Evaluation of suitability of substituting wheat flour with sweet potato and tiger nut flours in bread making

Chinelo V. Ezeocha*, Nnenna A. Onwuneme

Abstract: The study was carried out to assess the nutritional quality and palatability of bread after partially substituting wheat flour (WF) with sweet potato (SF) and tiger nut (TF) flours. Sweet potato (yellow fleshed) and tiger nut flours were used to substitute wheat flour at 5, 10, 15 and 20% level each. The bread quality of each of these composite flours evaluated on the basis of their nutritional quality, physical properties and acceptability by consumers. The findings indicate slight decrease in the protein content of the bread samples with increasing sweet potato and tiger nut supplementation (6.97% in 100% wheat flour to 3.80% in 20% level of substitution) while crude fibre content increased with increased sweet potato and tiger nut substitution (2.29% in 100% WF to 2.80% in 20% substitution) but there was no significant change (P<0.05) in the ash and fat contents. Carbohydrate which was the major component ranged from 73.47 – 79.42%. Findings on the study on the functional properties showed that water absorption capacity increases with increase in the level of sweet potato and tiger nut substitution (0.54g/ml in 100% WF to 1.12g/ml in 20% level of substitution). The loaf volume and specific volume of the bread samples decreased significantly with increase in the level of substitution with sweet potato and tiger nut and it ranged from 320cm³ (in 100% wheat flour) – 216cm³ (in 20% substitution) and 1.55cm³/g (in 100% wheat flour) to 0.98cm³/g (in 20% level of substitution) respectively. Bread from 100% wheat flour scored the highest in all the sensory properties evaluated. There was no significant difference between the control and bread from 5% level of substitution in terms of all the sensory parameters evaluated however bread from higher levels of substitution varied significantly with the control. All the bread samples were acceptable in all the parameters evaluated except bread from 20% level of substitution.

Keywords: sweet potato, tiger nut, bread, composite flour, substitution

1 Introduction

Bread, a staple food in developing countries is consumed in large quantities because it is affordable, is an excellent source of nutrients and is available in a “ready to eat” form (Darko, 2002). Wheat, the basic ingredient in bread making is one of the most important crops grown round the world, however it cannot be grown in all bread consuming areas hence it may need to be imported making it relatively expensive according to the reports of Edema et al. (2005) and Olaoye et al. (2006). Before now, imported wheat flour has been the only kind of flour used in bread production in Nigeria. However, over the years, in response to the increase in the price of wheat, reports have been published on successful composite bread technology (though such bread still requires at least 70% wheat flour to be able to rise) if substituting with indigenous crops like soybeans, plantain, cocoyam, sweet potato, breadfruit etc (Oluwole et al., 2005; Onuh and Egwuje, 2005; Olaoye et al. 2006; Eddy et al., 2007; Ade-Omowaye et al., 2008; Malomo, 2010; Malomo et al., 2011). Utilization of these composite flours would reduce the demand for imported wheat; conserve foreign reserves (Eddy et al., 2007) and widen the utilization of indigenous crops in food formulation (Ade-Omowaye et al., 2008).
Sweetpotato (*Ipomoea batatas*), a dicotyledonous plant belonging to the family, Convolvulaceae is a starchy crop which thrives well in almost any climate and matures in about 3-4 months. This gives it great potential for combating food shortage and malnutrition. Despite this it is yet to be fully exploited (Woolfe, 1992), and is still perceived as an underutilized yet nutritious food (Woolfe, 1992; Bovell-Benjamin, 2007; Rodriguez-Amaya et al., 2011). Oluwalana et al., 2012 reported that wheat flour could be substituted with as much as 15% sweet potato flour in bread making without adversely affecting the physicochemical and sensory properties. Micronutrient deficiency also known as hidden hunger is one of the major problems faced by developing countries such as Nigeria usually in relation to health and nutrition of its young children. The inclusion of crops such as sweet potatoes, which are rich in micronutrients especially carotenoids, into the production of widely consumed breads is a step towards reducing micronutrient deficiency.

Tiger nut (*Cyperus esculentus var sativa*) is a lesser known and underutilized crop, high in carbohydrate and dietary fibre with moderate protein, oleic acid, mineral, vitamin C and E contents as well as some therapeutic properties (Esteshola and Oreadu, 1996; Omode et al., 2004). Its flour is considered to be a good additive for the bakery industry, as its natural sugar content is fairly high, avoiding the necessity of adding too much extra sugar (Sánchez-Zapata et al., 2012).

