.0 ± 0.06^a	8.80 ± 0.06^b	9.0 ± 0.06^a	8.53 ± 0.06^c	8.53 ± 0.06^c
T_3	9.0 ± 0.06^a	8.73 ± 0.06^c	9.0 ± 0.06^a	8.73 ± 0.06^b	8.70 ± 0.06^b
T_4	9.0 ± 0.06^a	8.53 ± 0.06^d	9.0 ± 0.06^a	9.0 ± 0.06^a	9.0 ± 0.06^a
T_5	8.53 ± 0.06^b	8.03 ± 0.06^e	8.03 ± 0.06^c	8.03 ± 0.06^e	8.03 ± 0.06^d
T_6	8.03 ± 0.06^c	7.53 ± 0.06^f	7.53 ± 0.06^d	7.53 ± 0.06^f	7.83 ± 0.06^e
T_7	7.53 ± 0.06^d	7.03 ± 0.06^g	7.03 ± 0.06^e	7.03 ± 0.06^g	7.03 ± 0.06^f

Note: Treatment details are OFSP flour : AF : CSP; Control – 0:50:50, T_1 40:30:30, T_2 – 50:25:25, T_3 – 60:20:20, T_4 – 70:15:15, T_5 – 80:10:10, T_6 – 90:05:05, T_7 – 100:0:0. Values are expressed as mean ± *SD* of 20 independent determinations. Values in column followed by the same letter are not significantly different at $p \le .05$ as measured by Duncan's test.

TABLE 9 Effect of addition of 70% OFSP flour on microbial quality GF cookies

	Total plate count (cfu/g)	
Storage period (Days)	Control	Cookies with 70% OFSP flour
Fresh	Not detected	Not detected
30	1.1×10^3	1.3×10^3
60	1.8×10^3	2.2×10^3
90	3.5×10^3	4.2×10^3

Note: Each value is the average of three determinations.
Abbreviation: OFSP, orange-fleshed sweet potato flour.

The increase in the number of TPC could be due to favorable conditions available for the growth of microorganisms during storage. A similar trend of microbial growth is also reported by Nirmala (2016). The microbial loads of GF cookies were analyzed and were found that the total plate count less than 10^5 cfu/g. It was observed that the microbial count was found still within the acceptable limit, as reported in the FSSAI is 10^5 cfu/g. These results are in conformity with Wani et al. (2015).

4 | CONCLUSIONS

The orange-fleshed sweet potato flour could be successfully utilized along with amaranth flour and cassava starch powder for the development of GF cookies suitable for celiac patients and also can be consumed during fasting days. The higher content of fiber, minerals, bioactive components, especially carotenoids content, could be added advantages for developed OFSP flour-incorporated GF cookies. Based on organoleptic parameters, the combination of 70% orange-fleshed sweet potato flour, 15% amaranth flour, and 15% cassava starch powder was found most acceptable for making GF cookies without changing their overall quality parameters.

CONFLICT OF INTEREST

The authors have declared no conflicts of interest for this article.

ORCID

Namrata Ankush Giri https://orcid.org/0000-0002-2981-1152
Bhagwan Kashiram Sakhale https://orcid.org/0000-0002-5816-2286

REFERENCES

AACC. (2000). *Official methods of analysis* (18th ed). Author.

Adeleke, R. O., & Odedeji, J. O. (2010). Functional properties of wheat and sweet potato flour blends. *Pakistan Journal of Nutrition*, *9*(6), 535–538. https://doi.org/10.3923/pjn.2010.535.538

Adeyeye, E. I., & Aye, P. A. (1998). The effects of sample preparation on the proximate composition and the functional properties of the African yam bean (Sphenostylis stenocarpa Hochst ex A. Rich) flours. Note 1. *Rivista Italiana Delle Sostanze Grasse*, *75*(5), 253–261.

Amal, A. M. (2015). Quality evaluation of wheat-sweet potato composite flours and their utilization in bread making. *International Journal of Advanced Research in Biological Science*, *2*(11), 294–303.

Amerine, M. A., Pangborn, R. M., & Roessler, E. B. (2013). *Principles of sensory evaluation of food*. London: Elsevier.

AOAC. (2011). *Official methods of analysis of the association of official analytical chemists* (18th ed). AOAC International.

