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Optimization of taste and texture of biscuit produced from blend of plantain, sweet potato and malted sorghum flour

Ishiwu C. N.[1]*, Nkwo V. O.[2], Iwouno, J. O.[3] Obiegbuna J. E.[1] and Uchegbu, N. N.[4]

[1]Department of Food Science and Technology, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria.
[2]Department of Home and Rural Economics, Federal College of Agriculture Ishiagu, Ebonyi State, Nigeria.
[3]Department of Food Science and Technology, Federal University of Technology, Owerri, Imo State, Nigeria.
[4]Department of Food Technology, Institute of Management and Technology, Enugu- Nigeria.

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Biscuits were produced from blends of plantain, sweet potato and malted sorghum flour. This study was carried out to evaluate the effect of varying the proportions of these flour mixtures on the taste and texture of the produced biscuits. Mixture response surface methodology was used to model the taste and texture of the biscuits with single, binary and ternary combinations of the three flours. The optimum taste and texture of the biscuit were targeted and the responses optimizer of Minitab software (version 14.0) was used to obtain the mixture that gave these targets. Result showed that the taste and texture of biscuits samples differed significantly ($p < 0.05$). Sweet potato flour had the highest positive influence on the taste, while malted sorghum mostly improved the texture. The regression coefficients showed that the mixture of plantain and malted sorghum flour decreased both the taste and the texture of the biscuit, while the blend of sweet potato and malted sorghum flour had negative influence on the texture of the biscuit. The mixture of the three flours improved both the taste and the texture of the biscuit more than their single or binary combinations. Biscuit of acceptable taste and texture could be produced from the blend of these three flours.

Key words: Plantain flour, sweet potato flour, malted sorghum flour, biscuit, taste, texture.

INTRODUCTION

Among ready to-eat snacks, cookies and biscuits are widely consumed throughout the world. They are sold at markets, street shops and hawked at motor parks and schools where they could be bought and consumed by people of all ages (Lorenze, 1983). The fact remains that wheat is the choice flour for baked products because of its gluten content which other cereals lack. It has been reported that wheat is not sufficiently produced in most

*Corresponding author. E-mail: nwaejaka@yahoo.com.

countries of the tropics making them to rely on imported and expensive wheat flour (Holt et al., 1992; Eneche, 1999).

Products made from non wheat flour or from composite flour are latest trend in producing baked goods. Users of composite flour aim at mitigating the poor properties of flour produced from other non wheat grains. The substitute for wheat flour should be the flour that is readily available, cheap and able to replace wheat flour in terms of functionality. Some times, the interest in non-wheat products is based on their nutritional, health benefits and sensory properties. Celiac disease is a food induced immunological disease of the upper intestine triggered by the ingestion of gluten containing cereals in genetically susceptible individuals and these individual often resort to gluten-free baked goods. Researchers have developed gluten-free biscuits and cookies comparable in quality to ones produced from wheat (Okorie and Onyeneke, 2012).

Sorghum (*Sorghum guinea*) is readily available and acceptable in Nigeria. Even though it compares favorably with other cereals in terms of nutrient composition, many developed countries of the world still regard the grain as inferior (FAO, 1995). Malted sorghum has higher metabolisable energy, protein, soluble sugar and lysine than the unmalted sorghum and it has also been reported that malting reduces the tannin content of sorghum (Magness et al., 1971; Barrett and Larkin, 1974; Wu and Well, 1980). Sorghum has been reported as the fifth most important cereal among the world cereals (Dogget, 1989). But for tropical Africa, it is ranked the first with about six million tones produced yearly in Nigeria, this being the largest in Africa (Etuk et al., 2012).

Sweet potato (*Ipomea batata*) is abundant in many tropical and subtropical regions (Horton and Fano, 1985). Sweet potato is an important crop for food security in Nigeria where it is usually eaten boiled, or fried as chips. It is rich in nutrients especially dietary fibre, vitamins and minerals (Okorie and Onyeneke, 2012). It has been reported that incorporation of 40% sweet potato flour to wheat flour produced cookies with improved nutritional and sensory qualities (Singh et al., 2008).

