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Effect of Blend Level on Composite Flour Made From Wheat and Orange-Fleshed Sweetpotato and Bread Quality

Olatunde, S.J.*, Akinwande, B. A. and Ade-Omowaye, B.I.O.

Department of Food Science, Ladoke Akintola University of Technology, P. M. B. 4000, Ogbomoso, Oyo state, Nigeria

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ABSTRACT

Simple Lattice Design (SLD) was used to study the effect of level of inclusion of Orange Fleshed Sweetpotato (OFSP) on some physical parameters of bread made from wheat-OFSP composite flour, while the one hundred percent wheat flour bread (sample A) served as control. The chemical composition and physico-chemical analyses of the various flour blends used for the preparation of the breads were determined using standard methods. The bread loaves were evaluated for their nutritional composition and sensory attributes. The physico-chemical analyses results obtained showed an increase in the range of 0.72 g/cm^3 for BD, 0.97 g/g for WAC, 465.67 cP for trough, 1329.33 cP, 863.67 cP and decrease of 416.67 cP in setback values, respectively. The chemical analyses results obtained showed an increase in the range of 32.72% for moisture, 15.63% for protein, 0.30% for crude fibre, 1.25% for ash, 72.73 g/100g for starch 0.95 mg/100g for Beta carotene, respectively. There was also a decrease in Crumb Hydration Capacity (CHC) and bread volume by 47.51 and 38.03%, respectively, with inclusion of the OFSP flour. It was concluded that a substitution of 79.75g of wheat flour and 20.25 g of flour gave the optimal mixture for the productions of enriched the bread.

1. Introduction

Bread is one of the most commonly consumed staple foods (Emeje, 2010) by all ages irrespective of per capita income. The consumption of bread produced from wheat flour had become very popular in Nigeria and most developing nations of the tropics (Sanful and Darko, 2010). The flour for the bakery products is usually from wheat, however, wheat does not thrive well under Nigerian climate. This has led to a steady rise in wheat importation and consequently, huge foreign exchange expenditure for importation. Nigeria is spending nearly N1.8 billion daily for wheat importation (Ohimain, 2014). Over the years, efforts have been geared towards promoting the use of composite bakery products in which wheat flour is partially replaced with locally grown crops (Oluwalana, 2012). The use of root crops such as orange-fleshed sweetpotato (OFSP) for producing bakery products has not been widely exploited in Nigeria.

Orange-Fleshed Sweetpotato (OFSP) (*Ipomoea batatas* Lam) is an improved sweetpotato cultivar with enhanced micronutrient status through plant breeding (Bouis, 2002). It is an emerging, naturally bio-fortified crop, rich in β-carotene (pro vitamin A) range of 30-100 ppm in contrast to 2 ppm found in most local varieties (Meenakshi *et al.*, 2010). Bonsi et al (2014) reported that sweetpotato is a good composite to wheat flour if pureed for bread production. Research had also shown that OFSP can serve as a partial substitute (20-50%) for wheat flour in bakery products (Trejo-González et al., 2014). Improving the nutritional base of a convenience food such as bread with highly nutritious root and tuber like OFSP will be a step in the right direction. However, in a bid to enrich the nutrient base of the bread with flour from other plant sources, physical and chemical qualities must not be compromised. In preserving such qualities of bread, level of OFSP inclusion need to be optimized

Optimization is an effective statistical tool for the effective operation of experimental processes to obtain highest yield of desirable products. Zubair *et al.* (2013) had used Response Surface Methodology (RSM) in the optimization of bread by varying the amount of bran, the amount of yeast and the fermentation time on the amount of phytic acid in bread. Mohammed and Sharif (2011) had also optimized composite flour for the production of enhanced storability of leavened flat bread using RSM. The optimization of parameters can be achieved by various techniques; one of the effective techniques for this purpose is Simplex lattice Design (SLD). This present study aims at optimizing wheat/OFSP mixture in the production of composite bread and its effect on physical and chemical properties of the bread. This would ultimately help the industry to gain economic advantage with increased production of high quality OFSP enriched bread.

