Evaluation and Optimization of the Physical and Sensory Properties of Enhanced Bread Produced From Wheat Flour and Chemically Modified African Yam Bean and Cassava Starches

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Abstract: **Composite breads were made by supplementing wheat flour with chemically modified African yam bean and cassava starches after the flour – starch blends were produced from the cleaned seeds and roots using hammer milling system. Three mixture components were obtained from the D-optimal mixture design of Response Surface Methodology (RSM). The physical and sensory properties of the bread was determined and subjected to statistical analysis of variance (ANOVA) using cubic models to generate the regression equations from the experimental values. The linear, binary and ternary effects of the dependent responses and their interactions was generated and graphically represented using 3D response surface plots. The developed models were tested for adequacy and validated using criterion at $p<0.05$, non significant ($p>0.05$) lack-of-fit (LoF), >0.7 adjusted R^2 and >4 adequate precision to confirm adequate model signals. The numerical optimization outcomes had the desirability value of 0.86 depicting the ideal value. The optimized values for the optimum blends selected were 80.15 g wheat flour, 11.23 g African yam bean starch and 8.53 g cassava starch which will give the best composite flour -starch blends for enhanced bread products. The optimization was confirmed by performing confirmatory runs determining the 95 % confidence levels of the blends. The D – optimal mixture design of response surface methodology with three experimental components was adequate (propagated the design space) in evaluating and optimizing of the dependent responses tested; bread height, oven spring, loaf weight, loaf volume, specific volume and bulk density, appearance, crumb and crust, taste, aroma and acceptability.**

***Keywords*: Physical properties, Sensory properties, Enhanced bread, D-optimal mixture design**

I. INTRODUCTION

Bread is named as one of the staple foods in most countries even in the global – North laced with more nutrients than other foods, supplying 53 % countries with more than 50 % of their caloric total intake (Keswet *et al.*, 2003). In Nigeria, the use of dough for bread production and the use of bread vendors for the distribution of produced bread was introduced by Amos Shackleford in 1913 (Onyekwere, 1977). Dough rises during fermentation as a result of network of reaction complexes taking place in which the gluten retains CO_2, binding water temporarily, activating the gelatinization of starch and the formation of foam – raising structures of the bread (Lagrain *et al.*, 2013). Starches are the mostly used biodegradable polymer which plays an active role in the raising action, and different sources of starches gives an enhanced interaction. The association of starch and gluten provides a more malleable and stable network with adequate CO_2 retention and the structure of the bread devoid of collapse during fermentation and cooling (Delcour and Hoseney, 2009). Chemically modified starches are obtained when starches are treated with chemical reagents introducing subtle chemical constituents, activating molecular scission or molecular rearrangements and causing a new change in the structure of the starch (Huber and Bemiller, 2010). Chemically, starch has three chemical reaction points which takes place at the sites of the hydroxyl groups on 2, 3 and 6 carbon positions converting its anhydro-glucan units to cross – linked (acetylated) starches (Singh *et al.*, 2007). Bread produced with wheat flour and cross – linked (acetylated) starch showed increase in physical properties like crumb and crust structure, firmness and specific volume (Miyazaki *et al.*, 2008; Yeo and Seib, 2009). The African yam bean and cassava starches was produced and chemically modified by cross – linking (acetylation) to serve as a partial replacement for native wheat flour.

The African yam beans are laced with nutrients high in protein composition, fibre and minerals and has been studied and reported as similar when compared with abundant staple legumes. The amino acid profiles also, compared with those of soy beans, pigeon peas and cowpeas (Uguru and Madukaife, 2001).

Cassava starches are produced from cassava, an important root crops with high starch yield in the tropics which compares with sweet potato in percentage starch yields (Grace, 1977). Many researchers have successfully, partially substituted wheat flour by combining cassava flour for the bread productions (Oluwale *et al.*, 2018) and the inclusion of cassava starch weighs promising. This study will evaluate and optimize the physical and sensory properties of enhanced bread produced from wheat flour and chemically modified starches from African yam beans and cassava.

II. MATERIALS AND METHODS

2.1 Materials

Healthy seeds of African yam bean and wheat were obtained from local market at Ubani, Abia State while the fresh cassava roots were sourced from the extension department, National Root Crop Research Institute (NRCRI) Umudike.

2.2 Methods

2.2.1 Production of African yam bean starch

The method described by Sathe and Salunke (1981) was modified and used. African yam bean seeds were sorted and soaked in water for about 45 min. to soften the seed coat. Then the seeds were rasped between the palms and the softened testa was removed by decanting when floated. The dehulled seeds will then be oven dried (60^0C, 24 h) and milled into flour and pulverized using a mesh size of 0.4 mm, then a pack of 3 kg of bean flour will be extracted by the use of different solvents to produce starch.