Plantain (*Musa paradisca*) is one of the major sources of carbohydrate for millions of people in Africa, Caribiaean, Latin America, Asia and the Pacific (FAO, 1989). Unripe plantain is processed into flour in Nigeria and some other African countries and stirred in boiling water to form an elastic paste that is eaten with soup in Nigeria and has been used in making biscuits and cookies (Ishiwu, 2005; Ngalani and Crouzet, 1995).

Mixture response surface methodology (MRSM) is a statistical technique that can be used to determine the effect that components in a mixture have on the attributes of a finished product (Cornell, 1979; Myers et al., 2009; Okpala and Okoli., 2012).

The present study was undertaken with the aim to produce biscuits from blends of plantain flour, sweet potato flour and malted sorghum flour which are gluten-free flours and use MRS regression to study the effects of blends on taste and texture of the biscuits, and thereby optimize these attributes in the biscuits.

MATERIALS AND METHODS

Source of raw material

Sweet potato tubers (*I. batata*), sorghum grain (*S. guinea*), plantain (*M. paradisca*) and wheat flour were bought from Ogbete main market in Enugu, Nigeria.

Production of malted sorghum flour (MSF)

Sorghum grains were malted using the modified method for germinated cowpea described by Hallen et al. (2004) and Okpala and Okoli (2012). The cleaned grains were steeped in 1% sodium hypochlorite solution for 30 min to prevent mould growth. The steeped grain were again thoroughly washed and re-soaked in water (10 h). After soaking, the hydrated grains were spread on a moist jute bag which had been previously sterilized by boiling for 30 min and the grains were allowed to germinate for 4 day after which the ones that failed to germinated were discarded. The seeds germinated seeds were dried at 60°C in an oven (Gally kamp). Thereafter, the formed roots were manually rubbed off before milling and sieving through a sieve (Mesh no 80) and packaged in an air tight container until it is used.

Production of sweet potato flour (SPF)

The procedure reported by Adeyemi and Ogazi (1985) for the production of sweet potato flour was used with little modification. Four kilograms of sound tubers was weighed out after the potato had been cleaned, hand peeled, washed sliced into chips of varied length and weight (4 mm thickness) and blanched in hot water at 90°C for 30 s. Excess water on the chips were moped with hand towel before drying them at 60°C for 12 h in a hot air oven (Gallen kamp). The dried chips were milled and sieved using a laboratory test sieve (mesh no. 80). The flour was packaged with air tight plastics bucket.

Production of plantain flour (PF)

Unripe plantain was peeled, sliced (4 mm) and wrapped in muslin cloth and blanched for 30 s in hot water (90°C). After blanching, excess water on the slices was moped using a hand towel. The slices were further dried at 60°C in a hot air oven (Gally kamp) for 12 h. The dried slices were milled and sieved through sieve (no 80 mesh) to obtain fine flour. The flour was packaged in an air tight container until it was used.

Experimental design

The design was a three-component augmented simplex centroid design which was carried out using statistical software (Minitab version 14.0) as shown in Table 1. The three mixture components in this study were plantain flour (x_1), sweet potato flour (x_2) and malted sorghum flour (x_3). The proportion of each flour was expressed as a fraction of the mixture and for each treatment combination giving the sum of the component proportion as 100 where:

Table 1. Experimental design used to produce the flour blends.

Sample (S/N)	Plantain (g) (X_1)	Sweet Potato (g) (X_2)	Malted Sorghum (g) (X_3)
1	50.000	50.000	0.000
2	16.667	16.667	66.667
3	66.667	16.667	16.667
4	33.333	33.333	33.333
5	0.000	100.000	0.000
6	16.667	66.667	16.667
7	50.000	0.000	50.000
8	100.000	0.000	0.000
9	0.000	0.000	100.000
10	0.000	50.000	50.000
11	(100% wheat)		

$$\sum X_i = X_1 + X_2 + X_3 = 100 \quad (1)$$

In this design, the number of runs was 10 (Table 1). A sample making the total number of samples 11.

