



Effect of Partial Substitution with Organic Sweet Potato Flour on the Quality of White Wheat Bread

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Abstract

This study investigated the quality effects of using sweet potato flour (SPF) as partial substitution of white wheat flour (WWF) in bread making with substitution levels of 10, 20, 30 and 40 per cent while the 100 per cent WWF as control. The proximate composition of various flour blends were used for the preparation of breads which was determined using standard methods. Straight-dough procedure was adopted for producing the bread loaves and subsequently evaluated for their weight, loaf volume, specific volume and sensory attributes. The sensory analysis results showed that the substitution level up to 30 per cent of SPF produced adequate bread which was comparable with the control in terms of the overall acceptability of the bread.

Key words: White wheat flour, sweet potato flour, organic sweet potato functional bread, sensory attributes, dietary fibre

Introduction

Sweet potato (*Ipomoea batatas* L.) belongs to tuber crop and stands third after potato and cassava (127 million metric tons, FAO, 2004) in terms of production and is generally recognized as an underutilized nutritious food. It is commonly consumed as fried, baked, grilled, boiled or steamed products at household level. Manufactures of sweet potato purees, flours and starches augment possibilities for its utilization (Dansby and Bovell-Benjamin, 2003). It is commonly referred to a subsistence, food security or famine relief crop; its uses have varied considerably in the developing countries (Osundahunsi, 2003)

Sweet potato is considered as a rich source of carbohydrates and has a large potential to be used as food in developing countries because of its short maturity time, ability to grow under varied climatic conditions and can be cultivated even on the less fertile soil. Sweet potato flour can serve as a source of energy because it is rich in

carbohydrates, and it also contains beta carotene, minerals (Ca, Fe, P and K) and dietary fibre which can add natural sweetness, colour and flavour to processed food products (Shih and Adebawale, 2006). It could also be used as a daily nutrition supplement because flour provides 14 per cent -28 per cent of the dietary reference intake (DRI) for magnesium and 20-39 per cent for potassium (Van Hal. M, 2000)

Traditionally cookies are made from wheat flour with small quantities of other cereal flours or starches to give special flavour or structural properties of cookies. In recent years the interest of consumers has been shifted to high fibre foods. High dietary fibre supplemented cookies were prepared by replacing wheat flour with cereal by-products like corn bran, rice bran or barley husk to satisfy the needs of the consumers (Kalpana, 2003).

Many research have been done on the development of energy rich products using sweet potato flour rather than efficient methods to produce and store the flour (Peters

D, Wheatley 1997). Hagenimana Owori (1996) reported that the addition of orange fleshed sweet potato in buns, chapattis and mandaz is contributing to the increase of total carotenoids content. Addition of various proportion of sweet potato flour in wheat flour can increase the nutritive values in terms of fibre and carotenoids and thus it can be utilized for preparing the gluten free cookies to enhance the nutritional qualities of the product. This also helps in lowering the gluten level and prevent from coeliac disorders (Aniedu and Agugo, 2010). Blending of sweet potato flour with wheat flour can be practised for the production of bakery goods with improved textural, functional and nutritional properties and with reduced retro-gradation, staling rate and production time (Pasha *et al.*, 2002) and also helps in making a good baked product with increased economic value.

The sweet potato flour can be stored for about 6 months or even more in sealed containers without contamination. This flour can be used as a substitute for wheat flour in the following amounts, that is 100 per cent in white sauces, 25-50 per cent in cookies, cakes and flat breads, and 15-20 per cent in breads. Sweet potato flour would be marketed as a low cost alternative for imported wheat flour because, production and transportation cost will be minimized, especially for snack food and noodle processors. Small flour production and trials were made using local varieties, but technical improvement is necessary to make the high yield flour with low processing cost. Production of sweet potato flour is carried out in developing countries. Many institutions have focused on product formulation using sweet potato flour rather than focusing on efficient, low-cost flour (Palomar 1992).

Sweet potato based products are high quality products and could compete with existing products in the market (Chen and Voragen, 2003). An approach of this present study was to replace the wheat flour in bakery products by coloured sweet potato flour (gluten free flours) in order to increase the fibre and the other nutrient contents. The main objective of this study is to develop bread with less gluten, good taste, texture and appearance, which resembles wheat flour based products. The textural property and sensory quality of bread are taken into consideration to improve the quality of bread.