2. Materials and Methods

2.1. Source of Raw Materials

OFSP tubers, Mother's Delight (MD) variety, were harvested from an experimental farm in Offa, Kwara State, Nigeria. The yeast and wheat flour were bought from a standard market in Ogbomoso, Oyo State. All the reagents used in the analysis were of analytical grade. Other ingredients such as margarine, salt, sugar and yeast were of food grade and purchased from a standard market near the campus of

Tele:
E-mail address: sjolatunde@lautech.edu.ng

Ladoke Akintola University of Technology, Ogbomoso, Oyo State, Nigeria.

2.2 Flour Formulation

OFSP flour was produced using the method of Bibiana et al. (2014). OFSP tubers were sorted, washed, peeled and sliced. The sliced OFSP was spread out on trays and dried at 60 ºC for 24 hours. The dried sliced OFSP was milled using a hammer mill (9FC-360A JinJuhong machinery, China), sieved through a 500 μm mesh and stored in air tight containers at room temperature prior to use. Composite flour samples were produced from OFSP and wheat flours at different rations as presented in Table 1. Simplex Lattice Design under Mixture Methodology of Design Expert software (6.0.8) was employed. The mixture was thoroughly mixed by electric mixer (QBL – 15L40, Qlink, Shang-Hai, China). The flour blend was kept in HDPE polyethylene pouches for further use.

2.3 Production of Bread

Breads were prepared using the method previously described Awoyale et al., (2018) with slight modification. Briefly, Each composite flours (100 g) was put in a bowl followed by the addition of 2 g of salt and 0.5 g of ground nutmeg respectively. 25 g of sugar, 10 g of powdered milk, 1g of baking powder, were manually mixed with 25 g of margarine to form a batter (Table 1). The batter was then mixed with flours and 20 ml of water was added to the mixture, which was thoroughly kneaded to make fairly stiff dough. The dough was rolled tightly to 1cm thickness on a board and cut into uniform cubes and were fried in deep hot vegetable oil at 180ºC for 8 min until golden brown was observed.

2.4 Analyses

2.4.1 Proximate analysis of the composite flour

The determination of the chemical composition of the samples for moisture, ash, protein, fat, and fiber contents were determined by methods described by AOAC (2010). Carbohydrate content was determined by difference using the Atwater factors.

2.4.2 Functional properties of the composite flour

The bulk density, water and oil absorption capacities, foaming capacity and of the flour samples were evaluated according to the method of Onwuka (2018). Phytochemical analysis The AlCl3 method of Harborne (1993) was used for the determination of the total flavonoid content. The tannin content was determined using the Follin-Dennis spectrophotometric method as described by Pearson (1976). The spectrophotometric and titration methods described by Onwuka (2005) were used to determine the phytate, oxalate and hydrogen.

2.4.3 Physical properties of the Loaves

The physical properties of the cookies including Volume, thickness, weight and specific volume of loaves were determined. Loaf volume was measured by small seeds displacement method described by Khalil *et al.* (2000). Loaf was placed in a container of known volume into which rapeseeds was run until the container was full. The volume of seeds displaced by the loaf was considered as the loaf volumes which were measured in a graduated cylinder. The weight of the loaf was determined using a sensitive weighing balance and the specific volume of the loaf was determined by averaging the loaf volume with loaf weight.

2.5. Statistical Analysis of the Data

Data were analysed using Simplex-Lattice Design (SLD), Design-expert software Version 6.0.8 (StatEase Inc., Minneapolis, USA). Statistical parameters used to relate input variables to response are p-value, R^2 and lack of fit of the models. All models presented were significant at $p < 0.001$. The suitability of the fit was evaluated using analysis of variance (ANOVA).

