The Annals of the University Dunarea de Jos of Galati
Fascicle VI – Food Technology (2022), 46(1), 155-168

ORIGINAL RESEARCH PAPER

DEVELOPMENT OF PEARL MILLET FLOUR-BASED COOKIES SUPPLEMENTED WITH MUNG BEAN AND ORANGE FLESHED SWEET POTATO FLOURS

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Received on 12 January 2022
Revised on 13 May 2022

Abstract

The study explored the feasibility of producing cookies from pearl millet flour (PMF), mung bean flour (MF) and orange fleshed sweet potato flour (OFSPF). Sixteen formulations were produced by mixing the three basic ingredients: PMF, MF and OFSPF using optimal mixture design of response surface methodology. The sensory properties of cookies developed from these flour blends were evaluated and the result showed variations among cookie samples. Three samples were selected from the optimization results and compared with 100% wheat flour cookies (control). The selected flour blend samples showed a significant ($p<0.05$) increase in swelling capacity and water absorption capacity. Supplementation with MF improved the protein content of cookie samples while PMF led to an appreciable increase in crude fibre, β-carotene and total phenol contents. This study has confirmed that the production of acceptable cookies of high crude fibre, micronutrients and antioxidant sources that would help reduce the problems of malnutrition and diet-related non-communicable diseases is feasible through the optimization of the basic ingredients.

Keywords: cookies, optimization, supplementation, blends, antioxidant

Introduction

Baked goods are mainly produced from refined wheat flour (*Triticum* spp), fat and sugar with flavouring substances of choice. This leads to presenting high energy density products which are deficient in protein, dietary fibre and bioactive compounds that are essential to health (Pessanha *et al*., 2021). Food product development has advanced from ordinary production to the combination of ingredients for nutritional improvement (Akoja and Coker, 2018) and cookies are the best target snacks. Besides, wheat grain has disadvantages in terms of the high

https://doi.org/10.35219/foodtechnology.2022.1.12

foreign exchange rate in the countries whose climatic conditions are unfavourable to cultivation coupled with the issue of celiac disease (Olawoye and Gbadamosi, 2020). However, locally grown crops could be used to reduce the extensive importation of wheat grains and the application of gluten-free flours in cookies production could enhance nutrition and increase the rate of consumption.

Pearl millet (*Pennisetum glaucum*) is currently the most widely grown millet crop in Africa and India accounting for half of the world's millet production (Wang *et al*., 2019). Pearl millet grains contain 8–9% dietary fibre, 9–20% protein, 2–7% fat and 63–78% carbohydrates (Taylor and Kruger, 2016). It is reported to contain high antioxidant activity, ascorbic acid and phenolic compounds (Kaur *et al*., 2019). They are cultivated around the world for food due to their adaptability to harsh weather conditions (Suma *et al*., 2014). Recently, the utilization of whole pearl millet flour in total replacement of wheat flour in cookies production had been successful with improvement in sensory and nutritional properties through different processing methods such as roasting (semi-refined) according to Suma *et al*. (2014), and fermentation and malting as described by Adebiyi *et al*. (2017). There is a need for further improvement of pearl millet flour-based cookies through fortification as it is known to be an excellent tool in nutrient enhancement.

Mung bean (*Vigna radiata*) is a widely used leguminous seed belonging to the *Fabaceae* family. It is also called green gram or golden gram and serves as a good source of easily digestible quality protein for humans (Ratnawati *et al*., 2019). It contains high content of micronutrients and health promoting phytochemicals (Guo *et al*., 2012). It is often used as a better supplement with cereals due to its richness in lysine content.