The use of sweet potato and tiger nut composite flour in bread production would lead to reduction in the importation of wheat; would promote use of indigenous crops and provide a better supply of micronutrients as well as enhancing domestic agriculture and supporting rural development.

The objective of this work was to assess the functional properties of the flours and the qualities of breads produced from wheat composite flours containing sweet potato and tiger nut.

## 2 Materials and Methods

The yellow fleshed sweet potatoes used for this study were obtained from the multiplication farm of National Root Crops Research Institute, Umudike. Tiger nuts and other raw materials such as Wheat flour, sugar, yeast, margarine, salt and nutmeg were purchased from Urbani Market, Umuahia. The sweet potatoes were sorted, washed, peeled, washed again, chipped (using a locally fabricated chipping machine), blanched (62°C for 10 mins), oven dried at 60°C, milled (with a Thomas Wiley Mill, Model ED-5) and sieved with a 250 µm screen to obtain sweet potato flour (SPF). Tiger nuts were sorted, washed, drained, oven dried at 60°C, milled and sieved with a 250µm screen to obtain tiger nut flour (TNF).

Five blends were prepared by homogenously mixing sweet potato flour (SPF) and tiger nut flour (TNF) and wheat flour (WF) in the proportions: 0:0:100, 5:5:90, 10:10:80, 15:15:70 and 20:20:60 (SPF:TNF:WF) using a food processor (Kenwood). Baking tests were conducted with a modified straight dough procedure (AAC, 2000). Three loaves were prepared in each lot with the following ingredients: 300 g flour or composite flour, 15 g sugar, 20.1 g fat, 10.5 g compressed yeast, 3 g salt and 180 mL water. The Dough was mixed to optimum consistency, allowed to rest in bulk for 45 min, kneaded and left to proof for 15 min. After proofing the dough was manually rounded, rolled, put in baking pans and allowed to proof for 75 min at 30°C. Baking was done at 230°C in a gas oven for 15mins. The resulting bread samples were allowed to cool to room temperature (37°C) before further analysis was carried out.

The Bulk density, swelling index, water and oil absorption capacity and gelatinization temperature of the flours were determined using the method described by Onwuka et al. (2005). Moisture, fat, crude fibre, protein, reducing sugars and ash contents of the bread samples were determined by the method of AOAC (1999). Nitrogen-free extract, assumed to be carbohydrate, was calculated by difference. The loaf weight was determined by weighing the bread loaves 20 mins after baking, using the laboratory scale (A&D company Ltd serial no: 12318189) and the readings recorded in grammes. The loaf volume was determined by using modified Rape seed displacement method (AAC, 2000, Standard). This was done by loading sorghum grains into an empty box up to a marked level before unloading the grains again. The bread sample was put into the box and the measured sorghum was loaded back again up to the mark. Any remaining sorghum grains were measured using a measuring cylinder and this was recorded as loaf volume in cm³. The specific volume (volume to mass ratio in cm³/g) was then calculated. Sensory evaluation was conducted on the bread samples using 20 semi-trained panellists. The samples were evaluated for taste, crumb texture, crust colour, crumb colour and general acceptability. A nine (9) point hedonic scale as described by Iwe (2002) was used where 9= like extremely and 1= dislike extremely.

All analysis was performed in triplicate. The statistical analyses were conducted using one-way ANOVA. Statistical differences in samples were tested at p < 0.05. Duncan’s New Multiple-Range Test (DMRT) was used to
separate the means. All the analyses were done with SPSS (11.0) software.

3 Results and Discussion

Table 1 shows the Functional properties of the flour samples which are properties that determine the suitability of a food material for a particular purpose. The packed bulk density which ranged from 0.50 (in 100% wheat flour) - 0.87g/ml (20SP:20TN:60WF) increased with increase in the level of sweet potato and tiger nut substitution. The bulk densities of the substituted samples were higher than that of 100% wheat flour. Higher bulk density is desired for reduction of paste thickness (Udensi and Eke, 2000) while low bulk densities are desirable for ease of transportation and distribution (Agunbiade and Sanni, 2001)

Water absorption capacity of the samples ranged from 0.54-1.12g/ml with the highest water absorption capacity observed in 20% level of substitution. Oil absorption capacity ranged from 1.12 to 1.79g/ml. The water absorption increased with increasing wheat flour substitution. Variations in water and oil absorption activity may be due to different protein concentration in wheat, sweet potato and tiger nut flours, their degree of interaction with water and oil and possibly the conformational characteristics. Water absorption capacity is important in dough consistency and baking quality of products (Amandikwa et al., 2015).