Table 1. Experimental Design Matrix for Bread Production by SLD

Run	Wheat (X_1)	OFSP (X_2)
1	70.00	30.00
2	77.50	22.50
3	70.00	30.00
4	85.00	15.00
5	100.00	0.00
6	100.00	0.00
7	85.00	15.00
8	92.50	7.50

3. Results and Discussion

3.1. Functional Properties of the Composite Flour

Some selected properties of the composite flours are presented in Table 2. The bulk density of the flour mixture ranged from 0.72 to 0.80 g/cm^3. The flour mixture without substitution (Run 1 and 2) has the highest bulk density of 0.80 g/cm^3. The bulk density of the composite decreased as the percentage composition of OFSP increased from 7.5 to 30%, respectively. This indicates that the inclusion of OFSP affects the properties of wheat and may suggest an advantage in industry where weight is of concern. The values were higher than the value of 0.683 g/ cm^3 reported by Olapade and Ogunade (2014) for cream-fleshed sweetpotato. The high bulk density of the composite flours could be attributed to high enzyme activity of sweetpotato. Water Absorption Capacity (WAC) revealed the maximum values as 0.97 g/g in experimental Runs 7 and 8 of the MD flour while minimum value of 0.73 g/g was reported in Runs 3, 4, 5. The value is lower than the range of value (1.54 – 1.60 g/g) reported for flours from cultivars of cocoyam (Iwe and Egwueke, 2010). The differences in the WAC may be explained by their respective contents of hydrophilic constituents such as carbohydrate (Mbaeyi, 2005). WAC is important for certain product characteristics such as moistness of the product, starchy retrogradation and subsequent product staling (Siddiq *et al.*, 2010).

The highest setback values of 629 and 648 cP were obtained in experimental Runs 1 and 2, while least value of 404 cP was obtained in Run 7. Similar value (405.7 cP) was reported for *Brachystegia eurycoma* flour (Ikegwu *et al.*, 2010). Low setback value is an indication of high stability after cooking (Etudiaye *et al.*, 2009). Value obtained for trough was 466 cP (highest) at Run 6, and 365.33 cP at Run 3 as the least value, for OFSP flour. The result is higher than 202.3 RVU reported for fermented cassava flour by Osungabro *et al.* (2010). Trough is an index of starch granule stability to heating (Sanni *et al.*, 2008). The Peak Viscosity (PV) from MD flour has the maximum value at Runs 7 and 8 as 1329.33 cP and minimum value as 1142 cP at Run 2. The PV of fermented cassava flour has been found to be 226.5 RVU (Osungabro *et al.*, 2010). The high PV indicates that associative forces within the starch granules might have been weakened allowing easy granule swelling (Tsakama *et al.*, 2010). The maximum breakdown viscosity value obtained was 863.67 (MD) at Run 7, while the minimum value was 759.33 CP at Run 1. The breakdown viscosity of starch from a variety of cassava was 107.75 RVU. Hoover (2001) had earlier reported that sweetpotato flour normally has high viscosities because their starch molecules have long chain of starch granules. Adebowale *et al.* (2005) indicated that the higher the breakdown in viscosity, the lower the ability of the sample to withstand heating and shear stress during cooking. The highest value for MC was 9.5% at Runs 4 and 5. The lowest value of 8.56% was obtained at Run 7 for MD flour. This was similar to the value (6.68-8.51%) reported for blends of flour from germinated pigeon pea, fermented sorghum and fermented cocoyam flours by Okpala *et al.* (2013).The lower the MC, the longer the shelf life and the denser the nutrient composition (Kikafunda *et al.,* 2006; Muyanja *et al.,* 2012). The MC of the flour was generally low, and such it was unlikely to cause any adverse effect (Okpala, *et al.*, 2013).