Sweet potato (*Ipomoea batatas*) is an important crop ranked fifth after maize, wheat, rice, and potato with less cultivation requirements (Hou *et al*., 2020). Orange fleshed sweet potatoes (OFSP) are fast growing root crops with higher conservation of nutrients due to their adaptability to poor conditions. OFSP is a bio-fortified crop potentially used to manage vitamin A deficiency in less developed countries as a result of its high β-carotene content (Kolawole *et al*., 2020). It is a starchy root crop having high contents of carbohydrate, dietary fibre, ascorbic acid, mineral and phenolic compounds (Kolawole *et al*., 2016; Meng *et al*., 2019). The usefulness of OFSP flour as a replacement for wheat flour or partial supplementation in cookie production has been documented (Fateema *et al*., 2019; Giri *et al*., 2019; Bello *et al*., 2020). The present study aimed to exploit response surface methodology in optimizing the sensory properties of formulated cookies, assess the functional properties of the selected flour blends and evaluate the nutrient composition and antioxidant activity of the cookies developed.

Materials and methods

Materials procurement

Pearl millet and whole wheat grains were bought from Itam market in Uyo metropolis, Akwa Ibom State, Nigeria. Margarine, sugar, baking powder, vanilla flavour, egg, powdered milk and salt were also procured from Itam market in Uyo metropolis. Mung bean was obtained from the Department of Agronomy, Michael Okpara University of Agriculture, Umudike, Abia State while OFSP was procured from a local farmer in Benue State. The chemicals used were of analytical grade.

Production of flours used in cookies formulation

Pearl millet was prepared into flour according to the method described by Poongodi and Jemima (2009). The pearl millet was cleaned, winnowed and soaked in potable water for 24 h. The soaked grains were steamed for 20 min, drained and dried in an oven (NAAFCO BS Oven (OVH-102)) at 65ºC. The dried grains were milled using a locally fabricated milling machine, flour was sieved using 425 µm mesh size, packaged in an air-tight plastic container and stored at ambient temperature (27±2°C) prior to flour blend formulations.

Mung bean flour was prepared following the procedures explained by Offia-Olua and Madubuike (2015). Mung bean seeds were cleaned and soaked in potable water for 12 h and oven dried at 65ºC. After these pre-conditioning treatments, the dried beans were then dehulled abrasively and winnowed to separate the hulls from the cotyledons. The dehulled seeds were milled using a locally fabricated mill, the flour was sieved using a 425 µm mesh sieve size, packaged in an air plastic tight container and stored at ambient temperature prior to flour blend formulations.

OFSP tubers were sorted by removing the spoilt ones. The tubers were then washed in potable water, peeled with a knife and sliced into thin slices manually to enhance drying. The sliced tubers were water blanched at 65ºC for 15 min and oven dried at 55ºC. OFSP dried slices were milled into flour using a locally fabricated milling machine and sieve through 425 µm mesh size to obtain uniform flour size. The fine flour was then packaged in air tight plastic container and stored at ambient temperature prior to flour formulations.

The whole wheat grains were winnowed to remove chaff and sorted to remove sand and sticks. The good grains were washed in potable water and oven dried at 55°C, milled using a locally fabricated mill and passed through a 425 µm mesh sieve size to get the fine flour. The flour was packaged in an air tight container and kept at ambient temperature.

Experimental design

Optimal mixture design of response surface methodology (Design expert 12.0.3.0 version, Stat-Ease Inc., Minneapolis, USA) was used for the experiment. The independent variables included pearl millet flour, mung bean flour and orange fleshed sweet potato flour with low and high limit design constraints of 65-85%, 5-30% and 5-20%, respectively which generated sixteen formulations, as can be seen in Table 1 (experimental runs). The dependent variables were sensory properties (appearance, taste, aroma, texture, crispiness, aftertaste and general acceptability). Pearl millet flour, mung bean flour and orange fleshed sweet potato flour were blended at different mixture ratios as generated by experimental design. Blending was done using a mechanical blender (Panasonic (MX-AC210S), China) packaged in airtight plastic containers and labeled.

