

Nutrient composition and consumer acceptability of bread made with orange sweet potato puree

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Abstract

The Sustainable Technology for Orange and Purple Sweetpotatoes (STOPS) project, led by researchers from Tuskegee University, USA, identified gaps in the value chain from production, processing, product development to consumption of sweet potato, aimed at addressing vitamin A deficiency (VAD) and improving the health and nutritional status of vulnerable populations in rural communities in Ghana. The orange sweet potato (OSP) could be an inexpensive, year-round, rich source of β -carotene, a precursor of vitamin A. The anthocyanins that account for the purple pigmentation in the purple variety are powerful antioxidants with good bioavailability to be easily absorbed by the body. The STOPS project promotes the utilization of both varieties into value-added products from the root including flour, yogurt, and bread. Sweet potato-based bread, TUO vitabread, prepared from a composited wheat flour and OSP puree at a ratio of 2.5:1 ("as-is" basis) was compared with traditional wheat (white) bread on the Ghanaian market in compositional and sensory analyses. The proximate composition (moisture, protein, fat, ash and carbohydrate by difference) and energy content were not statistically different ($P>0.05$), although TUO vitabread contains 18% more moisture than the white bread. The β -carotene and lutein concentrations in the OSP-based bread were approximately 6-fold higher ($P=0.01$). The TUO vitabread could meet 17% of the daily adequate intake of vitamin A for a 1- to 3-year-old child consuming about 50 g of the bread, but only 3% from the white bread. Consumer preference assessment of 50 undergraduate students showed a high preference for the OSP puree-based bread but further work on extension of shelf-life under ambient conditions is warranted. Thus, the inclusion of OSP in the traditional diet can be an inexpensive and year-round source of dietary β -carotene to complement the vitamin A supplementation programme to reduce VAD in children.

Keywords: orange sweet potato, β -carotene, bread, children, vitamin A deficiency

INTRODUCTION

The prevalence of childhood malnutrition in sub-Saharan Africa is among the worst in the world (Black et al., 2013; Grantham-McGregor et al., 2007) and is reflected in high levels of wasting, stunting and infection. Of particular concern is vitamin A deficiency (VAD) because of the vital role that vitamin A has in the function of the immune system (de Azevedo Paiva et al., 2010; World Health Organization, 2009); eye health, growth and development of infants and children (Mayo-Wilson et al., 2011). The main cause of VAD is low dietary intake of carotenoid-rich foods.

In Ghana, according to FAO (2009) and WHO (2009) reports, the prevalence of subclinical VAD is high; about three-quarters of children under 5 being deficient, with 35% of them classified as severe (serum retinol $<10 \mu\text{g dL}^{-1}$). The frequency of women of childbearing age (15-49 years) afflicted with night blindness is about 1.5 times higher than the maximum cut-off of 5% for classification as a public health problem. Clearly, in Ghana, VAD among the vulnerable groups demands vigorous research to help address this predicament. It is worth mentioning that efforts have been made in Ghana to improve



dietary intake of vitamin A through fortification of wheat flour (<http://2013.gainhealth.addison.com/project/ghana-wheat-flour-and-vegetable-oil-fortification-project.html>). The fortification of wheat flour with 2.0 μg retinol activity equivalent (RAE) g^{-1} vitamin A is mandatory (Klemm et al., 2010).

The Sustainable Technology for Orange and Purple Sweetpotatoes (STOPS) project, led by researchers from Tuskegee University, USA, identified gaps in the value chain from production, processing, product development to consumption of sweet potato, aimed at addressing VAD and improving the health and nutritional status of the vulnerable population in rural communities of Ghana. Detailed description of the STOPS project is beyond the scope of this paper, and can be found elsewhere (http://hortcrsp.ucdavis.edu/main/35_sweet_potato.html). One of the project's activities is the refinement of Ghanaian recipes to include orange sweet potato (OSP). Bread was chosen as a recipe to refine because of its prominence in the Ghanaian diet, as reported in a survey by Ellis et al. (1997). In the survey, 58% of respondents (total number not indicated in the manuscript) took bread on a daily basis, while 31% took bread at least 2-5 times a week.