The maximum ash content of 1.25% of the flour mixture was recorded at Runs 7. However, the minimum value which was recorded at Runs 1 was 0.74% for MD flours. Antarlina (1994) reported 2.13% for the ash content of sweetpotato flours. Lower ash value observed from flour used in this study may be due to varietal differences (van Hal., 2000). Ash is inorganic residue after combustion at high temperature-long time (Idowu *et al.*, 2013). The highest protein content was 15.63% recorded at Runs 1 and 2 for MD, while the lowest values (14.68% and 15.32%) were recorded at Run 6. This was in agreement with value obtained for wheat flour (15.1%) as reported by Ade-Omowaye *et al*. (2008). The maximum crude fibre (for MD flour) which was 0.3% was observed at Runs 7 and 8, while 0.03% which was the minimum was observed at Runs 1 and 2. Okorie and Onyeneke (2012) had earlier reported 0.65% for sweetpotato flour. Flour with high fiber content should not be used as composite flour diluents (Bijtrebier, 1982). The low fiber content of OFSP flour therefore makes it good diluents in composite flour technology.

Furthermore, the maximum value (0.95 mg/100g) for beta-carotene content was obtained at Runs 7, 8 and the least value (0.38 mg/100g) was obtained at Runs 1 and 2. Burgos *et al.* (2001) indicated that beta carotene content ranged from 4.29 to 18.55 mg/ 100g in deep orange coloured sweetpotato. β-carotene content varied in the intensity of colouration of the sweetpotatoes. The loss of beta carotene may be caused by the exposure of samples to oxygen during different unit operations such as peeling, cutting and drying. This is because β-carotene is sensitive to heat and oxygen. The maximum value of 72.76 g/100g for starch content were recorded at Run 3 with the minimum value of 72.13 g/100g at Run 1. The starch content of the flour fall within the range of values (57–85%) reported by van Hal (2000) for starch potato flour. Starch is reported to be the predominant fraction of the dry matter of sweetpotato tubers (Olatunde *et al.*, 2016). Starch, which consists of two major molecular components (amylose and amylopectin) is the major component of bread (Zhu, 2007).

3.2. Physical Attributes of Loaves from Composite Flour

The result of physical attributes of control and optimized bread were shown in Table 4. The values for crumb hydration capacity (CHC) were 46.17 and 51.00 ml for optimized and control bread, respectively, with no significant difference ($p > 0.05$). Olanipekun (2013) also observed decrease in CHC value in the composite bread produced from fermented bambara-wheat flour. The volume values reported for optimized and control bread were 405 and 660 cm^3 with significant difference ($p < 0.05$). CHC serves as a measure of the extent of starch gelatinization in bread. The lower the CHC, the lower will be gelatinization rate. The higher value recorded for the control sample could be linked to higher quantity of gluten, which could have improved the extensibility and softness of dough. Increase in gluten content has been reported to aid retention of CO_2 that was produced during fermentation, with consequent increase in the loaf volume (Clarke *et al.,* 2002).

Decrease in loaf volume of the optimized bread could also be as result of decrease in structure forming proteins in wheat. This has the tendency of lowering the ability of the dough to rise during proofing with subsequent reduction in the bread volume (Sharma and Chauhan, 2000). This agreed with the observation of Malomo et al. (2011) where a similar decrease in volume was observed for bread produced from composite flour of wheat, breadfruit and breadnut. The loaf weight was between 226 and 211 g for optimized and control bread, respectively, as reflected in Table 4. Higher value of loaf weight, with significant difference ($p < 0.05$), was obtained in optimized sample compared with that made from 100% wheat flour. This could be as a result of large quantity of water absorbed by OFSP fibre (Escudero-Alverez *et al*.,2006), thus reducing the content of free water that can evaporate during the baking process.

The loaf weight reduction during baking was an undesirable quality attribute as consumers were often attracted to bread with high weight and volume believing that it has more substance for the same price. The loaf strength value for optimized and control samples was 81.17 and 73.67 mm respectively, with significant difference ($p < 0.05$). This could be attributed to the decreasing amount of gluten due to the decreased levels of wheat flour in the mixtures. Gluten was known to impact mellowness and elasticity to bread loaves (AOAC, 2005).