Cookies production

The creamy method described by Okpala *et al*. (2013) was adopted. A 20 g of margarine and 12.50 g of sugar were mixed together, 5 g of powdered milk was added and mixed thoroughly until the mixture became fluffy. Then 50 g of flour, baking powder (0.45 g), salt (0.25 g), powdered milk (5 g), vanilla flavour (2.5 ml) and 12.5 ml of egg were mixed together, added to the cream mixture in a bowl mixer (MC- HM6030, Master Chef and Crownstar, China) to form a moderately stiff dough. The formed dough was kneaded, cut into a uniform thickness, allowed to rest for 30 min at room temperature, baked in an oven at 185°C for 20 min and cooled. Cookies were packaged in high-density polyethylene material and labeled.

Sensory evaluation of formulated cookies

Sensory attributes of the formulated cookies were evaluated by semi-trained panelists of twenty people selected from the University of Uyo community. The panelists were briefed before the commencement of the evaluation process in which they were given the questionnaires and asked to rate cookies based on their appearance, taste, aroma, texture, after taste and general acceptability using nine-point hedonic scale ranging from 9 (like extremely) to 1 (dislike extremely) (Ihekoronye and Ngoddy, 1985). Panelists were good consumers of cookies and water at room temperature was provided to gaggle the mouth after each evaluation to reduce carry-over effect of cookies.

Determination of functional properties of selected flour blends and control

The method as described by Onwuka (2005) was adopted for the determination of bulk density, gelatinization temperature, water and oil absorption capacities, and wettability of flour blends. Bulk density was determined by filling the sample (2.5g) into a 100 ml graduated cylinder. Its bottom was hit on the laboratory table until the sample volume did not decrease.

Gelatinization temperature was determined by suspending a 10 g flour sample in a 250 ml beaker containing distilled water and made up to 100 ml. A thermometer with its bulb submerged in the suspension was attached to the retort stand and heated in a boiling water bath with steady stirring. When the suspension began to gel, the temperature was taken.

For water absorption capacity, 1 g of flour sample was mixed with 10 ml distilled water and after 30 min at room temperature, it was centrifuged at 3,000 rpm for 30 min. The percent water bound per gram of flour was used to measure water absorption. The same procedure as for water absorption was utilized for oil absorption capacity, except groundnut oil was used instead of water.

Wettability was carried out by placing 1 g of flour into a 25 ml graduated cylinder, securely closed, inverted, and fastened at a 10 cm height above the surface of a 600 ml beaker with 500 ml of distilled water in it. The test material was allowed to flow freely when the measurement cylinder was opened. The wettability is the amount of time it takes for a sample to become totally saturated.

The Olawuni *et al*. (2013) approach was used to determine the swelling index. The sample (1 g) was weighed into a graduated measuring cylinder with a 10 ml capacity. The volume occupied by the sample was measured after five (5) ml of distilled water was properly added. The samples were left undistributed in water for 1 h before the volume was measured again.

Antioxidant properties determination of selected cookies and control

The total phenolic contents of cookie samples were determined by following the procedures of Singleton *et al*. (1995). A 0.1 ml acidified methanolic extract of the ground cookies samples was added to 5 ml distilled water in a volumetric flask. Folin-Ciocalteu's reagent of 2.5 ml and 15% sodium carbonate solution (7.5 ml) was added to the mixture, mixed thoroughly, made up to 50 ml with distilled water and allowed to react for 30 min. The absorbance of the reaction mixture was read at 760 nm with the aid of a spectrophotometer. The calibration curve was prepared using a standard solution of gallic acid (R^2 = 0.9993) and the result was expressed as mg of gallic acid equivalent (GAE) per 100 g of cookie sample.

The 1,1-diphenyl-2-picrylhydrazyl (DPPH) scavenging activity of the cookies was determined by mixing 10 µl aliquot of the acidified methanolic extract with 90 µl distilled water followed by 3.9 ml of methanolic 0.1 M DPPH solution. The mixture was mixed thoroughly by vortex equipment, kept in the dark for 30 min and the absorbance was read at 515 nm. The result was expressed as percentage inhibition of the DPPH radical (De Ancos *et al*., 2002).