The swelling index of the flour blends decreased significantly (P≤0.05) as the proportion of sweet potato and tiger nut flour increased, it ranged from 0.30 to 1.31g/ml with 100% wheat flour having the highest value. Moorthy and Ramanujam (1986) reported that the swelling power of flour granules is an indication of the extent of associative forces within the granule. Therefore, the higher the swelling power, the higher the associate forces. Swelling power is also related to the water absorption index of the flour during heating (Ruales et al., 1993). The high swelling power observed in wheat may be as a result of gluten which is a protein found in wheat which contributes to the viscoelastic properties of wheat flour dough (Okaka, 2005).

The moisture content of the bread samples ranged from 11.09 to 15.10%. There was no significant difference in the moisture content of the bread samples except the 20 SP:20 TN:60 WF sample with the highest moisture content which implies that this sample maybe more susceptible to spoilage by microbial invasion especially fungi and mould (Ihekoronye and Ngoddy, 1985). The result suggests an increase in moisture content with increasing sweet potato and tiger nut substitution. A similar result was reported by Adebowale et al. (2009) on sweet potato-wheat bread.

Crude protein content of the bread samples ranged from 3.80% (in bread with 20% SP: 20% TN: 60% WF) to 6.97% (in bread with 100% WF). This is less than the range of 10.15% -12.44% obtained by Oluwalana et al. (2012) for sweet potato-wheat bread. This difference may be due to inclusion of tiger nut in the composite flour. The protein content decreased as more sweet potato and tiger nut flours were incorporated into wheat flour. Indicative of low protein content of the additives as compared to wheat.

The crude fibre content of the bread samples ranged from 2.29 to 2.80%, which is similar to the range shown by Eke-Ejiofor and Deedam (2015). The crude fibre content was observed to increase with increasing tiger nut and sweet potato flours. Dietary fibre intake provides many health benefits. A generous intake of dietary fibre reduces the risk of developing diseases such as coronary heart disease, stroke, hypertension, diabetes, obesity, and

| Samples       | Bulk density (g/cm³) | Water absorption Capacity (g/ml) | Oil Absorption Capacity (g/ml) | Gelatinization Temp. (°C) | Swelling Index (g/ml) |
|---------------|----------------------|---------------------------------|-------------------------------|--------------------------|------------------------|
| 0:0:100       | 0.50±0.01            | 0.54±0.05                       | 1.75±0.02                     | 67.00±1.00               | 1.31±0.02              |
| 5:5:90        | 0.60±0.01            | 0.60±0.01                       | 1.71±0.01                     | 62.67±1.15               | 0.97±0.09              |
| 10:10:80      | 0.77±0.03            | 0.76±0.05                       | 1.12±0.03                     | 66.67±1.15               | 0.41±0.01              |
| 15:15:70      | 0.85±0.01            | 0.83±0.06                       | 1.60±0.01                     | 63.37±1.19               | 0.37±0.06              |
| 20:20:60      | 0.87±0.02            | 1.12±0.03                       | 1.79±0.01                     | 66.67±0.58               | 0.30±0.10              |

Means followed by the same letter in a column are not significantly different at p≤0.05
Values are means of triplicate readings
0:0:100 = 0% sweet potato flour: 0% tiger nut flour: 100% wheat flour
5:5:90 = 5% sweet potato flour: 5% tiger nut flour: 90% wheat flour
10:10:80 = 10% sweet potato flour: 10% tiger nut flour: 80% wheat flour
15:15:70 = 15% sweet potato flour: 15% tiger nut flour: 70% wheat flour
20:20:60 = 20% sweet potato flour: 20% tiger nut flour: 60% wheat flour
certain gastrointestinal disorders. Furthermore, increased consumption of dietary fibre improves serum lipid concentrations, lowers blood pressure, improves blood glucose control in diabetes, promotes regularity, aids in weight loss, and appears to improve immune function (Anderson et al., 2009). This implies that sweet potato and tiger nut flour can be used for producing high fibre breads.