The specific volume of the optimized bread sample decreased generally in comparison with 100% wheat flour. The higher value of 2.98 cm^3/g was recorded for the control sample, while 1.79 cm^3/g was recorded for optimized sample with significant difference ($p < 0.05$). Nwosu *et al.* (2014) had earlier reported similar decrease in value (3.94 – 2.35 cm^3/g). This was mainly due to dilution of the gluten by this flour and/or interference with the protein network by its components (Bakkalbas *et al.*, 2008). The decrease in the specific volume of optimized bread samples in this study may be explained by the dilution of gluten responsible for gas retention during baking (Shittu *et al*., 2007). The specific volume, which was the ratio of weight and volume, has been generally adopted in the literature as a more reliable measure of loaf size.

3.3. Proximate Composition and Energy Content of the Bread

The moisture content of optimized bread was 28.68% while that of control sample was 32.72% (Table 5). Similar trend was observed by Ade-Omowaye *et al*. (2008) in the production of bread from tiger nut-wheat flour. Decrease in moisture content value of the optimized sample might not be unconnected with the low level of protein content (Ade-Omowaye *et al.,* 2008). Researchers have shown the lower moisture contents improve the better shelf life of a product (Muyanja *et al.,* 2012). Decrease in moisture content of optimized sample may lead to increase in shelf life of the bread (Igbabul *et al.,* 2014).

The ash content ranged from 0.99 to 1.11% for control and optimized samples, respectively, with no significant difference ($p>0.05$).is in line with the range of value (0.45 – 1.60%) reported by Ade-Omowaye *et al.* (2008) for tigernut - wheat composite bread. This observation might rather be attributed to the flour blends (Kalekristos, 2010).

Ash which is an important food constituent was inorganic residue after combustion at high temperature and prolonged time (Idowu *et al.,* 2013). Protein value for the control and optimized samples was 16.49 and 16.68% respectively, with no significant different ($p > 0.05$). This is found to be higher range of value (7.65 – 12.12%) as reported by Igbabu *et al.* (2014) for composite bread for wheat, maize and OFSP flour. The slight increase in the protein content of the optimized samples could be traced to the combined effect of blending and baking at prolonged time which could result to protein concentration (Oluwole *et al.*, 2014).

The fat content value for the control and optimized bread was 17.33% and 3.59% with significant difference ($p < 0.05$). The low fat content value in the optimized sample could be due to presence of hydrophilic group from the OFSP flour incorporated. Igbabul *et al.* (2013) also reported hydrophilic nature of flour from cassava. Baljeet (2010) reported that higher oil retention improves the mouth feel and retains the flavor. The fibre content for the control and optimized samples was 0.02 and 0.01%, respectively, with no significant difference. The value is low when compared with the value reported (0.77 – 0.95%) by Igbabul *et al.* (2014) for composite bread. However, Kidane *et al*. (2013) had earlier reported increased fibre content due to increased addition of OFSP flour in other baked products. The low fibre contents in the optimized sample maybe due to the high wheat flour that was contained in the blend. Wheat flour has low fibre content compared to OFSP flour (Srivastava *et al.*, 2012).

The values reported for carbohydrate were 49.2 and 32.34%, with no significant difference ($p > 0.05$), for control and optimized samples respectively. This was similar to the report of Amadinkwa *et al.* (2015) who observed decrease in carbohydrate content of wheat-yam composite bread. Lower carbohydrate levels in an optimized sample might not be unconnected to OFSP maturity at harvest, and varietal differences (Amadinkwa *et al.,* 2015). The energy content of both control and optimized samples were 374 and 396 Kcal/100g, respectively. This was expected as OFSP has been reported to be high in carbohydrate. It implies that the bread would also be a source of high energy and nutrients dense food for consumers (Schneeman, 2002). World Health Organization (WHO) recommended 1790 Kcal to 2500 Kcal/day of energy for children aged between 5 and 19 years (USDA, 2009). Consumption of 4 g of the optimized sample will meet the daily requirement of children. This suggests that optimized bread from OFSP could be included in school feeding programmes for children.