The procedures described by Zhishen *et al.* (1999) were followed for the total flavonoid content determination of cookie samples. A 0.1 ml of extract was mixed with distilled water (4.9 ml) and $NaNO_2$ (0.3 ml). $AlCl_3$ of 0.3 ml and 1 M NaOH (2 ml) were added at 5 min and 6 min, respectively. The mixture was made up to 10 ml with distilled water, mixed well with the aid of vortex equipment and the absorbance was read at 510 nm. The calibration curve was prepared using a standard of catechin hydrate (R^2 = 0.9994) and the result was expressed as mg catechin equivalents per 100 g of the cookie sample.

Determination of nutrient composition of selected cookies and control

Moisture, ash, crude fibre, crude protein and crude lipid content were determined following the procedures stated in AOAC (2005). Carbohydrate content was calculated by difference, *i.e.* % Total carbohydrate = 100 - (%moisture + %ash + %crude fibre + %crude protein + %crude lipid). The caloric value was calculated using the Atwater factor based on the contents of crude protein, fat and carbohydrate using conversion factors of 4, 9 and 4 kcal, respectively.

According to Rodriguez-Amaya and Kimura (2004), the β-carotene concentrations of samples were determined. Ten (10) g of ground cookies sample was homogenized for 3 min with 40 ml of 99.8% C_2H_5OH and 10 ml of 100% (w/v) KOH. The mixture was saponified using refluxing equipment, then heated for 30 min on a heating mantle and cooled down to room temperature. To avoid aggregation, the mixture was stirred frequently. 50 mL of n-C_6H_{14} (hexane) was added to the mixture in a separating funnel. After allowing the layers to separate, the upper layer (hexane extract) was pipetted out, pooled, and washed with distilled water until it was alkali-free. Anhydrous Na_2SO_4 was used to filter the extract in order to eliminate any remaining water. A rotary evaporator was used to extract the hexane residue under reduced pressure at 40°C.

Vitamin C content was determined following the 2, 6-dichlorophenoltitrimetric method of AOAC 967 .21 (2005). Two (2) g of the sample was homogenized with acetic acid solution and extracted. Vitamin C standard solution was prepared by dissolving 50 mg standard ascorbic acid tablet in a 100 ml volumetric flask with distilled water. The sample solution was filtered and 10 ml of the filtrate was added into a conical flask in which 2.5 ml acetone had been added. This was titrated with indophenol dye solution (2, 6 - dichlorophenol indophenol) for 15 s. The procedure was also followed for the standard.

Statistical analysis

Data obtained were analyzed using SPSS version 20.00. Significant ($p<0.05$) differences between the means were determined by the analysis of variance (ANOVA) and means were separated using Duncan's new multiple range test.

Results and discussion

Sensory parameters of formulated cookies

Sensory quality is recognized as an important factor considered by the consumer in food acceptance. The appearance (colour) scores of the formulated cookies ranged between 6.00 and 7.40 with the highest score observed in run 12 (Table 1). It was observed that the appearance of cookies improved with the inclusion of orange fleshed sweet potato flour (OFSPF). The highest taste score (7.90) of cookies was recorded for runs 12 and 16. Taste is a factor that has the highest impact on the market success of a product. The aroma scores of cookie samples ranged from 6.00 to 6.70 with the highest score found in run 16.

The texture scores (5.70 to 6.90) of cookie samples were increased as the supplementation level of OFSPF increased. The texture is an essential attribute that determines product quality. Saeed *et al.* (2012) reported a positive correlation between the texture and fibre content of cookies as a result of an increase in sweet potato flour. The crispiness scores of the cookies ranged between 5.90 (run 5) and 7.50 (run 16). The scores obtained for the aftertaste ranged from 5.80-6.60 with the highest scores observed in runs 9 and 13. The scores for the general acceptability of the formulated cookies ranged between 6.10 (run 14) and 7.00 (runs 9 and 15).