Bloksma, A. H., & Bushuk, W. (1988). Rheology and chemistry of dough. In Y. Pomeranz (Ed.), *Wheat chemistry and technology* (Vol. 2, pp. 131–217). American Association of Cereal Chemists.

Brito, I. L., de Souza, E. L., Felex, S. S. S., Madruga, M. S., Yamashita, F., & Magnani, M. (2015). Nutritional and sensory characteristics of gluten-free quinoa (*Chenopodium quinoa* Willd)-based cookies development using an experimental mixture design. *Journal of Food Science and Technology*, *52*(9), 5866–5873. https://doi.org/10.1007/s13197-014-1659-1

Centro Internacional de la Papa. Sweet Potato. (2009). Retrieved 06.10.12 from http://www.cipotato.org/sweetpotato/) Buttriss, J.L., & Stokes, C. S. (2009). Dietary fiber and health. *Nutrition Bulletin*, 33, 186–200.

Chan, K. W., Khong, N. M., Iqbal, S., Umar, I. M., & Ismail, M. (2012). Antioxidant property enhancement of sweet potato flour under simulated gastrointestinal pH. *International Journal of Molecular Sciences*, *13*(7), 8987–8997. https://doi.org/10.3390/ijms13078987

Dako, E., Retta, N., & Desse, G. (2016). Effect of blending on selected sweet potato flour with wheat flour on nutritional, anti-nutritional and sensory qualities of bread. *Global Journal of Science Frontier Research*, *16*(4), 31–41.

Frances, W. G., Ibok, O., Faustina, D. W. M., John, L. Z. Z., & Ibok, O. (2017). A traditional biscuit fortified with orange-fleshed sweet potato puree and cowpea flour. *Food Science and Nutrition Technology*, *2*(2), 000122.

Giri, N. A., & Sakhale, B. K. (2019). Development of sweet potato flour based high protein and low calorie gluten free cookies. *Current Research in Nutrition and Food Science Journal*, *7*(2), 427–435. https://doi.org/10.12944/CRNFSJ.7.2.12

Giri, N. A., & Sakhale, B. K. (2020). Optimization of whey protein concentrate and psyllium husk for the development of protein-fiber rich orange fleshed sweet potato (*Ipomoea batatas* L.) bread by using response surface methodology. *Journal of Food Measurement and Characterization*, *14*(1), 425–437. https://doi.org/10.1007/s11694-019-00304-3

Giri, N. A., Sheriff, J. T., Sajeev, M. S., & Pradeepika, C. (2016). Development and physico-nutritional evaluation of sweet potato flour based gluten free cookies. *Journal of Root Crops*, *42*(1), 74–81.

Gopalan, C., Rama Sastri, B. V., & Balasubramanian, S. C. (2007). *Nutritive value of Indian foods* (pp. 18–29). National Institute of Nutrition, ICMR.

Grace, M. H., Yousef, G. G., Gustafson, S. J., Truong, V. D., Yencho, G. C., & Lila, M. A. (2014). Phytochemical changes in phenolics, anthocyanins, ascorbic acid, and carotenoids associated with sweetpotato storage and impacts on bioactive properties. *Food Chemistry*, *145*, 717–724. https://doi.org/10.1016/j.foodchem.2013.08.107

Grant, V. (2003). Select markets for taro, sweet potato and yam. *Rural Industries Research and Development Corporation*, *3*, 875–880.

Herawati, D., Simanjuntak, F., Syamsir, E., Lioe, H. N., & Briawan, D. (2015). Physicochemical properties of sweet potato cookies fortified with some nutrients. *International Food Research Journal*, *22*(2), 684–690.

Hue, S. M., Boyce, A. N., & Somasundram, C. (2012). Antioxidant activity, phenolic and flavonoid contents in the leaves of different varieties of sweet potato ('*Ipomoea batatas*'). *Australian Journal of Crop Science*, *6*(3), 375.

Islam, M. S., Yoshimoto, M., Yahara, S., Okuno, S., Ishiguro, K., & Yamakawa, O. (2002). Identification and characterization of foliar polyphenolic composition in sweetpotato (*Ipomoea batatas* L.) genotypes. *Journal of Agricultural and Food Chemistry*, *50*(13), 3718–3722.