Table 2. Functional Properties of Loaves From Composite Flour

Run	Wheat (g)	OFSP (g)	BD g/cm^3	WAC (g/g)	Setback (cP)	Trough (cP)	Peak value (cP)	Breakdown (cP)
1	100.00	0.00	0.80	0.87	629.00	382.67	1142.00	759.33
2	100.00	0.00	0.80	0.87	629.00	382.67	1142.00	759.33
3	92.50	7.50	0.79	0.73	566.67	365.33	1132.00	766.67
4	85.00	15.00	0.77	0.73	468.33	431.33	1160.33	729.00
5	85.00	15.00	0.77	0.73	468.33	431.33	1160.33	729.00
6	77.50	22.50	0.73	0.87	404.00	466.00	1212.67	746.67
7	70.00	30.00	0.72	0.97	416.00	465.67	1329.33	863.67
8	70.00	30.00	0.72	0.97	416.00	465.67	1329.33	863.67

OFSP – Orange-fleshed Sweet Potato, BD – bulk density, WAC – Water Absorption capacity

Table 3. Chemical Composition of Loaves From Composite Flour

Run	Wheat (g)	OFSP (g)	MC (%)	Ash (%)	CP (%)	CF (%)	βC (mg/100g)	Starch (g/100)
1	100.00	0.00	10.27	0.74	15.63	0.03	0.38	72.13
2	100.00	0.00	10.27	0.74	15.63	0.03	0.38	72.13
3	92.50	7.50	9.32	1.35	15.31	0.03	0.54	72.76
4	85.00	15.00	9.56	0.88	14.98	0.06	0.58	72.33
5	85.00	15.00	9.56	0.88	14.98	0.06	0.58	72.33
6	77.50	22.50	8.70	1.22	14.68	0.3	0.91	72.72
7	70.00	30.00	8.56	1.25	14.69	0.3	0.95	72.73
8	70.00	30.00	8.56	1.25	14.69	0.3	0.95	72.73

OFSP – Orange-fleshed sweetpotato, MC – Moisture Content , CP – Crude protein, CF – Crude fibre, βC – Beta carotene

Table 4. Physical Properties of Loaves From Composite Flour

Parameters	Crumb hydration capacity (ml)	Loaf volume (cm^3)	Loaf weight (g)	Loaf strength (mm)	Loaf specific volume (cm^3/g)	Density (g/cm^3)
Optimized bread	46.17±2.20	405.00±0.00	226.27±4.93	81.17±1.53	1.79±0.00	0.56±0.00
Control	51.00±2.00	660.00±5.77	211.20±2.33	73.67±7.09	2.98±1.00	0.32±0.100
T-test	*	*				*

Table 5. Proximate Composition and Energy Content of The Bread

Sample	MC (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	CHO (%)	Energy (kcal/100g)
Control	29.68± 1.00	0.99±1.00	16.49±1.00	3.59±1.00	0.02± 0.00	49.29±1.00	374.09±1.00
Optimized	32.72±1.06	1.11±0.52	16.68±1.00	17.35±1.00	0.01±0.01	32.34±0.10	396.78±1.00
T-test	*			*			

Values are mean ±SD * Significant at *p*<0.05

4. Conclusions

Simplex Lattice Design (SLD) was successfully used to optimize the wheat and OFSP composite flours in the production of wheat/OFSP composite bread. The SLD design of Mixture was found to be effective to determine the level at which the OFSP flour will be added to the wheat flour, that will not negatively affect the physical and chemical properties of the product. The optimal mixture of the flours was therefore be used in the production of enriched bread with acceptable physical chemical characteristics.

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