Selected formulated cookies

The three flour blend cookies selected based on the general acceptability were run 9 (85.00% millet flour, 5.00% mung bean flour and 10.00% OFSPF), run 15 (78.03% millet flour, 9.90% mung bean flour and 12.07% OFSPF) and run 16 (75% millet flour, 5.00% mung bean flour and 20% OFSPF). The selected samples were compared with WFC (100% wheat flour cookies) for further analyses.

Table 1. Sensory scores of the millet, mungbean and orange fleshed sweet potato flour blends cookies.

	Cookies flour blends			Sensorial attributes						
Run	**A (%)**	**B (%)**	**C (%)**	**Appe-arance**	**Taste**	**Aroma**	**Texture**	**Crispi -ness**	**After taste**	**General accept.**
1	65.00	30.00	5.00	6.70	6.70	6.40	5.70	6.00	6.30	6.60
2	75.31	19.57	5.12	6.50	6.30	6.60	6.70	6.30	6.30	6.70
3	65.00	20.79	14.21	6.00	7.20	6.00	6.40	6.20	6.10	6.50
4	80.96	14.04	5.00	6.70	6.70	6.10	6.60	6.50	6.30	6.90
5	71.51	16.54	11.95	6.70	7.00	6.00	5.90	5.90	5.80	6.30
6	68.73	23.52	7.75	6.70	6.10	6.30	6.30	6.30	6.00	6.40
7	80.96	14.04	5.00	6.60	6.70	6.10	6.50	6.50	6.00	6.90
8	85.00	5.00	10.00	6.60	6.90	6.60	6.40	6.40	6.50	6.90
9	85.00	5.00	10.00	6.50	7.00	6.50	6.40	6.40	6.60	7.00
10	65.00	15.00	20.00	6.20	7.80	6.10	6.50	6.50	6.10	6.30
11	65.00	30.00	5.00	6.70	6.80	6.40	6.00	6.0	6.20	6.50
12	75.00	5.00	20.00	7.40	7.90	6.60	7.50	7.50	6.30	6.90
13	71.12	11.00	17.88	7.20	7.50	6.50	6.90	6.90	6.60	6.80
14	65.00	15.00	20.00	6.10	7.80	6.30	6.50	6.50	6.30	6.10
15	78.03	9.90	12.07	7.30	7.10	6.50	6.50	6.50	6.30	7.00
16	75.00	5.00	20.00	7.30	7.90	6.70	7.50	7.50	6.40	6.80

A = Millet flour, B = Mungbean flour, C = Orange fleshed sweet potato flour

Functional properties of the flour blends used for selected cookies and control

The usage of flour as a food ingredient is determined by its functional quality. The processing application, food quality, and eventually acceptance and use in food formulations are all influenced by functional characteristics, either directly or indirectly. The functional properties of flour samples are presented in Table 2. The bulk density ranged from 0.90-0.96 g/ml with control (WF) having the highest value while the selected flour blends were not significantly ($p>0.05$) different. The values obtained in the present study are higher compared to the values (0.73-0.77 g/ml) reported by Adeola *et al*. (2019) for blends produced from OFSPF and pigeon pea flour. The gelatinization temperature ranged between 70.38°C and 74.00°C for run 16 and WF, respectively. It was observed that selected flour blends were gelled at lower temperatures. OFSPF supplementation significantly ($p<0.05$) increased the swelling capacity of flour blends ranging between 15.00 g/ml (WF) and 22.00 g/ml (run 16). This observation confirms the work of Julianti *et al*. (2015) who reported a similar trend for flour blends produced from sweet potato, maize starch and soybean. Tuber starches have been reported to have a greater swelling capacity than cereal starches (Akpapunam and Darbe, 1994).