Jemziya, M. B. F., & Mahendran, T. (2017). Physical quality characters of cookies produced from composite blends of wheat and sweet potato flour. *Ruhuna Journal of Science*, *8*, 12–23. https://doi.org/10.4038/rjs.v8i1.23

Jisha, S., & Padmaja, G. (2011). Whey protein concentrate fortified baked goods from cassava-based composite flours: Nutritional and functional properties. *Food and Bioprocess Technology*, *4*(1), 92–101. https://doi.org/10.1007/s11947-008-0175-6

Karuna, D., Noel, D., & Dilip, K. (1996). *Food and nutrition bulleting*, Vol. 17(2). United Nation University.

Kaushal, P., Kumar, V., & Sharma, H. K. (2012). Comparative study of physicochemical, functional, antinutritional and pasting properties of taro (*Colocasia esculenta*), rice (*Oryza sativa*) flour, pigeonpea (*Cajanus cajan*) flour and their blends. *LWT-Food Science and Technology*, *48*(1), 59–68. https://doi.org/10.1016/j.lwt.2012.02.028

Khatkar, B. (2004). *Rheology and Chemistry of dough*. Post-graduated diploma in bakery science and technology. Directorate of Distance Eduction, Guru Jambheshwar University of Science and Technology.

Kinsella, J. E. (1979). Functional properties of soy proteins. *Journal of the American Oil Chemists' Society*, *56*(3Part1), 242–258. https://doi.org/10.1007/BF02671468

Krishnakumar, T., & Sajeev, M. S. (2018). Effect of ultrasound treatment on physicochemical and functional properties of cassava starch. *International Journal of Current Microbiology and Applied Science*, *7*(10), 3122–3135. https://doi.org/10.20546/ijcmas.2018.710.362

Kulkarni, K. D., Kulkarni, D. N., & Ingle, U. M. (1991). Sorghum malt-based weaning food formulations: Preparation, functional properties, and nutritive value. *Food and Nutrition Bulletin*, *13*(4), 1–7. https://doi.org/10.1177/156482659101300401

Kure, O. A., Bahago, E. J., & Daniel, E. A. (1998). Studies on the proximate composition and effect of flour particle size on acceptability of biscuit produced from blends of soyabeans and plantain flours. *Namida Tech-Scope Journal*, *3*, 17–21.

Manuel, S.-G., Arias-Olguín, I. I., Montes, J. P. C., Ramírez, D. G. R., Figueroa, J. S. M., Flores-Valverde, E., & Valladares-Rodríguez, M. R. (2018). Nutritional functional value and therapeutic utilization of Amaranth. *Journal of Analytical and Pharmaceutical Research*, *7*(5), 596–600.

Mishra, A., Devi, M., & Jha, P. (2015). Development of gluten free biscuits utilizing fruits and starchy vegetable powders. *Journal of Food Science and Technology*, *52*(7), 4423–4431.

Mitra, S. (2012). Nutritional status of orange-fleshed sweet potatoes in alleviating vitamin A malnutrition through a food-based approach. *Journal of Nutrition and Food Science*, *2*(8), 160.

Nirmala, R. (2016). Study on microbial profile of bread during storage. *International Journal of Advanced Research in Biological Science*, *3*(9), 60–63.

Okaka, J. C., & Potter, N. N. (1977). Functional and storage properties of cowpea powder-wheat flour blends in breadmaking. *Journal of Food Science*, *42*(3), 828–833.

Onwuka, G. I. (2005). *Food analysis and instrumentation: Theory and practice* (pp. 133–137). Napthali Prints.

Rangana, S. (1979). *Manual of analysis of fruit and vegetable products*. Tata McGraw-Hill.

Rathod, R. P., & Annapure, U. S. (2016). Development of extruded fasting snacks by using vari rice, sweet potato and banana powder with applying response surface methodology. *Journal of Food Measurement and Characterization*, *10*(3), 715–725.

Rawat, S., Jugran, A., Giri, L., Bhatt, I. D., & Rawal, R. S. (2011). Assessment of antioxidant properties in fruits of Myrica esculenta: A popular wild edible species in Indian Himalayan region. *Evidence-Based Complementary and Alternative Medicine*, *2011*, 8.