2.2.2 Production of starch from cassava

Starch was produced from cassava using methods described by Moorthy *et al*. (1996). Roots of cassava were harvested, cleaned of dirt, peeled, washed and grated. The cassava mash produced was ground again and water mixed using the ratio of 1: 5 w/v %. Resulting mash was then passed in double layered nylon cloth to filter it and to obtain the resulting solution of starch. The resultant starch was separated using sedimentation method and the effluent was subsequently decanted. The produced starch was then put in the oven for drying at a temperature of 60^0C for 24 h.

2.2.3 Production of modified starches

A mono-type of cross-linked African yam bean and cassava starches was produced using the reagents: sodium acetate, a method described by Akpa and Dagde (2012). About 200g of native starches was weighed into a container made of plastic, 0.2g silicon oxide was added as a fluxing agent to the starch, then mixed for about 5 minutes then preceded with the addition of 20g of sodium hydroxide as an alkaline catalyst, then mixed for about 20 minutes, 29g of sodium acetate was also added to the mixture as a cross linking agent, then mixed for another 15 minutes. The mixture is then heated using water bath running at temperature of 75°C and stirred steadily for about 1 hour, then the mixture is poured out to cool.

2.2.4 Composite flour preparations

The composite flour made up of wheat flour (x_1) and chemically modified starches from African yam bean (x_2) and cassava (x_3) were prepared using the D – optimal mixture combination adopted from the experimental design generated from the design expert software as described in Table 1.

2.2.5 Formulation of enhanced bread

The method described by Demiate *et al*. (2000) was modified and adopted (Figure 1). Twelve grams of each blend of the Wheat: AYB: Cassava sample was partially cooked by addition of 10 ml of boiled de-ionized water over the mass. The recipe used in the production of enhanced bread runs was 50 g of flour, 0.5 g of salt, 3 g of sugar, 5 g of margarine, 1.5 g of yeast, and water. Both the dry and wet ingredients and flour – starch blends were mixed thoroughly using dough mixer for about 5 min. The mixed dough was allowed to prove in a bowel enclosed with clean damp muslin cloth for about 55 min at ambient temperature (28^0C) before kneading was performed twice for about 30 sec each thereafter preceded to about 60 min and 120 min respectively. The kneaded dough was divided into double fractions and were moulded into a loaf, placed in a baking tin and completed proving in the cabinet for about 30 min at 30^0C. The blend was homogenized and the dough were baked in an electric oven (200°C for 25 min).

2.3 Determination physical properties of bread

Physical characteristics of bread samples such as oven spring, loaf weight, loaf volume, specific loaf volume and bread density were evaluated.

2.3.1 Bread height

The bread height was determined using the method reported by AOAC (2005), in which a meter rule was used to measure the length of the bread.

2.3.2 Oven spring

The method reported by Makinde and Akinoso (2014) was adopted in which the oven spring was estimated from the difference in height of dough before and after baking.

2.3.3 Loaf weight

Loaf weight was measured 30 minutes after the loaves were removed from the oven using a laboratory scale (CE- 410I, Camry Emperors, China) and the readings recorded in grams

2.3.4 Loaf volume

Loaf volume as reported by Giami *et al.* (2004) was modified and used as follows: A cylinder of internal volume 5591.30 cm^3 was put in a tray, half filled with rice grains, shaken vigorously 4 times, then filled till slightly overfilled so that overspill fell into the tray. The box was shaken again twice, and then a straight edge was used to press across the top of the cylinder once to give a level surface. The seeds were decanted from the cylinder into a receptacle and weighed. The procedure was repeated three times and the mean value for seed weight was noted (C g).

A weighed loaf was placed in the cylinder and weighed seeds were used to fill the cylinder and levelled off as before. The overspill was extracted back into a receptacle and the loaf removed from the cylinder extracting the remaining seeds into another receptacle and weighed. The value for seed weight was noted (I g) and from the weight obtained the weight of seeds around the loaf and volume of seed displaced by the loaf were calculated using the following equations:

Seeds displaced by loaf (L g) = $C\ (g) - L\ (g)$

Volume of the loaf (g/cm^3) = $\frac{L\ (g)\ X\ Vol.\ of\ container\ (cm^3)}{C\ (g)}$

Where:

L = Weight of seeds displaced by loaf
C = Weight of seeds that filled the cylinder
I = Weight of seeds after loaf has been removed

2.3.5 Specific volume

The specific loaf volume was determined by dividing the loaf volume by its corresponding loaf weight (cm^3/ g) as described by Araki *et al*. (2009) as shown below:

Specific volume (cm^3/g) = $\frac{Loaf\ volume\ of\ bread}{Weight\ of\ bread}$

2.3.6 Bulk density

The method reported by AOAC (2005) was adopted in which the bulk density was measured with the equation as shown below:

Density (g/cm^3) = $\frac{Weight\ of\ bread}{Loaf\ volume\ of\ bread}$

2.4 Sensory evaluation

A sensory evaluation was also conducted on the baked dough. The attributes evaluated were appearance, crumb and crust, aroma and taste. The evaluation was carried out using 25 semi – trained panelists. The values generated for each attribute were averaged as the overall acceptability. Attributes were ranked on a 9 – point hedonic scale (1 = dislike extremely, 9 = like extremely).