Water absorption capacity (WAC) ranged from 240% to 380% with run 15 having the highest value while the lowest value was recorded for WF. There is a positive correlation between WAC and the carbohydrate content of foods. The high WAC of the flour blends could be a result of the OFSPF as it contains higher (752%) WAC as reported by Chandra and Samsher (2013). This suggests that the flour could be used for bakery products. Oil absorption capacity ranged from 100-160%. The oil acts as flavour retainer and also increases the mouthfeel and overall palatability of food. The findings from this study imply that the flours are good flavour retainers.

Table 2. Functional properties of the selected flour blends and wheat flour.

Run	Bulk density (g/ml)	Gelatinization Temp. (°C)	Swelling capacity (g/ml)	Water absorption capacity (%)	Oil absorption capacity (%)	Wettability (sec)
9	0.92^{b}±0.01	72.67^{b}±0.47	20.00^{a}±1.00	280^{c}±5.03	100^{d}±7.64	26.00^{b}±2.00
15	0.90^{b}±0.01	70.38^{c}±0.32	19.00^{a}±1.00	380^{a}±5.10	140^{b}±4.00	28.00^{b}±2.00
16	0.91^{b}±0.01	71.67^{bc}±0.58	22.00^{a}±2.00	360^{b}±6.00	120^{c}±2.50	35.00^{a}±3.00
WFC	0.96^{a}±0.02	74.00^{a}±0.50	15.00^{b}±1.00	240^{d}±5.00	160^{a}±3.00	30.00^{ab}±1.00

Means with different superscripts on the same column are significantly different ($p<0.05$). Run 9= 85.00% millet flour, 5.00% mungbean flour and 10.00% OFSP flour, run 15= 78.03% millet flour, 9.90% mungbean flour and 12.07% OFSP flour, run 16= 75% millet flour, 5.00% mungbean WFC= 100% wheat flour (control)

Nutrient composition of selected cookie samples and control

Macro and micronutrient compositions of selected cookies and whole wheat flour cookies are presented in Table 3. The moisture content (5.34-5.57%) of cookie samples was not significantly ($p>0.05$) different. The finding is higher than the value (2.18%) reported for foxtail millet, amaranth and copra meal flour blends biscuits (Singh and Kumar, 2019). The low moisture content obtained would not encourage microbial spoilage but enhance the keeping qualities of cookies. Ash signifies the presence of mineral content in foods. The high ash content (2.98-6.98%) obtained in the present study signifies that selected cookies are rich in desirable minerals when compared with WFC (1.50%). The finding agrees with Xu *et al*. (2020) who claimed that potatoes are an excellent source of minerals. Mohammad *et al.* (2016) reported the range ash values of 1.17-4.33% for OFSPF which confirms its highest contribution as a source of mineral to the formulated cookies.

The crude fibre content (2.12-5.21%) of selected cookie samples significantly ($p<0.05$) increased as the supplementation of OFSPF in the samples increased. These values were significantly higher than WFC (1.14%). The presence of high fibre in food products is essential as it improves the human digestive system. Fibre contributes to the stability of bakery products during processing. The crude fibre of Run 16 was higher than the values (4.65%) reported by Bashir *et al*. (2020) for cookies produced from pearl millet, flaxseed and psyllium husk flour blends. The highest (9.10%) crude protein content was observed in run 15, while the lowest value (8.23%) was found in run 9. The noticeable increase in crude protein content of the cookie sample (run 15) as a result of an increase in levels of mung bean flour could be attributed to the high protein content of mung bean flour. The values obtained in this study were lower than the value (15.20%) reported by Inyang *et al*. (2018) for cookies from 75% whole wheat flour supplemented with 25% kidney beans flour.

Table 3. Nutrient composition of selected millet, mungbean and orange fleshed sweet potato flour blends cookies and control.