Biscuit preparation

The ingredients used were: Flour 100 g, hydrogenated vegetable fat 40 g; sugar 10 g; salt 0.5 g; baking powder 2 g; water varied between 20 and 30 ml. Fat, salt and sugar were mixed in a Hobart mixer. The baking powder and sifted flour were added to the mixture and manually mixed. Water was carefully added in bits to form dough. The dough was rolled and cut in to circular shapes of 5 cm diameter. Baking was carried out at 180°C for about 30 min. Biscuit samples produced were cooled and stored in polyethylene bags and again in a wide screw mouth glass bottle until analyzed. Biscuit was made from 100 % wheat flour with the same amounts of ingredients above to serve as a control.

Determination of taste and texture

In order to evaluate these attributes, sensory evaluation was conducted on the biscuit samples: A total of twenty semi-trained panelists were recruited from staff and students of Nnamdi Azikiwe University, Awka. Each panelist evaluated all the samples on the attributes of taste and texture in one session. A 9-point hedonic scale was used with: 1 = dislike extremely; 2 = dislike very much, 3 = dislike moderately, 4 = dislike slightly, 5 = neither like nor dislike, 6 = like slightly, 7 = like moderately, 8 = like very much and 9 = like extremely (Ihekoronye and Ngoddy, 1985; Iwe, 2002). Samples were coded with 3 alphabets and randomly presented to the panelists. The panelists were instructed to rinse their mouths with water after evaluating each sample.

Statistical analysis

Data generated from the sensory evaluation of taste and texture of the samples were subjected to analysis of variance (ANOVA) using a statistical software (SPSS version 17.0). Significant differences between the samples were determined at $P < 0.05$. Minitab version 14.0 was also used to analyze the data for the regression coefficients used to form the mathematical models that explained the relationship between the independent variable: plantain flour (x_1), sweet potato flour (x_2) and malted sough flour (x_3) and the response variables: taste (y_1) and texture (y_2) of the biscuit samples. The model search was started with linear, through full quadratic and the equation that gave high R^2adj was selected as shown in Equation 1 below:

$$Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} X_2 X_3 + \beta_{123} x_1 x_2 x_3 \quad (2)$$

Where y is the predicted responses (taste and texture); β is the parameter estimate (coefficient) for each linear and cross product term for the prediction model; x_1, x_2, x_3, x_1x_2, x_1x_3 and $x_1x_2x_3$ are the linear terms for plantain, sweet potato and malted sorghum and their cross product terms.

Graphical optimization of taste and texture

In order to optimize the taste and texture of the biscuit, a degree of likeness was targeted as 7.0 which represents like moderately in the hedonic scale. The response optimizer in Minitab 14.0 was clicked and high value (8.0) which represents like very much, the target (7.0) and low value (6.0) which represents like slightly were typed into the provided boxes to generate the flour ratio that would produce the biscuit with the targeted sensory score (7.0) for taste and texture.

RESULTS AND DISCUSSION

The mean values of the sensory scores for taste and texture of the biscuits are shown in Table 2. Significant differences ($P<0.05$) existed among the blends, this is in agreement with the earlier reports (Capitani et al., 2009; Okpala and Okoli., 2012) which stated that the minimum requirement for modeling a surface is that variation among the samples should be observed.

Table 3 shows the coefficients estimates, adjusted regression coefficients (R^2adjusted) for taste and texture for the biscuits, the multiple regression analysis showed that the full quadratic model was significant in predicting the taste and the texture of the biscuits. The model that explained the relationship between the taste of the biscuits and the independent variables (x_1, x_2 and x_3) is shown in Equation 3:

Table 2. Mean scores of taste and texture of biscuits produced from the flour blends and the control.