Materials and Methods

The experimental studies were carried out in laboratories of Department of Agri-Business Management & Food

Technology, North Eastern Hill University, Tura Campus, Meghalaya.

Procurement of raw material

Superior quality of sweet potatoes and other ingredients (white wheat flour, sugar, shortening, baking powder, fat, yeast and eggs) for the preparation of bread were purchased from local market of Tura, Meghalaya.

Preparation of sweet potato flour

Sweet potato roots were washed and trimmed immediately after the purchase to make them free from soil and other foreign materials, and insect damage. These were manually peeled and cut into thin slices. Slices were then immersed in the solution containing potassium meta-bisulphite (0.5%) for 15 minutes. Sweet potato slices were dried on perforated wooden trays in a tunnel dehydrator at 60°C till it reached 10 percent moisture content. Flour mill was used to mill the dried slices to get fine flour and was passed through 80 mesh sieve to obtain flour of uniform size. Flow diagram for preparation of sweet potato flour is given in Fig. 1.

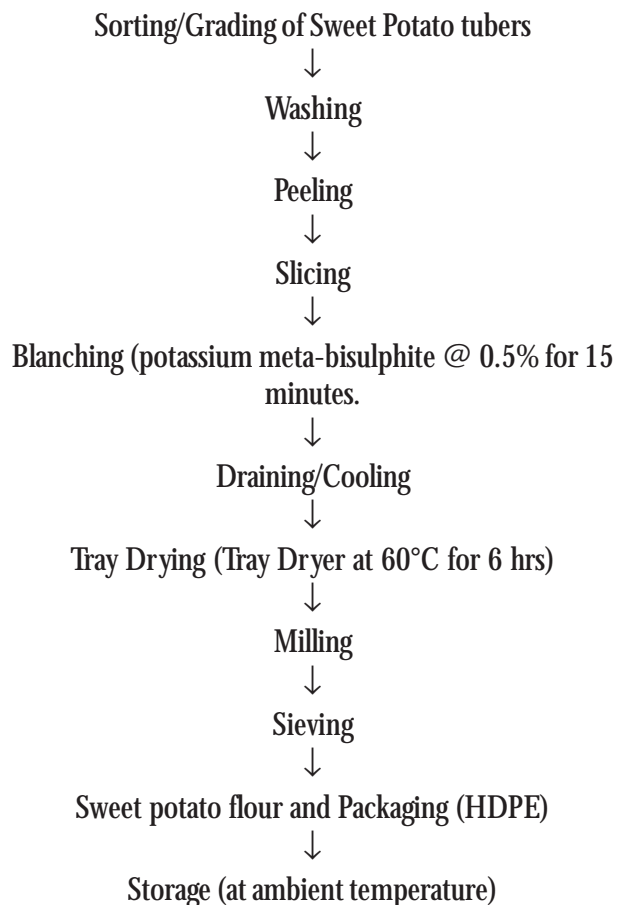


Fig. 1. Preparation of sweet potato flour

Table 1. Experimental design of sweet potato flour substitution

| Treatment | Sweet potato flour (%) | Whole wheat flour (%) |
|-----------|------------------------|-----------------------|
| T0 | 0 | 100 |
| T1 | 10 | 90 |
| T2 | 20 | 80 |
| T3 | 30 | 70 |
| T4 | 40 | 60 |

Table 2. Formulae of bread substituted with different levels of sweet potato flour

| Ingredients (g) | Weight in different treatments | | | | |
|-----------------------------|--------------------------------|-----|-----|-----|-----|
| | T0 | T1 | T2 | T3 | T4 |
| White Wheat Flour | 500 | 450 | 400 | 350 | 300 |
| Coloured Sweet Potato Flour | 0 | 50 | 100 | 150 | 200 |
| Yeast (Dry) | 20 | 20 | 20 | 20 | 20 |
| Fat | 30 | 30 | 30 | 30 | 30 |
| Sugar | 30 | 30 | 30 | 30 | 30 |
| Baking Powder | 3 | 3 | 3 | 3 | 3 |
| Salt | 2 | 2 | 2 | 2 | 2 |
| Eggs (No.) | 2 | 2 | 2 | 2 | 2 |
| Water (ml) | 250 | 250 | 250 | 250 | 250 |

Proximate analysis

Moisture, ash, protein, fat, and crude fibre contents of the flour samples were determined by standard methods as described in AOAC (1999). Available carbohydrate was determined by difference (Onwuka, 2005).