Reddy, C. V. K., Sreeramulu, D., & Raghunath, M. (2010). Antioxidant activity of fresh and dry fruits commonly consumed in India. *Food Research International*, *43*(1), 285–288.

Reilly, N. R., & Green, P. H. (2012). Epidemiology and clinical presentations of celiac disease. *Seminars in Immunopathology*, *34*(4), 473–478. https://doi.org/10.1007/s00281-012-0311-2

Rubio-Tapia, A., & Murray, J. A. (2010). Celiac disease. *Current Opinion in Gastroenterology.*, *26*(2), 116. https://doi.org/10.1097/MOG.0b013e3283365263

Saeed, S., Mushtaq Ahmad, M., Kausar, H., Parveen, S., Masih, S., & Salam, A. (2012). Effect of sweet potato flour on quality of cookies. *Journal of Agricultural Research* (03681157), *50*(4), 525–538.

Sathe, S. K., & Salunkhe, D. K. (1981). Functional properties of the great northern bean (*Phaseolus vulgaris* L.) proteins: Emulsion, foaming, viscosity, and gelation properties. *Journal of Food Science*, *46*(1), 71–81.

Singh, S., Riar, C. S., & Saxena, D. C. (2008). Effect of incorporating sweet potato flour to wheat flour on the quality characteristics of cookies. *African Journal of Food Science*, *2*(6), 65–72.

Singh, U. (2001). Functional properties of grain legume flours. *Journal of Food Science and Technology (Mysore)*, *38*(3), 191–199.

Singleton, V. L., & Rossi, J. A. (1965). Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American Journal of Enology and Viticulture*, *16*(3), 144–158.

Srivastava, S., Genitha, T. R., & Yadav, V. (2012). Preparation and quality evaluation of flour and biscuit from sweet potato. *Journal of Food Process Technology*, *3*(12), 113–118. https://doi.org/10.4172/2157-7110.1000192

Steel, R. G. D., Torrie, J. H., & Dickey, D. (1997). *Principals and procedures of statistics* (3rd ed). McGraw Hills.

Taghinia, P., Ataye Salehi, E., & Sheikholesami, Z. (2016). Impact of pre-treated rice bran on wheat dough performance and barbari bread quality. *Journal of Agricultural Science and Technology*, *18*(1), 135–144.

Truong, V. D., & Avula, R. Y. (2010). Sweet potato purees and dehydrated powders for functional food ingredients. In R. C. Ray (Eds.), *Sweet potato: Post harvest aspects in food, feed and industry* (pp. 117–162). Nova Science Publishers Inc.

van Jaarsveld, P. J., Faber, M., Tanumihardjo, S. A., Nestel, P., Lombard, C. J., & Benadé, A. J. S. (2005). β-Carotene–rich orange-fleshed sweet potato improves the vitamin A status of primary school children assessed with the modified-relative-dose-response test. *The American Journal of Clinical Nutrition*, *81*(5), 1080–1087. https://doi.org/10.1093/ajcn/81.5.1080

Wang, J. C., & Kinsella, J. E. (1976). Functional properties of novel proteins: Alfalfa leaf protein. *Journal of Food Science*, *41*(2), 286–292. https://doi.org/10.1111/j.1365-2621.1976.tb00602.x

Wani, S. H., Gull, A., Allaie, F., Safapuri, T. A., & Yildiz, F. (2015). Effects of incorporation of whey protein concentrate on physicochemical, texture, and microbial evaluation of developed cookies. *Cogent Food & Agriculture*, *1*(1), 1092406. https://doi.org/10.1080/23311932.2015.1092406

Wu, K. L., Sung, W. C., & Yang, C. H. (2009). Characteristics of dough and bread as affected by the incorporation of sweet potato paste in the formulation. *Journal of Marine Science and Technology*, *17*(1), 13–22.

Yusufu, P. A., Netala, J., & Opega, J. L. (2016). Chemical, sensory and microbiological properties of cookies produced from maize, African yam bean and plantain composite flour. *Indian Journal of Nutrition*, *3*(1), 122.

How to cite this article: Giri NA, Sakhale BK. Effects of incorporation of orange-fleshed sweet potato flour on physicochemical, nutritional, functional, microbial, and sensory characteristics of gluten-free cookies. *J Food Process Preserv*. 2021;45:e15324. https://doi.org/10.1111/jfpp.15324