Sample (S/N)	Plantain (g) (X_1)	Sweet potato (g) (X_2)	Malted sorghum (g) (X_3)	Taste (mean)	Texture (mean)
1	50.000	50.000	0.000	5.40^{c}	5.55^{c}
2	16.667	16.667	66.667	6.00^{b}	6.25^{b}
3	66.667	16.667	16.667	6.00^{b}	4.75^{d}
4	33.333	33.333	33.333	6.75^{a}	6.25^{b}
5	0.000	100.000	0.000	6.75^{a}	5.50^{c}
6	16.667	66.667	16.667	6.50^{b}	5.25^{c}
7	50.000	0.000	50.000	4.75^{c}	3.75^{d}
8	100.000	0.000	0.000	5.50^{c}	5.00^{c}
9	0.000	0.000	100.000	5.98b^{c}	5.68b^{c}
10.	0.000	50.000	50.000	6.50^{b}	5.20^{c}
11. (Control)				8.00^{w}	7.00^{a}

Sample 11 = Control sample (100% wheat flour biscuit). Scores are based on 9-point hedonic scale. Data are mean scores by the panelists. Data in the same column bearing different superscript differ significantly ($p < 0.05$).

Table 3. Coefficient estimates and adjusted regression coefficient (R^2adj.) for taste and texture of biscuit produced from blends of plantain, sweet potato and malted sorghum flours.

Variable	Taste	Texture
X_1	5.494	4.98
X_2	6.744	5.48
X_3	5.974	5.66
X_1X_2	-2.925	0.98
X_1X_3	- 3.985	-6.44
X_2X_3	0.515	-1.64
$X_1X_2X_3$	108.032	121.53
R-Sq (adj.)	98.10%	86.62%

X_1 = Plantain flour (PF); X_2 = sweet potato flour (SPF); X_3 = malted sorghum flour (MSF).

$$y_1 = 5.494x_1 + 6.744x_2 + 5.974x_3 – 2.925x_1x_2 – 3.985x_1x_3 + 0.515x_2x_3 + 108.032x_1x_2x_3 \quad (3)$$

The positive (+) sign in the equation means that the response variable (y_1) increased with increase of the variable bearing that positive coefficient whether it is linear, binary or ternary combinations while the negative (-) sign means that the response variable decreased with increase of the variable bearing the negative coefficient thereby producing antagonistic affect. From the equation, it was observed that increasing the linear, binary and ternary combinations where sweet potato flour was incorporated increased the taste of the biscuit, but the binary combination of plantain and malted sorghum decreased the taste of the biscuit. Sweet potato flour exhibited the highest effect in increasing the taste of the biscuit than plantain or malted sorghum flour having the highest positive coefficient than the other two flours. The combination of plantain and malted sorghum flour resulted in decrease in taste since the coefficient is negative. The blend of plantain, sweet potato and malted sorghum produced biscuit whose taste and the texture were liked slightly. The R^2adj. for the taste was 98.10%. This high value suggests that the effect of the independent variables contributed 98.10% of the observed changes in the taste while the remaining 1.90% changes in the taste was caused by other variables not factored in the experiment. Similarly, it was an indication that the model is adequate for predicting the taste of the biscuit under these experimental conditions. Biscuit produced with 100% wheat flour rated highest in terms of taste preference. Its taste was like very much. The biscuit produced with flour ratio: PF = 33.333, SPF = 33.333 and MSF = 33.333 was liked slightly and ranked next to 100% wheat flour biscuit in terms of taste. Also, there was no significant difference ($p < 0.05$) between its taste and the taste of biscuit produced with 100% sweet potato flour which was also like slightly. The regression model for predicting the texture of the biscuit samples was shown in Equation (4) below:

$$y_2 = 4.98\ x_1 + 5.48\ x_2 + 5.66\ x_3 + 0.98\ x_1x_2 – 6.44\ x_1x_3 – 1.64\ x_2x_3 + 121.53\ x_1x_2x_3 \quad (4)$$

From the regression equation, linear, binary and ternary combinations of the three flour components had influence on the texture of the biscuits. Combination of plantain and sweet potato flours increased the texture of the biscuit whereas combination of plantain and malted sorghum or sweet potato and malted sorghum had antagonistic or