Processing of bread

Dough was prepared using the one-stage method using a laboratory mixer (Hakka Commercial Dough Mixer-DN5) and further moved in a proofing cabinet for 30 minutes at 30°C and then the product was kept in the oven and baked at 180°C for 35 minutes.

Determination of weight, loaf volume and specific volume of bread loaf weight

After 2 hours of cooling on a cooling rack, loaf weights (W) of the bread samples were measured on digital scale.

Loaf volume of bread

Rapeseed displacement method was adopted to measure the loaf volume of bread (AACC, 2000). The loaf was put in a metallic container with known volume (V_C). The container was topped up with rapeseed, the loaf was removed and the volume of the rapeseed was noted (V_R).

Loaf volume (V_L) was then calculated according to the following formula

$$V (CC) = V_C - V_R$$

Specific volume of bread

Specific volume (V_S) of bread was measured by using the following expression:

$$V_s \left(\frac{CC}{g} \right) = V_L / W$$

(CC/g)- cm^3/g , V^L – Loaf volume, W- Loaf weight

Sensory evaluation

Ten panellists were involved to evaluate the sensory attributes such as crust colour, crumb texture, taste and overall acceptability. A 9 point hedonic scale was used to evaluate the score of the samples. Score 1 implies 'extremely dislike' and score 9 implies 'like extremely' (Ihekoronye and Ngoddy, 1985). After each evaluation panellist were instructed to drink water or rinse their mouths to clear the palate. Sensory evaluation was done on the same day of the bread preparation.

Statistical analysis

Values were obtained as means \pm standard deviation of three determinations. Data were analysed by analysis of variance (ANOVA) and Duncan's multiple-range test. Differences among samples were considered significant at $P \geq 0.05$ (Ihekoronye and Ngoddy, 1985).

Results and Discussion

Proximate composition

Results of the proximate composition of the sweet potato flour (SPF) samples are shown in Table 3. The substitution of SPF with WWF the (Table 4) proximate values increased with increasing levels of SPF substitutions except for crude protein values which showed the reverse. The high carbohydrate content of 100 per cent WWF was processed from the endosperm which contain carbohydrates.

The moisture content of the flour samples increased with SPF substitution and the values ranged from 12.23 per cent to 14.33 per cent. Banu *et al.* (2012) reported moisture contents of 12.3 per cent and 11.3 per cent for SPF and whole wheat flour respectively. Zatica and Jolana (2010) reported moisture content of 12.5 per cent for SPF and 11.6 per cent for whole meal flour. The

Table 3. Physicochemical analysis of sweet potato flour

| Sl. No | Constituents | Percentage * (%) |
|--------|------------------|------------------|
| 1 | Moisture (d.b) | 6.7± 0.2 |
| 2 | Starch | 77.7± 0.70 |
| 3 | Reducing Sugar | 5.9± 0.2 |
| 4 | Total Sugar | 11.2± 0.23 |
| 5 | Fat | 0.58± 0.03 |
| 6 | Ash | 2.74± 0.5 |
| 7 | Water Absorption | 5.72± 0.1 |
| 8 | Fibre | 1.056± 0.3 |

*Each value is average of minimum three determinations.

differences in moisture content of the flour samples could be due to the differences in storage and processing methods of the samples, since they were not from the same source. Increase in fibre content has been associated with increase in moisture content (Maneju *et al.*, 2011).

The range of values of moisture content implied that the flour blends had good storage potential, as it was known that moisture and water activity of a product determines greatly its keeping quality (Ajani *et al.*, 2012). These values were minimal and may not have adverse effect on the quality characteristics of the product. High moisture content is associated with short shelf life of a product as they encourage microbial proliferation that lead to spoilage (Ezeama, 2007).