There is a plethora of evidence that sweet potato could be used as an ingredient for bread -baking to produce consumer-acceptable loaves (Grabowski et al., 2008; Hamed et al., 1973; Idolo, 2011; Low and van Jaarsveld, 2008), but OSP puree was used in only one of them (Low and van Jaarsveld, 2008). Hamed et al. (1973) and Low and van Jaarsveld (2008) opined that compositing OSP and wheat flour would provide policymakers in Africa with a unique opportunity to create income for rural farmers, reduce foreign exchange expenditure for wheat, and significantly contribute to reduction of VAD. However, these suggestions have not been exploited to reduce the burden of wheat importation on the economy of most countries in Africa, as well as addressing VAD. Importation of wheat has been rising steadily, and has doubled from 2000 to mid-2014 (from 298,000 to 595,000 metric tonnes), with almost a steady increase in Ghana (Barrientos and Soria, 2014).

Considering losses of β -carotene, a precursor of vitamin A, during drying (Bechoff et al., 2011), and the expense involved in drying, the use of OSP puree could have some nutritional advantages. Also, OSP-based bread could contain a measurable amount of lutein, which has been shown to be essential for maintaining good eye health (Bone et al., 2000; Menelaou et al., 2006). It is in this vein that the STOPS project carried out recipe refinement of bread by incorporating OSP puree as an ingredient to reduce the amount of wheat flour to be used in bread baking, and to increase the β -carotene in it.

The objectives of this study were to bake bread (TUO vitabread) from a composite blend of white flour and OSP puree, to compare the nutrient composition, and to assess consumer preferences of the TUO vitabread with 100% wheat (white) bread.

MATERIALS AND METHODS

Sweet potato (*Ipomoea batatas* L.) 'TUO', brought to Ghana by researchers from Tuskegee University, USA, was multiplied for planting material. The vine cuttings obtained from the multiplication were planted and harvested at 150 days after planting. Roots were harvested from three different plots, and stored separately for 7 days before using it for the bread recipe refinement. Three batches of TUO vitabread were baked as follows.

Approximately 3.1 kg 'TUO' roots and 6.5 kg wheat flour were weighed, and given to a commercial baker. The baker was advised to use about half the quantity of sugar that would be used for baking 9.6 kg wheat (white) bread, called "sugar bread" in Ghana, which is one type of white bread with about 14% of the ingredients being white sugar (Ellis et al., 1997).

The 'TUO' roots were boiled, peeled and mashed into a puree. The following ingredients were added and thoroughly mixed (mixture A): 500 g sugar, 50 g iodized salt, 170 g full-cream evaporated milk (Ideal milk), 10 g nutmeg powder, 1.5 tablespoons cinnamon powder and 60 mL strawberry essence. For mixture B, to the wheat flour, 3 teaspoons baker's yeast, 2 teaspoons baking powder and 50 g margarine were added and mixed. Mixtures A and B were combined and mixed by hand, and the dough obtained was taken to a commercial mill for kneading. The kneaded dough was rolled and moulded into rolls, left to rise for about 4 h, and then baked in a gas oven until done. Products from the

three batches were sampled for laboratory analysis and consumer acceptance test. Freshly baked white bread loaves were purchased for comparative assessment with TUO vitabread for compositional and sensory analyses.

The samples for the analytical analyses were wrapped in aluminium foil and frozen at -18°C until required. Analytical blind triplicate samples of each bread type were sent to the Nutrition Department, Noguchi Memorial Institute of Medical Research, and Ghana Standards Authority. Both laboratories offer analyses on a fee-for-service basis. Total sugars was analysed by the Ghana Standards Authority, while moisture, protein, fat, ash, β -carotene and lutein were handled by the other laboratory.

Fifty first-year undergraduate students (19-25 years) from the University for Development Studies were selected for the consumer preference study, a day after baking; 25 of the panellists were requested to come and assess the two bread types at 3 days after baking in storage. Bread samples were placed on a table and in a fridge for the storage consumer's preference assessment. Samples were randomly assigned 3-letter codes and blindly served to the panellists.