	Run 9	Run 15	Run 16	WFC
Moisture (%)	5.50^{b}±0.02	5.38^{c}±0.03	5.34^{c}±0.01	5.57^{a}±0.03
Ash (%)	4.54^{b}±0.01	2.98^{d}±0.02	6.98^{a}±0.03	4.50^{c}±0.02
Crude fibre (%)	3.28^{b}±0.00	2.12^{d}±0.02	5.21^{a}±0.03	3.14^{c}±0.01
Crude protein (%)	8.23^{b}±0.02	9.10^{a}±0.35	8.24^{b}±0.18	8.93^{a}±0.18
Crude lipid (%)	24.92^{c}±0.04	27.70^{a}±0.06	23.95^{d}±0.05	25.58^{b}±0.03
Carbohydrate (%)	53.53^{a}±0.05	52.72^{b}±0.07	50.28^{d}±0.10	52.28^{c}±0.03
Caloric value (kcal)	483.32^{c}±0.61	508.58^{a}±0.53	461.63^{d}±0.54	487.06^{b}±0.32
β-carotene	14.00^{b}±0.020	4.80^{c}±0.010	16.25^{a}±0.010	1.48^{d}±0.001
¶Vitamin A	1.17^{b}±0.002	0.40^{c}±0.001	1.35^{a}±0.040	0.12^{d}±0.000
Vitamin C	6.24^{a}±0.010	6.22^{a}±0.040	5.36^{b}±0.041	ND

Values are means ± SD of three replicates determinations. Means with different superscripts along the row are significantly different (p <0.05). Run 9= 85.00% millet flour, 5.00% mungbean flour and 10.00% OFSP flour, run 15= 78.03% millet flour, 9.90% mungbean flour and 12.07% OFSP flour, run 16= 75% millet flour, 5.00% mungbean, WFC= 100% wheat flour (control), ND= Not detected. ¶Vitamin A was calculated at the ratio of 12:1 from beta-carotene. The retinol activity equivalent (RAE) is based on the assumption that 12 µg beta-carotene will be converted to 1 µg retinol

The significant increase in the lipid content (23.95-27.70%) of cookie samples connotes a higher caloric value. Lipids give support to the bubbles formed during baking before starch gelatinization, stabilizing the structure and sensory appeal of bakery products (Nieto- Mazzocco *et al.*, 2019). The observed high lipid contents may be due to margarine used in the cookie production since all the flour samples (pearl millet, mung bean and orange fleshed sweet potato) have been reported to contain low-fat content of 2.25% (Adebiyi et al., 2017), 1.31% (Ratnawati et al., 2019) and 0.37% (Kolawole et al., 2020), respectively. Carbohydrate content ranged between 50.28% for run 16 and 57.28% for WFC. A reduction in carbohydrate content of the selected cookies was observed as the proportion of mung bean flour supplementation increased. The values obtained were lower than the findings of Offia-Olua and Akubuo (2019) for sprouted mung bean and malted sorghum flour blend cookies. The caloric value ranged significantly from 449.63-496.58 kcal with run 15 having the highest value. The caloric value in the present study was higher than cookies produced from whole wheat flour, acha and kidney bean flours (Inyang *et al*., 2018).

The highest β-carotene content (16.25 µg/g) was found in run 16 and was significantly ($p<0.05$) higher than WFC (1.48 µg/g). The higher β-carotene content obtained in run 16 could be due to the 20% OFSPF supplementation (Kolawole *et al*., 2020). β-carotene is considered a provitamin A carotenoid. It increased as the quantity of OFSPF increased in cookie samples. β-carotene plays a major role in protecting the human body against infections by building a strong immune system. The results corroborate with the increasing trend reported by Arienkoko *et al*. (2019) for wheat, yellow maize and beniseed flours cookies where calculated vitamin A and β-carotene content increased with an increase in yellow maize supplementation. Vitamin A content significantly ranged between 0.12 µg/g and 1.35 µg/g for WFC and run 16, respectively. It followed a similar trend with β-carotene content.