There was also a decrease in the protein content of the flour blends with SPF substitution in the range of 12.87 per cent to 8.12 per cent. WWF contains more protein than SPF (Ziaulhaq *et al.*, 2004) as it contains the macronutrients of the wheat’s bran and germ (rich in

fibre and protein). The fat content of the flour blends increased from 1.41 to 3.25 per cent with increased level of SPF substitution in the WWF. Fat plays a significant role in the shelf life of food products and relatively high fat content could be undesirable in food products. This is because fat can promote rancidity in foods, leading to produce unpleasant and odorous compounds (Ihekoronye and Ngoddy, 1985).

The crude fibre content of the flour samples showed a percentage increase in the range of 0.61 to 2.10 per cent as the SPF was substituted with WWF. This could be attributed to the high crude fibre content of the SPF. Crude fibre most likely from the represents variable fraction of dietary fibre and includes mostly the lignin, cellulose and hemicelluloses components (Abdelghafo *et al.*, 2011). The increased fibre content of the flour blends has several health benefits as it aids in the digestion of the flour samples in the colon when they are processed into bread and reduce constipation often associated with bread produced from white wheat flour (Jideani and Onwubali, 2009). According to well documented studies, it is now accepted that dietary fibre plays a major role in the prevention of several diseases such as cardiovascular diseases, diverticulosis, constipation, cancer, irritable colon and diabetes (Slavin, 2005).

Ash content of the flour blends increased at higher SPF substitution. The same observation was made by Banu *et al.* (2012) who reported that addition of 3 to 30 per cent wheat bran stream (WBS) to the white flour increased the ash content. Ash content in flour samples with 10 per cent, 20 per cent, 30 per cent and 40 per cent SPF increased by 1.24, 1.77, 2.02 and 2.30 per cent

Table 4. Proximate composition of flour blends

| Treatment | Proximate composition * | | | | | |
|-----------|-------------------------|------------------|-------------|-------------------|-----------------|------------|
| | Moisture (%) | Carbohydrate (%) | Fat (%) | Crude protein (%) | Crude fibre (%) | Ash (%) |
| T0 | 12.23± 0.51 | 74.12± 0.054 | 1.41± 0.021 | 12.87± 0.0121 | 0.61± 0.45 | 0.93± 0.01 |
| T1 | 12.38± 0.44 | 75.66± 0.053 | 1.91± 0.024 | 11.16± 0.0211 | 0.82± 0.43 | 1.24± 0.02 |
| T2 | 13.16± 0.55 | 77.91± 0.053 | 2.11± 0.023 | 10.85± 0.0232 | 1.28± 0.40 | 1.77± 0.03 |
| T3 | 13.88± 0.48 | 78.16± 0.056 | 2.95± 0.031 | 9.94± 0.0120 | 1.82± 0.44 | 2.02± 0.03 |
| T4 | 14.33± 0.52 | 79.15± 0.051 | 3.25± 0.041 | 8.12± 0.0130 | 2.10± 0.40 | 2.30± 0.02 |

T0- 100% white wheat flour bread, control sample; T1- sample with 10% sweet potato flour; T2- sample with 20% sweet potato flour; T3- sample with 30% sweet potato flour, T4- sample with 40% sweet potato flour

* Each value is average of minimum three determinations

respectively compared to the control. The significant increase in ash may be attributed to the increased amount of minerals such as calcium and iron at higher SPF substitution levels in the flour samples. The amount of minerals in flour increases with extraction rate and can be determined by burning a sample of the flour to ashes (Scade, 1975).

Loaf volume

Loaf volume is an important indicator for identifying bread characteristics because it provides the quantitative measurement of baking performance. Bread samples at higher SPF substitution levels elucidated lower loaf volume compared to the control. A pronounced decrease of loaf volume was exhibited in bread sample with 40 per cent SPF. The significant decrease in loaf volume at higher SPF substitution levels was attributed to the gluten dilution effect which was associated with the low protein network in the dough (Rosell *et al.*, 2001) and indicated weak interaction between starch and gluten of flour. Substitution of SPF which contains dietary fibre (Pollard *et al.*, 2002) and non- gluten networks into the bread formulation caused a negative effect on carbon dioxide gas production and retention during dough proofing that exerted lower loaf volume. Gomez *et al.* (2003) reported that, the main problem of dietary fibre addition in baking is the important factor in reduction of loaf volume and the different texture of the breads obtained.