The compositional data were subjected to two-sample t-test analysis; Mann-Whitney's test and general linear model for two factors were used for the fresh and storage sensory data generated, respectively. Minitab® 16.2.2 (Minitab Inc., State College, PA, USA) was used for all the statistical analyses, and significance was at the 95.0% confidence level. Tukey's method was used for post-hoc tests where appropriate.

RESULTS AND DISCUSSION

Food-based approaches, refining existing local food recipes by incorporating biofortified food crops, for example, OSP, would be a more sustainable way of improving the nutrition and health of the most vulnerable groups. Earlier work reported that bread was eaten daily as part of the diet of most Ghanaians, consumed as a convenience food or snack, and the most preferred bread type was wheat (white) bread (Ellis et al., 1997). Hence the rationale of choosing this bread type in Ghana as the recipe to refine.

Nutrient composition

The proximate composition (moisture, protein, fat, ash and carbohydrate by difference) and energy were not statistically different ($P>0.05$), although TUO vitabread contained 18% more moisture than the traditional white bread (Table 1).

Table 1. Proximate composition, energy, β -carotene and lutein concentrations of sweet potato-based bread (TUO vitabread) and wheat (white) bread.

Bread type	100 g ⁻¹ dry matter basis except for moisture values								
	Moisture (g)	Protein (g)	Fat (g)	Ash (g)	Tot. CHO (g)	Tot. sugar (g)	Energy (kJ)	β -Carotene (mg)	Lutein (mg)
TUO vitabread	32.41±1.90	14.75±0.64	11.36±3.92	4.63±0.42	36.85±4.90	29.76±2.00	1297±12	1.57±0.10 (17%) ¹	0.38±0.03
Wheat (white) bread	26.83±0.94	14.67±0.22	8.81±1.50	4.57±0.60	45.11±1.40	27.71±1.50	1342±21	0.26±0.03 (3.0%) ¹	0.06±0.01
P-value ²	0.12	0.92	0.40	0.94	0.25	0.47	0.25	0.01	0.01

¹Values in parentheses are percentages of the dietary reference intake per day of vitamin A for a child (1 to 3 years old) (Food and Nutrition Board and Institute of Medicine and National Academies, 2004), who will consume 50 g of each bread. The calculation was adjusted to 79% trans- β -carotene retention (Low and van Jaarsveld, 2008), and using a conversion ratio of 12 μ g trans- β -carotene = 1 μ g retinol activity equivalents (Food and Nutrition Board and Institute of Medicine and National Academies, 2004).

²Parameters with $P<0.05$ indicate significant differences between the two types of bread.

As expected, the β -carotene and lutein levels in the OSP-based bread were significantly (approximately 6-fold) higher ($P=0.01$) than the levels in the white bread. Synthetic food colours, which may not be approved for baking, are being added to bake different-coloured

bread on the Ghanaian market; the orange colour of OSP served this purpose (Aniedu and Agugo, 2010), and also has the added advantage of being a dietary source of β -carotene. The TUO vitabread could supply 17% of the adequate daily intake of vitamin A for a 1- to 3-year-old child consuming about 50 g of the loaf, compared with only 3% from the white bread. It is worth mentioning that the percentage of the dietary reference intake for vitamin A might be higher for both bread types than stated above, because we did not include retinol assays due to fund limitation. Although there is no recommended daily allowance for lutein, dietary intake of about 6-10 mg per day has been associated with positive effects on eye health (Seddon et al., 1994). The lutein content in TUO vitabread is far below the level associated with positive effect on eye health, but regular consumption may lead to some health benefits.

Consumer preference

Consumption of bread is centrally related to its sensory attributes. All the sensory attributes, appearance, colour, aroma, overall degree of liking and ease of slicing, for the 1-day-old bread samples were similarly ranked, with median scores of 7 and 8 (Figure 1). This ranking corresponds to “like moderately” (7) and “like very much” (8). Apart from the overall degree of liking, which had the same consumer preference score, TUO vitabread was ranked significantly higher ($P < 0.05$) for aroma and ease of slicing. The wheat (white) bread was preferred to the OSP-based bread for colour and appearance.