2.5 Experimental design

The D – optimal mixture design of response surface methodology was used to achieve the goals of optimization as described by Da-Wen (2008). The method was used to generate predictive experimental models investigating the linear, binary and ternary effects of the mixture independent variables (wheat flour, chemically modified African yam bean and cassava starches) and their interactions on the physical and sensory properties of the enhanced bread. A total of 14 runs were generated as representation of the design points. Two runs were duplicated in – order to measure the internal error in between design points (Table 1). Analysis of variance (ANOVA) were determined on the physical and sensory properties of enhanced bread to evaluate model adequacy and fitness. A probability level (p<0.05) was used to judge model adequacy, non significant (p>0.05) lack-of-fit were also considered for model adequacy (Cornell, 1986). Other fitness statistics used were >0.7 adjusted R^2 and >4 adequate precision of the model (Table 2). All the plots generated for the adequate models, ANOVA and other fit statistics used for evaluating model adequacy was done using Design – Expert (Version 12.0.10, Stat – Ease Inc., Minneapolis, 2021) software. Cubic model was adopted using the equation below:

$$Y = \sum_{k=1}^{a} \beta_k x_k + \sum_{k \neq m}^{a} \beta_{km} x_k\, x_m + \sum_{k \neq m \neq n}^{a} \beta_{kmn} x_k\, x_m x_n + \varepsilon_{kmn}$$

Where, β_k represents the main effects, β_{km} represents the binary effects between the $k^{th}$and m^{th} components, β_{kmn} also represents the ternary effects in between the k^{th}, m^{th} and n^{th} components. The predicted response is taken as the Y, a is the product components (a = three product components), ε_{kmn} represents the experimental error used in measuring the mixture components from the experimental data. The cubic model (actual components) selected for the dependent variables (Y) is largely expressed with the equation below:

$$Y = \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 + \beta_{123} x_1 x_2 x_3$$

Where, Y represents the dependent variables predicted, $\beta's$ represents the model terms across the linear, binary and ternary effects of the model, thus, x_1 represents wheat flour, x_2 represents African yam bean starch and x_3 represents cassava starch. The criterion for the optimization of the dependent variables were presented and numerical optimization were used as described by Myers *et al.* (2009) as presented in Table 3 and 4. Validation of the model was done by generating the plot of predicted values against the actual values as described by Vining *et al.* (1993).

III. RESULTS AND DISCUSSION

3.1 Physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava

The result obtained for the physical properties of the bread samples produced from flour – starch blends were presented in Table 1.

3.1.1 Bread height

The bread height ranged from 3.5 cm – 6.4 cm, in which run 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the lowest mean value for bread height (3.5 cm), while run 82.5:10:7.5 (82.5 g wheat flour; 10 g African yam bean starch; 7.5 g cassava starch blends) had the highest mean score (6.4cm) for bread height. The linear effect of wheat flour (4.59 x_1), African yam bean starch (4.63 x_2) and cassava starch (6.61 x_3) significantly (p<0.05) increased the bread height with wheat flour contributing more to the effect followed by cassava starch while African yam bean had the least contribution for the bread height as represented in Table 2. The model showed significance (p = 0.0314) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.9671 with the adjusted R^2 >0.7 with the adequate precision ratio >4 which indicate adequate signal. The result obtained in the study compared favorably with the whole wheat (100% wheat) bread mean value (6.9 cm) for bread height reported by Onoja *et al.* (2014). The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on bread height as represented in Figure 2. Validation of the model was done by generating the plot of predicted values against the actual values with good correlation observed between the actual and real values (Figure 13). The final significant (p<0.05) model equation is given as:

$$Bread\ Height = 4.59\ x_1 + 4.63\ x_2 + 6.61\ x_3$$

3.1.2 Oven spring

The mean value for oven spring ranges from 0.7 cm – 3.2 cm, in which sample 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the lowest mean value for oven spring (0.7 cm), while sample 82.5:10:7.5 (82.5 g wheat flour; 10 g African yam bean starch; 7.5 g cassava starch blends) had the highest mean score (3.2 cm) for bread height. The result obtained from oven spring correlated with the mean values obtained for bread height dictating that the higher the oven spring, the higher the bread height. The linear effect of wheat flour ($1.73\,x_1$), African yam bean starch ($1.63\,x_2$) and cassava starch ($3.41\,x_3$) significantly (p<0.05) increased the oven spring with cassava starch contributing more to the effect followed by wheat flour while African yam bean had the least contribution for the oven spring as represented in Table 2. The model showed significance (p = 0.0348) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.8568 with the adjusted R^2 >0.7 with the adequate precision ratio >4 which indicate adequate signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on oven spring is represented in Figure 3. Validation of the model was done by generating the plot of predicted values against the actual values against the actual values with adequate correlation observed between the actual and real values (Figure 14). The final significant (p<0.05) model equation (actual components) is given as:

$$Oven\ spring\ = 1.73x_1 + 1.63\,x_2 + 3.41\,x_3$$

3.1.3 Loaf weight

The mean scores for loaf weight are presented in Table 1. The result observed ranged from 266.7 g – 442.05 g, in which sample 85:10:5 (85 g wheat flour; 10 g African yam bean starch; 5 g cassava starch blends) had the lowest mean value for loaf weight (266.7 g), while sample 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the highest mean score (442.05 g) for bread weight. The result obtained for loaf weight parameter was comparable to the mean range (227.25 to 240.20 g) of the composite bread samples produced and reported by Makinde and Akinoso (2014). The linear effect of wheat flour ($286.30\,x_1$), African yam bean starch ($349.19\,x_2$) and cassava starch ($362.57\,x_3$) increased the loaf weight significantly (p<0.05). The observed increase in loaf weight was as a result of less retention of carbon dioxide gas in the blended dough, hence providing dense bread texture (Rao and Hemamalini, 1991). The ternary effect of wheat flour and African yam bean starch ($-588.32\,x_1x_2(x_1 - x_2)$, wheat flour and cassava starch reduced the loaf weight significantly (p<0.05). The model is significant (p = 0.0447) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.9712 with the adjusted R^2 of 0.9565 with the adequate precision ratio >4 indicating an adequate signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 4. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 15). The final significant (p<0.05) model equation (actual components) is given as:

$$Loaf\ weight\ = 286.30x_1 + 349.19\,x_2 + 362.57x_3 - 588.32x_1x_2(x_1 - x_2)$$

3.1.4 Loaf volume

The mean values for loaf volume are presented in Table 4.1. The result obtained ranged from 254.71 cm^3 to 764.14 cm^3. The sample 80:15:5 (80 g; wheat flour; 15 g African yam bean starch; 5 g cassava starch blends) had the lowest mean value for loaf volume (254.71 cm^3) while run 82.5:10:7.5 (82.5 g wheat flour; 10 g African yam bean starch; 7.5 g cassava starch blends) and 80:12.5:7.5 (80 g wheat flour; 12.5 g African yam bean starch; 7.5 g cassava starch blends) had the highest mean scores (764.14 cm^3) for loaf volume. The linear effect of wheat flour ($492.15\,x_1$), African yam bean starch ($402.64\,x_2$) and cassava starch ($782.70\,x_3$) significantly (p<0.05) increased the loaf volume (Table 2). Contrarily, reductions in loaf volume as a result of blending wheat flour with more than 5% legume and oilseed flours and protein concentrates have been reported for sunflower (Yue *et al*., 1991), quinoa and soybean (Ndife *et al*., 2011). The model is significant (p = 0.0342) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.8586 with the adjusted R^2 >0.7 with the adequate precision ratio of 6.7660 indicating an adequate signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 5. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 16). The final significant (p<0.05) model equation (actual components) is given as:

$$Loaf\ volume\ = 492.15x_1 + 402.64\,x_2 + 782.70x_3$$

3.1.4 Specific volume

The mean values for specific volume are presented in Table 4.1. The result obtained ranged from 0.74 cm^3/g to 2.34 cm^3/g for specific volume response. The sample 80:15:5 (80 g wheat flour; 15 g African yam bean starch; 5 g cassava starch blends) had the lowest mean value for specific volume (0.74 cm^3/g), while run 82.5:10:7.5 (82.5 g wheat flour; 10 g African yam bean starch; 7.5 g cassava starch blends) and 80:12.5:7.5 (80 g wheat flour; 12.5 g African yam bean starch; 7.5 g cassava starch blends) had the highest mean scores for specific volume (2.34 cm^3/g). The linear effect of wheat flour ($1.62x_1$), African yam bean starch ($1.20x_2$) and cassava starch ($2.34x_3$) significantly (p<0.05) increased the specific volume (Table 2). The linear model is significant (p = 0.0278) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.9448 with the adjusted R^2 >0.7 with the adequate precision ratio of 5.4179 which indicate model adequacy. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 6. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 17). The final significant (p<0.05) model equation (actual components) is given as:

$$Specific\ volume\ = 1.62x_1 + 1.20x_2 + 2.34x_3$$

3.1.5 Bulk density

The mean values for bulk density oscillated from 0.43 to 1.36 g/cm^3, with runs 82.5:10:7.5 (82.5 g wheat flour; 10 g African yam bean starch; 7.5 g cassava starch blends) and 80:12.5:7.5 (80 g wheat flour; 12.5 g African yam bean starch; 7.5 g cassava starch blends) having the lowest mean scores (0.43 g/cm^3) for bulk density, while run 80:15:5 (80 g wheat flour; 15 g African yam bean starch; 5 g cassava starch blends) had the highest mean score (1.36 g/cm^3). The linear effect of wheat flour ($0.85x_1$), African yam bean starch ($1.29x_2$) and cassava starch ($0.49x_3$) significantly (p<0.05) increased the bulk density but, the binary effect of the wheat flour and cassava starch ($-0.28x_1x_3$) significantly (p<0.05) reduced the bulk density. The binary model is significant (p <0.0001) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.9495 with the adjusted R^2 of 0.7679 with the adequate precision ratio of 5.2117 which indicate model adequacy. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 7. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 18). The final significant (p<0.05) model equation (actual components) is given as:

$$Bulk\ density = 0.85x_1 + 1.29x_2 + 0.47x_3 - 0.28x_1x_3$$

3.2 Sensory evaluation of wheat bread enhanced with chemically modified starches from African yam bean and cassava

The result for the sensory evaluation of the bread runs is presented in Table 1. Run 85:10:5 (85 g wheat flour; 10 g African yam bean starch; 5 g cassava starch blends) compared poorly than the rest of other blends while run 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the best sensory scores for appearance, crumb and crust, taste and aroma which may be due to its moderate taste, bright appearance and taste of the runs (Bates, 1985).

3.2.1 Appearance

The result obtained for appearance ranged from 5.32 to 7.48 (Table 1). Sample 85:10:5 (85 g wheat flour; 10 g African yam bean starch; 5 g cassava starch blends) had the lowest mean score (5.32 = neither like nor dislike) for appearance while sample 84.5:10:5.5 (84.5g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the highest mean score (7.5 = like very much) (Table 1). The analysis of variance of the ternary model for appearance is presented in Table 2. The linear effect of wheat flour ($5.47x_1$), African yam bean starch ($6.08x_2$) and cassava starch ($6.65x_3$) significantly (p<0.05) increased the appearance of the bread, the binary effect of the wheat flour and African yam bean starch ($4.68x_1x_2$) and African yam bean and cassava starch ($3.77x_2x_3$) significantly (p<0.05) increased the appearance. The model is significant (p <0.0001) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.8277 with the adjusted R^2 >0.7 with the adequate precision ratio >4 indicating adequate model signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 8. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 19). The final significant (p<0.05) model equation (actual components) is given as:

$$Appearance = 5.47x_1 + 6.08x_2 + 6.65x_3 + 4.68x_1x_2 + 3.77x_2x_3$$

3.2.2 Crumb and crust

The results for crumb and crust are presented in Table 1. The mean ranged from 4.72 to 7.08. Run 85:10:5 (85 g wheat flour; 10 g African yam bean starch; 5 g cassava starch blends) had the lowest mean score (4.72 = neither like nor dislike) for the crumb and crust while sample 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the highest mean score (7.08 = like moderately). The analysis of variance of the model for crumb and crust is presented in Table 1. The linear effect of wheat flour ($4.86x_1$), African yam bean starch ($5.81x_2$) and cassava starch ($6.12x_3$) significantly (p<0.05) increased the crumb and crust of the bread, the binary effect of the wheat flour and African yam bean starch ($2.08x_1x_3$). The ternary effect of African yam bean and cassava starch ($-11.20x_2x_3(x_2 - x_3)$) significantly (p<0.05) reduced the crumb and crust of the bread. The model is significant (p = 0.0268) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.8169 with the adjusted R^2 >0.7 with the adequate precision ratio >4 indicating adequate model signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 9. Validation of the model was done by generating the plot of predicted values against the actual value with adequate correlation observed between the actual and real values (Figure 20). The final significant (p<0.05) model equation (actual components) is given as:

$$Crumb\ and\ crust = 4.86x_1 + 5.81x_2 + 6.12x_3 + 2.08x_1x_3 - 11.20x_2x_3(x_2 - x_3)$$

3.2.3 Taste

The mean value for taste ranged from 5.32 to 7.24. Run 80:15:5 (80 g wheat flour; 15 g African yam bean starch; 5 g cassava starch blends) had the lowest mean score (5.32 = neither like nor dislike) for taste while sample 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the highest mean score (7.24 = like moderately). The analysis of variance of the model for taste is presented in Table 2. The linear effect of wheat flour ($4.06x_1$), African yam bean starch ($5.30x_2$) and cassava starch ($5.52x_3$) significantly (p<0.05) increased the taste of the bread, the binary effect of the African yam bean and cassava starch ($6.90x_2x_3$) also significantly (p<0.05) increased the taste. The model is significant (p = 0.0323) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.9547 with the adjusted R^2 >0.7 with the adequate precision ratio >4 indicating adequate model signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 10. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 21). The final significant (p<0.05) model equation (actual components) is given as:

$$Taste = 4.06x_1 + 5.30x_2 + 5.52x_3 + 6.90x_2x_3$$

3.2.4 Aroma

The mean values obtained ranged showed from 5.2 to 7.36. Run 80.83:10.83:8.34 (80.83 g wheat flour; 10.83 g African yam bean starch; 8.34 g cassava starch blends) had the lowest mean score (5.2 = neither like nor dislike) for aroma parameter while sample 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the highest mean score (7.36 = like moderately) (Table 1). The analysis of variance of the model is presented in Table 2. The linear effect of wheat flour ($4.20x_1$), African yam bean starch ($5.09x_2$) and cassava starch ($5.75x_3$) significantly (p<0.05) increased the aroma of the bread The binary effect of wheat flour and cassava starch ($3.18x_1x_3$) also significantly (p<0.05) increased the aroma. The ternary effect of wheat flour, African yam bean and cassava starch ($-5.96x_1x_2x_3$) reduced the aroma of the bread significantly (p<0.05). The model is significant (p <0.0001) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.8608 with the adjusted R^2 >0.7 with the adequate precision ratio >4 indicating adequate model signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 11. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 22). The final significant (p<0.05) model equation (actual components) is given as:

$$Aroma = 4.20x_1 + 5.09x_2 + 5.75x_3 - 5.96x_1x_2x_3$$

3.2.5 Acceptability

The results for acceptability are presented in Table 1. The mean ranged from 4.41 to 7.29. Run 85:10:5 (85 g wheat flour; 10 g African yam bean starch; 5 g cassava starch blends) had the lowest mean score (4.41 = dislike slightly) for acceptability while run 84.5:10:5.5 (84.5 g wheat flour; 10 g African yam bean starch; 5.5 g cassava starch blends) had the highest mean score (7.29 = like moderately). The analysis of variance of the model is presented in Table 1. The linear effect of wheat flour ($4.65x_1$), African yam bean starch ($5.57x_2$) and cassava starch ($6.01x_3$) significantly (p<0.05) increased the acceptability of the bread. The binary effect of the wheat flour and African yam bean starch ($4.72x_1x_2$) and wheat flour and cassava starch ($6.90x_1x_3$) combination also increased the acceptability significantly (p<0.05). The model is significant (p <0.0001) with non significant (p>0.05) lack-of-fit relative to the pure error. The fit statistics had R^2 of 0.8459 with the adjusted R^2 >0.7 with the adequate precision ratio >4 indicating adequate model signal. The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on loaf weight is represented in Figure 12. Validation of the model was done by generating the plot of predicted values against the actual values with adequate correlation observed between the actual and real values (Figure 23). The final significant (p<0.05) model equation (actual components) is given as:

$$Acceptability = 4.65x_1 + 5.57x_2 + 6.01x_3 + 4.72x_1x_2 + 6.90x_1x_3$$

3.3 Optimization of wheat bread enhanced with chemically modified starches from African yam bean and cassava

The optimization of all the significant (p<0.05) responses of the flour – starch blends was evaluated using numerical optimization generated from Design Expert software (Version 12.0.10, Stat-Ease, Inc., Minneapolis, USA). The optimization applied desirability function ranked between 0 and 1 scale which shows the closeness of a dependent response to its ideal value; if the dependent response ranks within the unacceptable intervals, the desirability value is zero (0), also if the response falls within 0.5, the desirability is in neutrality (neither accepted nor rejected) and finally if the response falls within the ideal intervals or the response reaches the ideal value, the desirability is one (1). The goal of the optimization focused on maximizing the desirable responses (dependent variables) and reducing the undesirable responses where the goals, lower-limit, upper-limit, lower-weight, upper-weight and importance were pre-set for both the dependent and independent variables (Table 3). The optimum values generated (Wheat flour: 80.15 g, African yam bean starch: 11.32 g, cassava starch: 8.53 g: bread height: 6.01 cm, oven spring: 2.89 cm, loaf weight: 364.25 g, loaf volume: 673.51 cm^3, specific volume: 2.02 cm^3/g, bulk density: 0.39 g/ cm^3, appearance: 7.70, crumb and crust: 7.27, taste: 7.26, aroma: 6.82 and acceptability: 7.26) with desirability of 0.86 selected (Table 4). The 3D plot showing the effect of wheat flour, African yam bean starch and cassava starch on desirability is represented in Figure 24.

3.4 Optimization confirmations (Two – sided Confidence Interval = 95 %)

The confirmation of the optimization run is presented in Table 5 showing optimum values (Two – sided Confidence Interval (CI) = 95 %) for the evaluation and optimization of the sensory and physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava. The prediction interval (PI) annexed for the confirmation attribute, The PI high and low indicates a range in which the data mean will fall within, if the data mean falls below the PI low or higher than the PI high, the optimization is not confirmed. The Standard deviation (Std Dev) also indicates variability from the data mean which are close to each value. The standard error predicted (SE Pred) indicates that the data means are reliable. Therefore, 80.15 g of wheat flour, 11.23 g of African yam bean starch, and 8.53 g of cassava starch yielded an optimized enhanced bread.