The physical properties of the bread samples are shown in Table 3. The loaf volume and specific volume of the bread samples decreased significantly (P<0.05) with increased substitution of WF with sweet potato and tiger nut flours. Samples with 100% wheat flour had the highest loaf volume (320 cm³) and specific volume (1.55 cm³/g) while the sample with 20% sweet potato and tiger nut flour substitution had the lowest (175 cm³ and 0.98 cm³/g respectively). The decrease in loaf volume and specific volume observed could be due to the decrease in the gluten content of the flours as a result of dilution of wheat flour with sweet potato and tiger nut flours, thereby lowering the ability of the dough to rise during proofing. The specific volume of all the samples including the control was lower than 6 cm³/g which is the specific volume for standard bread according to China Grain Products Research and Development Institute (Lin et al., 2009). The loaf weight of bread made with 100% wheat flour was lower (206.45 g) than that of breads with sweet potato and tiger nut flour substitution with 20% substitution producing the heaviest loaf (220.41 g). A similar observation was made by Ade-Omowaye et al. (2008) and Olaoye et al. (2006). The lower specific volume of the bread samples substituted with sweet potato and tiger nut flours may be responsible for their higher weights. The high weight could also be related to the high water absorption capacity of the substituted flours. This increase in weight may be desired by consumers as there is the tendency to buy products that will give better fill.

Table 4 shows the result of the sensory evaluation on the bread samples. There was not much significant difference between the taste of the substituted breads and the control. The taste of the bread samples following

| Samples | Moisture content (%) | Ash (%) | Crude protein (%) | Fat (%) | Crude fibre (%) | CHO (%) |
|---------|----------------------|--------|------------------|--------|----------------|--------|
| 0:0:100 | 12.51* +0.04         | 1.61*+0.01 | 6.97a+0.06       | 3.15a+0.01 | 2.29b+0.06     | 73.47b+0.05 |
| 5:5:90  | 11.09*+0.06          | 1.68a+0.02 | 4.73b+0.03       | 1.64a+0.02 | 2.29b+0.06     | 79.42*+0.03 |
| 10:10:80| 14.22*+0.02          | 1.73a+0.01 | 4.63a+0.02       | 2.20a+0.04 | 2.39a+0.04     | 75.63*+0.05 |
| 15:15:70| 14.85*+0.04          | 1.77a+0.03 | 4.50a+0.02       | 2.43a+0.08 | 2.77a+0.02     | 74.40*+0.02 |
| 20:20:60| 15.10*+0.01          | 1.85a+0.03 | 3.80a+0.04       | 3.06a+0.05 | 2.80a+0.03     | 73.98b+0.06 |

Means followed by the same letter in a column are not significantly different at p≤0.05 Values are means of triplicate readings

| Samples | Loaf volume (cm³) | Loaf weight (g) | Specific volume (cm³/g) |
|---------|-------------------|-----------------|-------------------------|
| 0:0:100 | 320+0.03          | 206.45+0.00     | 1.55+0.01               |
| 5:5:90  | 285+0.01          | 210.00+0.01     | 1.36+0.01               |
| 10:10:80| 268+0.01          | 211.50+0.04     | 1.27+0.02               |
| 15:15:70| 220+0.02          | 218.60+0.01     | 1.01+0.02               |
| 20:20:60| 216+0.01          | 220.41+0.03     | 0.98+0.01               |

Values are means of triplicate readings
Evaluation of suitability of substituting wheat flour with sweet potato and tiger nut flours in bread making

15% substitution of wheat with sweet potato and tiger nut flours was scored the highest in terms of taste showing how sweet potato and tiger nut substitution can improve the taste of bread. The 100% WF control ranked highest in terms of crumb texture, crust colour and crumb colour, though none of the substituted bread samples was disliked in terms of the mentioned parameters. The 15% level of substitution with sweet potato and tiger nut was the most acceptable of the substituted breads. In general, the substituted bread samples compared well with the wheat flour breads and were well accepted.