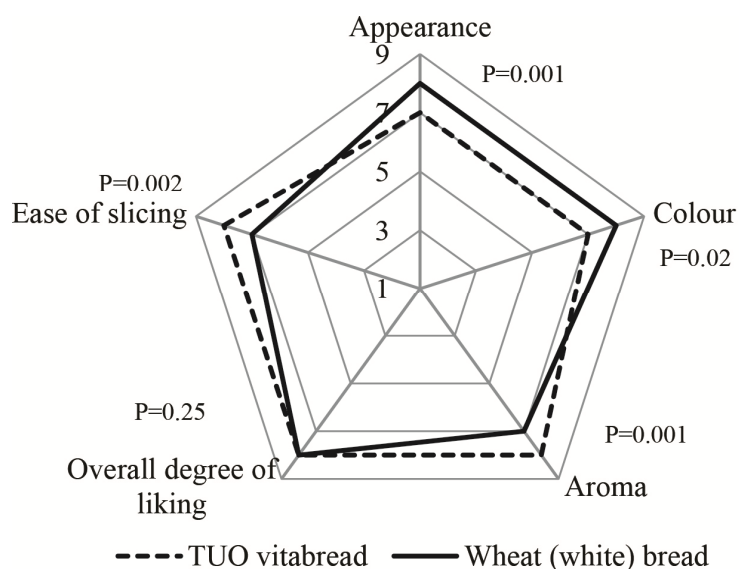


Figure 1. Consumer sensory ranking for sweet potato-based bread (TUO vitabread) and wheat (white) bread. Values are median scores. Sensory attributes with $P < 0.05$ indicate significant differences between the two types of bread. A 9-point hedonic scale was used: 1 = least acceptable/dislike extremely; 5 = Neutral; 9 = highly acceptable/like extremely.

These findings indicate that Ghanaian consumers would accept the OSP-based when introduced to the market, as their responses in Figure 2 indicate. Eighty per cent (40/50) and 74% (37/50) of the panellists responded that they would like to have the TUO vitabread and wheat (white) bread, respectively, on the Ghanaian market. Our results support earlier findings, that bread has become a critical part of the Ghanaian diet (Ellis et al., 1997).

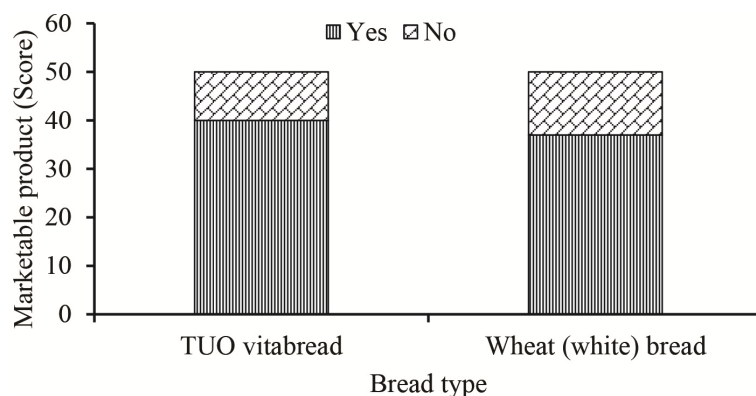


Figure 2. Consumer scores to have product on the Ghanaian market.

In Figure 3, the participants ranked the sweetness intensity score of “just-about-right” of the bread types almost equally (58 vs. 60%, for TUO vitabread and white bread, respectively). However, as suggested by Stone and Sidel (2004), neither product met the recommended 70% to indicate acceptability in terms of sweetness intensity. Interestingly, 24% ranked the OSP-based bread as too sweet, although we suggested the baker use half the amount of sugar that would normally be used for preparing 9.6 kg of 100% wheat flour. This suggests that the quantity of sugar could be reduced further, and may lead to a cost-saving. This supports the earlier suggestions that compositing wheat flour with sweet potato would present some economic benefits to low-income countries (Hamed et al., 1973; Low and van Jaarsveld, 2008).