Vitamin C content of cookie samples ranged significantly from 5.36-6.24 µg/g. No significant ($p>0.05$) difference was observed in runs 9 and 15 having 6.24 µg/g and 6.22 µg/g, respectively. The vitamin C content agrees with the value (6.50 µg/g) reported for cookies by Fateema *et al*. (2019) at a 40% inclusion level of sweet potato with 60% wheat flour. Low vitamin C content observed in the present study could be a result of heat during the baking of cookies while no value was detected in WFC.

Antioxidant properties of selected cookie samples and control

Natural antioxidants according to Nanditha and Prabhasankar (2009) are effective in enhancing the shelf life of bakery products without affecting the sensory or nutritional qualities. Phenolic compounds are the vital phytochemicals drivers of health (Rani and Singh, 2018). The total phenolic content (TPC) was the highest (0.52 mg GAE/100g) in run 16, while the lowest (0.21 mg GAE/100g) was detected in WFC (Table 4). Supplementation with mung bean and OFSPF enhanced TPC. Runs 9 and 15 were not significantly ($p>0.05$) different. The present results are higher than the range values of 1.20 mg GAE/g to 3.42 mg GAE/g as reported for pearl millet-tigernut biscuits (Omoba *et al*., 2015).

Table 4. Antioxidant properties of selected cookie samples and control.

	Run 9 (85*A*:5*B*:*10C*)	**Run 15 (78.03*A*:9.9*B*:12.07*C*)**	**Run 16 (75*A*:5*B*:20*C*)**	**WFC**
Total Phenolic (mg GAE/100g)	$0.22^{b}\pm0.010$	$0.21^{b}\pm0.010$	$0.52^{a}\pm0.010$	$0.05^{c}\pm0.010$
DPPH (%)	$5.72^{b}\pm0.290$	$6.03^{a}\pm0.130$	$5.47^{b}\pm0.211$	$5.57^{b}\pm0.015$
Total Flavonoid (mg QE/100g)	$0.004^{a}\pm0.000$	$0.004^{a}\pm0.000$	$0.004^{a}\pm0.001$	$0.003^{b}\pm0.000$

Values are means ± SD of three replicates determinations. Means with different superscripts on the same row are significantly ($p<0.05$) different. *A* pearl millet flour, *B* mung bean flour, *C* OFSPF, *WFC* 100% wheat flour cookies

DPPH contents of cookie samples were not significantly ($p>0.05$) different except for run 15 which was higher (6.03%) than the other cookie samples. All cookie samples revealed strong antioxidant activity with a value greater than 0.50% (Gull *et al*., 2016). The total flavonoid content ranged from 0.003-0.004 mg/100g. No significant ($p>0.05$) difference was observed in runs 9, 15 and 16 but their values were higher than WFC. TPC and DPPH radical scavenging activity were lower than those reported by Lee and Kang (2018) where they increased with increased inclusion of oats in sugar-snap cookies. The low TPC and TFC in cookie samples could be a result of the baking process as previous studies have reported that heat processing reduced the antioxidant properties of baked products (Venkatachalam and Nagarajan, 2017; Sharma and Gujral, 2014).

Conclusions

The findings in the present study showed the possible use of response surface methodology in optimizing the flour blends of millet, mung bean and orange fleshed sweet potato for cookie production. It was observed that run 15 (cookies from 78.03% millet flour, 9.90% mung bean flour and 12.07% OFSPF) had the highest values of crude protein, lipid, caloric value and DPPH while the highest values of ash, crude fibre, β-carotene and total phenol content were observed in run 16 (cookies from 75% millet flour, 5.00% mung bean flour and 20% OFSPF). These blends are favourably compared with 100% wheat flour cookies. The outcome of the present research could be used as valuable information for the development of high protein and β-carotene products that would help to reduce the problems of malnutrition.

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