4 Conclusion

This study has shown the possibility of producing breads of acceptable quality from wheat flour substituted with sweet potato and tiger nut flour. Wheat flour could be substituted with sweet potato and tiger nut flour up to 15% inclusion level without detracting from the sensory properties. Indeed, the taste of the substituted breads was more acceptable than that of the control. Sweet potato and tiger nut flours are therefore recommended to bakers for the production of nutritious and tasty composite breads. Further study is warranted to evaluate the comparative cost of production of 100% wheat bread versus sweet potato and tiger nut substituted breads.

Table 4: Sensory evaluation scores of the bread samples

| Samples     | Taste   | Crumb texture | Crust colour | Crumb colour | General acceptability |
|-------------|---------|---------------|--------------|--------------|-----------------------|
| 0:0:100     | 7.65±1.39 | 7.70±1.30     | 7.45±1.43    | 7.95±1.28    | 8.10±1.17             |
| 5:5:90      | 7.70±0.97 | 7.10±1.07     | 6.50±1.10    | 6.80±1.01    | 6.85±1.27             |
| 10:10:80    | 7.80±1.32 | 6.90±1.29     | 6.40±1.23    | 6.65±1.09    | 6.60±1.31             |
| 15:15:70    | 7.95±1.15 | 7.10±0.97     | 6.30±1.26    | 7.15±1.27    | 6.95±1.32             |
| 20:20:60    | 7.50±1.40 | 6.25±1.02     | 6.35±0.99    | 5.65±1.73    | 6.15±1.35             |

Means followed by the same letter in a column are not significantly different at p≤0.05

Values are means of triplicate readings

0:0:100 = 0% sweet potato flour: 0% tiger nut flour: 100% wheat flour
5:5:90 = 5% sweet potato flour: 5% tiger nut flour: 90% wheat flour
10:10:80 = 10% sweet potato flour: 10% tiger nut flour: 80% wheat flour
e 15:15:70 = 15% sweet potato flour: 15% tiger nut flour: 70% wheat flour
20:20:60 = 20% sweet potato flour: 20% tiger nut flour: 60% wheat flour

Sensory characteristics of wheat-sweetpotato composite bread. Niger. Food J., 27, 204-209

Ade-Omowaye, B.I.O., Akinwande, B.A., Bolarinwa, I.F., and Adebiyi, A.O. (2008). Evaluation of tigernut (Cyperus esculentus) wheat composite flour and bread. Afr. J. Food Sci., 2, 87-91

Agunbiade, S.O. and Sanni, M.O. (2001). The effect of ambient storage of cassava tubers on starch quality. In Root Crops. The small processor and development of local food industries for market economy. Proceedings of the Eight Triennial Symposium of the International Society for Tropical Root Crops. African Branch (ISTRC-AB). 12-16 Nov 2001. IITA Ibadan, Nigeria, p. 189-194

Amandikwa, C., Iwe, M.O., Uomah, A. and Olawuni, A. (2015). Physico-chemical properties of wheat-yam flour composite bread. Nigerian Fd. J., 3(1), 12-17

Anderson, J.W., Baird, P., Davis, R.H., Ferreri, S., Knudtson, M., Koraym, A. (2009). Health benefits of dietary fibre. Nutr. Rev., 67, 188–205

AOAC. (1999). Official Methods of Analysis of the Association of Official Analytical Chemists, 16th ed., 5th revision. Methods 925.10, 920.39C, 962.9E, 920.87 and 923.03. Washington DC: AOAC

Bovelli-Benjamin, A.C. (2007). Sweet Potato: A review of its past, present, and future role in human nutrition. Advances in Food Nutrition Research, 52(1), 1-59

Darko, K. (2002). The Role of Street Food Vendors in the Transmission of Enteric - 547. Pathogens. Ghana Medical Journal Bulletin of the World Health Organization, 80(7), 546

Eke-Eiofor, J. and Deedam, J.N. (2015). Effect of Tigernut Residue Flour Inclusion on the Baking Quality of Confectioneries. Journal of Food Research, 4(5), 172-180

Esteshola, E., and Oreadu, A. C. I. (1996). Fatty acids composition of Tiger nut tubers (Cyperus esculentus L.), baobab seeds

References

AACC. (2000). Approved Methods of the American Association of Cereal Chemists, 10th Ed. Methods 54-21 and 10-10B