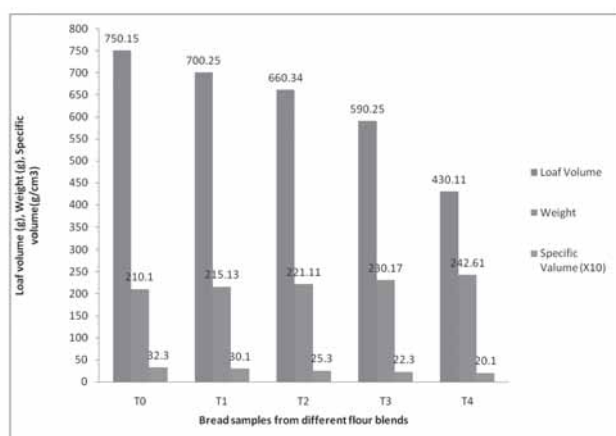


Fig. 2. Loaf volume, weight and specific volume of breads from different blends of white wheat flour and sweet potato flour

T0- 100 % white wheat flour bread, control sample; T1- sample with 10% sweet potato flour; T2- sample with 20% sweet potato flour; T3- sample with 30% sweet potato flour; T4- sample with 40% sweet potato flour

Specific volume of bread

The specific volume of the bread samples decreased significantly at higher SPF substitution. Bread with 40 per cent SPF had a substantial decrease in specific volume of 1.46g/cm³ compared to the control. A similar result was reported by Gomez *et al.* (2003) and Sullivan *et al.*, (2011) who used wheat fibres and barley. Banu *et al.*, (2012) also reported decreased specific loaf volume and slice area in wheat bran stream containing breads. The lower value of specific volume was directly proportional to the lower loaf volume of the bread samples. The occurrence of lower loaf volume and specific volume was due to the higher quantity of amylopectin which increased the water retention and decreased the gas retention (Lee *et al.*, 2001) of loaf during baking, thus resulting in reduction of loaf volume.

Weight

Weight of the bread samples gradually increased at higher substitution levels because of decrease in volume and specific volume. Bread with 40 per cent whole wheat flour had the highest weight (230.13g).

Sensory evaluation

The process by which bread quality is determined still relies heavily on subjective assessment (Cauvain, 1998b). Sensory evaluation results are shown in Table 5.

Crust colour

The crust refers to the outside layer of the bread. It should be smooth and golden brown (Sanful, 2011). The score for crust colour increased significantly ($p < 0.05$) as SPF substitution level increased. However, no significant difference was observed for the control (T0) and bread sample that had 10 per cent of SPF (T1). Bread with 40

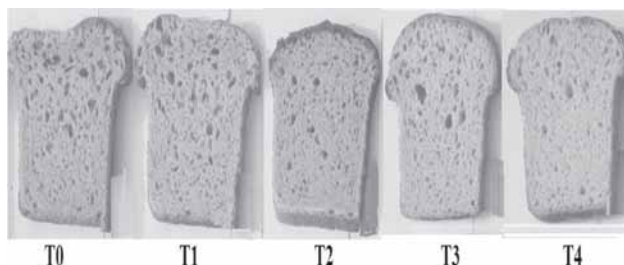


Fig. 3. Blended flour breads

T0- 100% white wheat flour bread, control sample; T1- sample with 10% sweet potato flour; T2- sample with 20% sweet potato flour; T3- sample with 30% sweet potato flour; T4- sample with 40% sweet potato flour

per cent SPF had the highest score for crust colour indicating that crust colour was not attractive at higher SPF substitution levels. The same observation was made by Sanful (2011) for taro and whole wheat flour composite bread. The effect of blending the SPF on the crust colour of bread was more pronounced when the substitution level increases from 15% to 20%. The darker colour may be attributed due to the greater amount of maillard reaction between reducing sugars and proteins. The results of this study are in line with findings of Hallen *et al.* (2004) and Sharma *et al.* (1999).