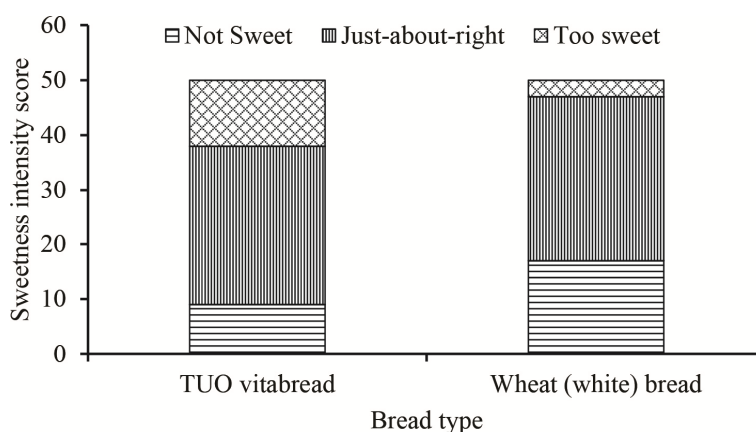


Figure 3. Sweetness intensity scoring for sweet potato-based bread (TUO vitabread) and wheat (white) bread. Scoring was done on a 3-point scale, and responses were categorised as “not sweet”, “just-about-right” and “too sweet”. A “just-about-right” score of 70% and above indicates acceptability (Stone and Sidel, 2004).

Generally, the bread samples did not store well when left under ambient conditions compared with storage in the fridge. The TUO vitabread placed on a table had the lowest median score, of 4 (“dislike moderately”) (Figure 4). Further studies on extension of the shelf life of the OSP-based bread are warranted.

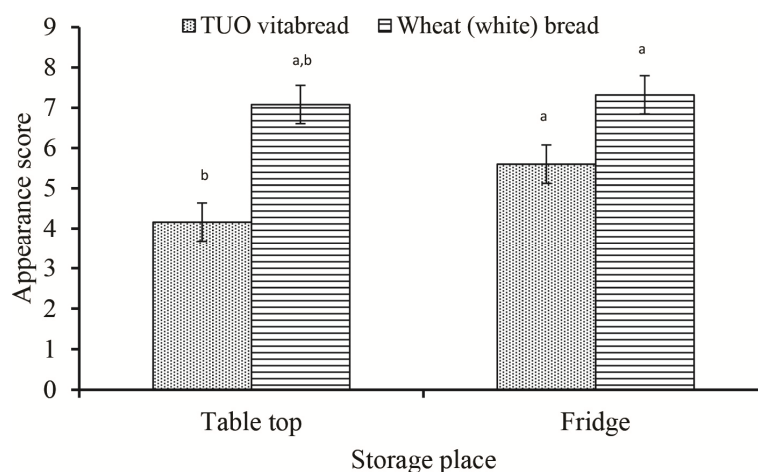


Figure 4. Preference for appearance for sweet potato-based bread (TUO vitabread) and wheat (white) bread after 3 days of storage under ambient and fridge conditions. Bar values indicate mean \pm standard error; bars with different letter are significantly different. A 9-point hedonic scale was used: 1 = least acceptable/dislike extremely; 5 = neutral; 9 = highly acceptable/like extremely.

CONCLUSIONS

Incorporating OSP as an ingredient could be an inexpensive and year-round dietary source of β -carotene. More nutritional studies need to be carried out to ascertain whether this approach would effectively complement vitamin A supplementation initiatives in most low-income countries in Africa.

There is a need to carry out economic analysis to investigate the benefits, if any, of incorporation of OSP puree in bread baking. Also, comparison of TUO vitabread with bread produced using a nationally released OSP cultivar, 'Apomuden', which has a more intense orange colour than 'TUO', is recommended. Additionally, other bread types available in Ghana could be considered in a similar study. Adoption of the vitabread would have economic benefits by reducing the high foreign exchange used for importation of wheat flour.

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