IV. CONCLUSION

D – optimal mixture design of response surface methodology (RSM) showed adequate signal in the evaluation and optimization of the sensory and physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava. The optimization of the responses (dependent variables) of the physical properties of the bread (bread height, oven spring, loaf weight, loaf volume, specific volume and bulk density) showed adequate models. Also, the sensory properties (appearance, crumb and crust, taste, aroma and acceptability) were evaluated and optimized with adequate signals used in the propagating of the design space observed. The optimized acceptability of the bread was ranked 7.26 (liked moderately) on hedonic rating. The 3D response surface plotted the linear, binary and ternary effects of the wheat flour, African yam bean and cassava starches. Diagnostic correlations using the predicted and actual values was used to validate the adequate models. The optimized blends selected were 80.15 g of wheat flour, 11.23 g of African yam bean starch, and 8.53 g of cassava starch with the desirability of 0.86 which is the suggested optimized blend with improves responses. The desirability trace plot (piepel view) is presented in Figure 25. The beneficiaries of the developed models would be processors seeking an enhanced bread with a legume-based starch product and wheat flour fractional replacements.

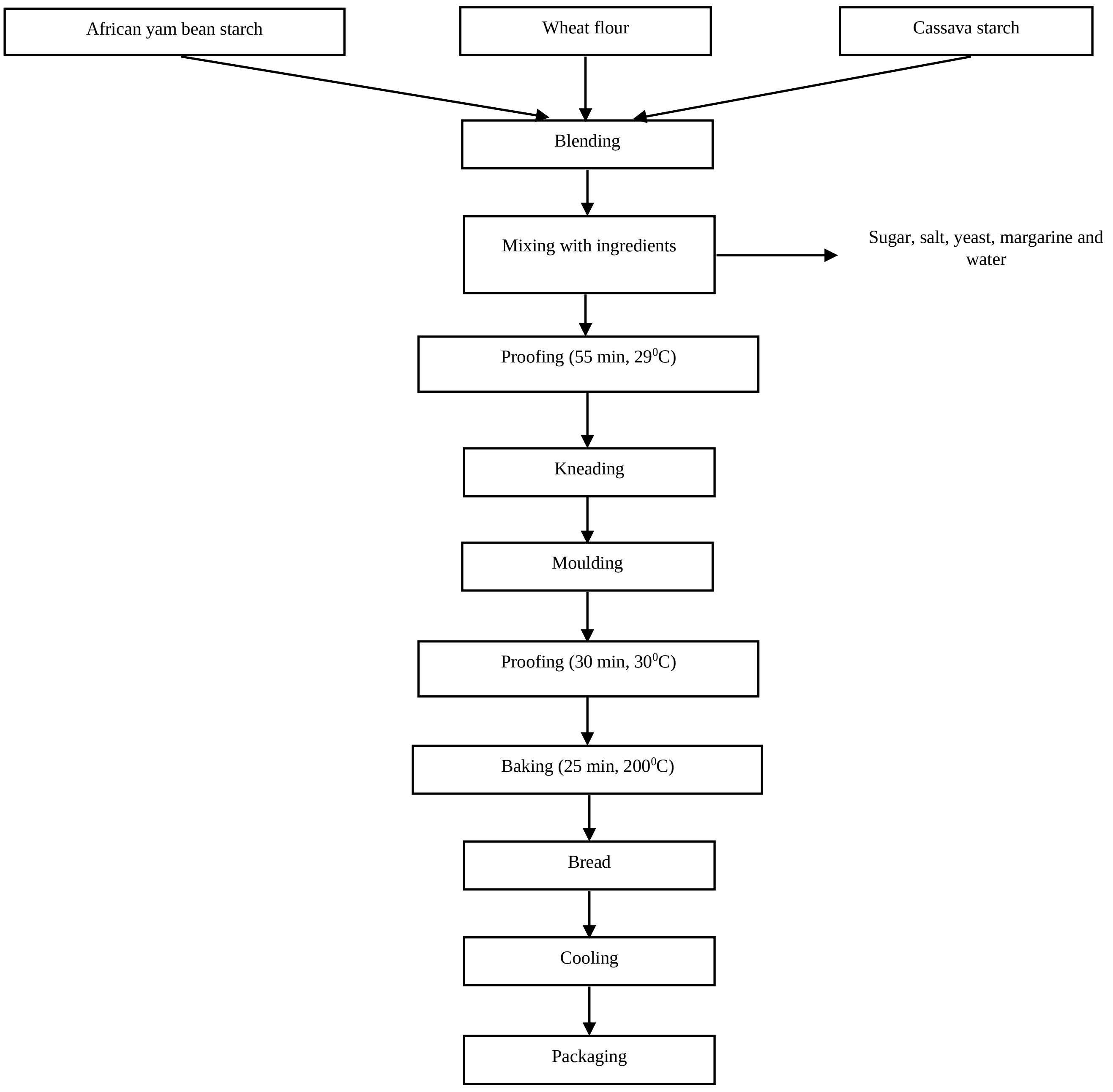

Figure 1: Flow diagram for the production of wheat bread enhanced with chemically modified starches from African yam bean and cassava