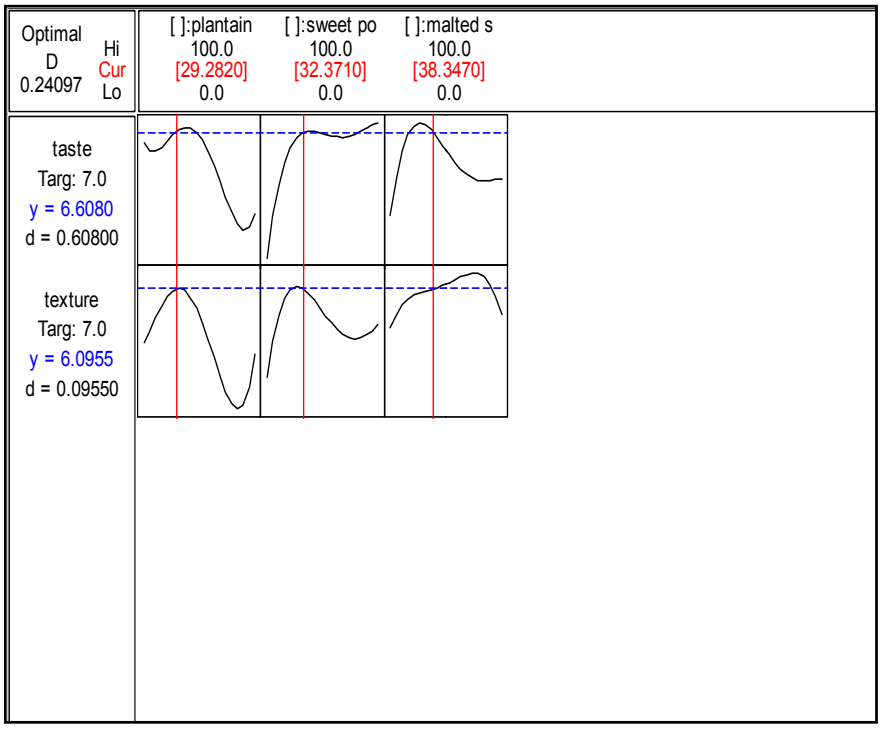

Figure 1. Optimization plot for targeted taste and texture of the biscuit.

negative effect on the texture of the biscuit. However, the combination of the three flour components positively influenced the texture of the biscuits. The R^2adj was 86.62%, suggesting that the model was adequate in predicting the texture of the biscuits up to 86.62%, while 3.38% of the changes in the texture of the biscuits were caused by extraneous variables not considered in the experiment. Biscuit produced from 100% wheat flour exhibited the highest textural quality when compared with other samples. Its texture was like moderately, while the texture of the biscuit sample produced with equal proportion of the three flour blend was like slightly, and ranked next to 100% wheat flour biscuit in texture. Significant differences in texture existed among samples ($p < 0.05$).

Figure 1 presents the graphical optimization of the taste and texture of the biscuit. The optimum taste and texture for the biscuit produced from the three flour blend were targeted to be like moderately. The current blend, the one written in red ink, PF = 29.2820, SPF = 32.3710, MSF = 38.3470 was arrived at as the closest ratio that could be mixed and used to produce biscuit that would hit the targeted sensory score of like moderately (7) for both the taste and texture.

Conclusion

MRSM was successfully used to identify the optimum combination of plantain, sweet potato and malted sorghum flour for biscuit production. The final goal was to obtain a novel biscuit produced from blend of gluten-free flours with an acceptable taste and texture. The biscuit produced from the blend of PF (29.2820), SPF (32.3710) and MSF (38.3470) will exhibit the taste and texture that would be liked slightly if the blend is used in producing biscuit as evidenced from the graphical optimization. The modeling of experimental data generated useful equations for use in predicting the taste and texture of the biscuit under these three different flour combinations.

The terms selected to fit the regression model was based on significant model ($p < 0.05$) and high R^2adj. (Cornell, 1986; Opkala and Okoli, 2012).

Conflict of Interests

The author(s) have not declared any conflict of interests.

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