Adebawale, O.J., Idowu, M.A. and Bankole, M.O. (2009). Influence of sweet potato flour diastatic activity on rheological, baking and
(Adansonia digitata L.) and their mixtures. J. American oil chemists society, 73, 255-257
Ihekoronye, A.I. and Ngoddy, P.O. (1985). Integrated Food Science and Technology for the Tropics, Macmillian Publishers Limited, London, p. 236-253
Iwe, M.O. (2002). Handbook on sensory methods and analysis. Rejoint communication service Ltd., Enugu, Nigeria, p. 7-12
Lin, L., Liu, H., Yu, Y., Lin, S.D. and Mau, J. (2009). Quality and antioxidant property of buckwheat enhanced wheat bread. Food Chemistry, 37, 461-467
Malomo, S.A. (2010). Effect of partial substitution of wheat flour with breadfruit and Breadnut flour on bread quality and Consumer Perception. M. Tech. Thesis. Food Science and Technology Department, Federal University of Technology, Akure, Nigeria
Malomo, S.A., Eleyinmi, A.F. and Fashakin, J.B. (2011). Chemical composition, rheological properties and bread making potentials of composite flour from breadfruit, breadnut and wheat. African Journal of Food Science, 5(7), 400-410
Moorthy, S.N. and Ramanujam, T. (1986). Variation in properties of starch in cassava Varieties in relation to age of the crop. Starch tarke, 38, 58-61
Okaka, J.C. (2005). Bread making ingredients and Technology. In: Handling storage and processing of plant foods. OCJ Publishers, Enugu, p. 45-78
Olaoye, O.A., Onilude, A.A. and Idowu, O.A. (2006). Quality characteristics of bread produced from composite flours of wheat, plantain and soybeans. Afr. J. Biotechnol., 11: 1102-1106
Oluwalana, I.B., Malomo, S.A., and Ogbogogbo, E.O. (2012). Quality assessment of flour and bread from sweet potato wheat composite flour blends. International Journal of Biological and Chemical Sciences, 6(1), 65-76
Oluwole, O.B., Oke, O.U., Oyegbami, F.O., Adeyoju, A.O., Adetuyi, D.O., Olapade, A.A., Derenle, A., Ozumba, A.U. (2005). Swelling Profile of Processed Sweet Potato Flour. NIFST AGM, 11-13 October, 2005, 266-267
Omode, A. A., Fatoki, O. S., & Olaogun, K. A. (2004). Physico-chemical properties of some underexploited and nonconventional oil-seeds, Agric food chem., 43, 2850-3
Onuh, J.O., Egwuje, S. I. D. (2005). Sensory and Microbial Quality of Stored Sweet Potato (Ipomea batatas L.) Flour. NIFST Proceedings of the 29th Annual Conference, 11-13 October, 2005, 284-285
Onwuka, G.I. (2005). Food analysis and instrumentation theory and practices, Nigeria, Naphthali prints, p. 68-70
Rodriguez-Amaya, D.B., Nutti, M.R., Viana de Carvalho, J.L. (2011). Carotenoids of sweet potato, cassava, and maize and their use in bread and flour fortification. Em: Preedy, V.R., Watson, R.R., and Patel, V.B. (Eds.). Flour and Breads and their Fortification in Health and Disease Prevention. London: Academic Press, p. 301-311
Ruales, J., Valencia, S and Nair, B (1993). Effect of processing on the physiochemical characteristics of guinea flour. (Chenopodium guinea Wild) starch 46 (1), 13-19
Sánchez-Zapata, E., Fernández-López, J. and Angel Pérez-Alvarez, J. (2012), Tiger Nut (Cyperus esculentus) Commercialization: Health Aspects, Composition, Properties, and Food Applications. Comprehensive Reviews in Food Science and Food Safety, 11: 366–377, DOI: 10.1111/j.1541-4337.2012.00190.x
Udensi, A. and Eke, O. (2000). Proximate composition and functional properties of flour produced from Mucuna cochinensis and Mucuna utles. In: Proceedings of the 1st Annual Conference of the College of Agriculture and Veterinary Medicine, Abia state University. 10-13th Sept., pp. 170-174
Woolfe, J.A. (1992). Sweet Potato. An untapped food source. Cambridge: Cambridge University Press