Crumb texture

Crumb texture was observed to reduce significantly with increased SPF substitution level. Texture is the quality of the bread which can be decided by touch, the degree to which it is rough or smooth, hard or soft. Hard crumb texture, caused by increased fibre from wheat bran substitution was reported by Eiman *et al.* (2008). The baking conditions (temperature and time variables), state of the bread components (such as fibres, starch, gluten etc.) and the amounts of absorbed water during dough mixing contributes to the final texture of breads (Gomez *et al.*, 2003).

The number of cells in a bread slice gives an indication of the amount of gas bubbles captured during proofing. To obtain the quality bread usually a large number of small sized cells are desirable and they observed that the incorporation of wheat bran stream into the white flour leads to a coarse structure of bread (Banu *et al.* (2012). Sullivan *et al.* (2011) explained that the low number of cells is the result of gas escaping during

proofing, suggesting a disruption of the gluten matrix in the dough. The control sample had a significantly higher score ($P \leq 0.05$) for crumb texture compared to the other samples. However, no significant difference for crumb texture ($P > 0.05$) was found between the control and bread sample with 10 per cent and 20 per cent whole wheat flour.

Taste

Taste is the sweet sensation felt in the mouth when bread was consumed. This sensation was termed as taste and this may be due to the sweetening agent. The taste characteristics of bread are vital in determining the overall acceptability of the product. The taste diminished significantly as SPF substitution level increased. The control and bread samples with 10 per cent did not differ significantly in taste.

Overall acceptability

The score for overall acceptability decreased significantly as whole wheat flour substitution level increased. The overall acceptance expresses how the consumers or panellists accept the product generally. The control received the highest score for overall acceptability followed by the 10 per cent and 20 per cent SPF breads. The bread with the highest SPF (40%) was unacceptable because it contained the lowest score for overall acceptability. Thus, bread substituted with up to 10 per cent and 20 per cent SPF were acceptable and these bread samples were comparable with the control in terms of the overall acceptability of the bread. The baking properties of SPF are often impaired as well as the organoleptic attributes of the products, because of the dilution of the gluten content (Dewettinck *et al.*, 2008; Jideani and Onwubali, 2009). Thus, different proportions of both synthetic and organic improvers such as malt flour, ascorbic acid and vital wheat gluten can be included in dough formulation to improve the baking and sensory qualities of the product (Rodriguez *et al.*, 2006).

Table 5. Sensory evaluation of blended flour bread

| Bread Treatment | Bread sensory characteristics | | | | |
|-----------------|-------------------------------|-------------------|-------------------|-------------------|-----------------------|
| | Crust colour | Crumb texture | Taste | Flavour | Overall acceptability |
| T0 | 8.67 ^a | 8.60 ^a | 8.70 ^a | 8.68 ^a | 9.00 ^a |
| T1 | 8.10 ^b | 8.00 ^b | 8.11 ^a | 8.00 ^a | 8.10 ^b |
| T2 | 7.97 ^b | 7.90 ^b | 7.89 ^b | 7.80 ^c | 7.90 ^c |
| T3 | 7.50 ^c | 7.43 ^b | 7.49 ^b | 7.40 ^c | 7.50 ^c |
| T4 | 6.90 ^e | 6.89 ^d | 6.70 ^d | 6.40 ^d | 6.80 ^d |

T0- 100% white wheat flour bread, control sample; T1- sample with 10% sweet potato flour; T2- sample with 20% sweet potato flour; T3 - sample with 30% sweet potato flour, T4 - sample with 40% sweet potato flour

*Means in the same column bearing different superscripts are significantly different ($P \leq 0.05$).

Conclusion

Substitution of WWF with SPF greatly improved the nutritional quality of bread. The bread samples would serve as functional food because of its high content of fibre. However, further research work should be focused on how to improve the organoleptic qualities and hence acceptability of SPF enriched breads and did not studied the impact of carotenoid pigment in the bread. Public enlightenment on the nutritional benefits of the SPF supplemented functional foods would help to improve their sensory acceptability. There is also the need to adjust the mixing ingredients and baking techniques in order to improve the bread qualities. The future research work will be carried out on quality impact of carotenoid pigment in the bread and their effectivity on sensory characteristics.

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