Source: Demiate *et al*. (2000)

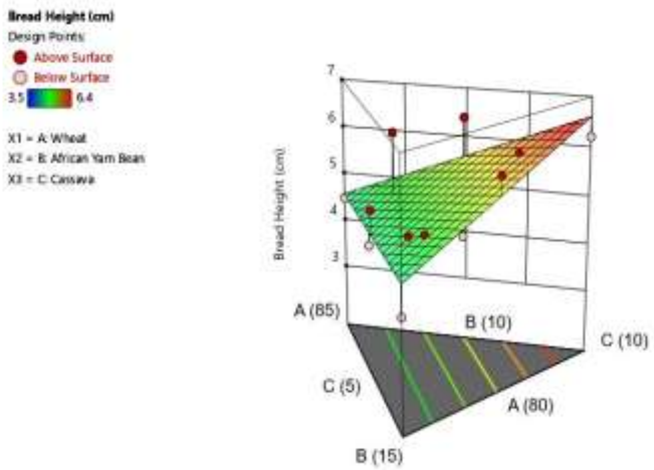

Figure 2: 3D plot for bread height

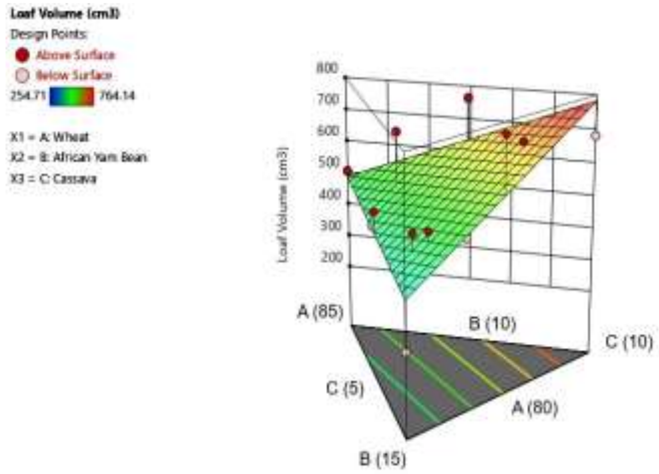

Figure 5: 3D plot for loaf volume

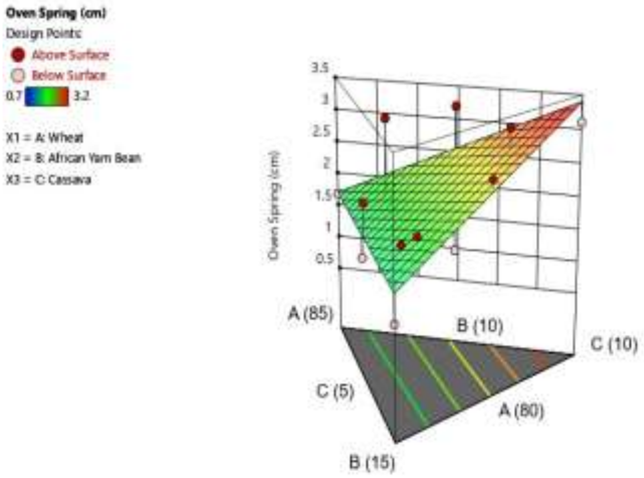

Figure 3: 3D plot for oven spring of bread

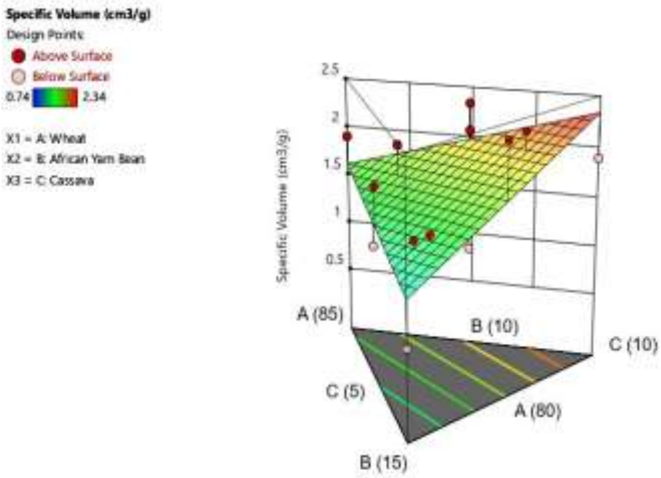

Figure 6: 3D plot for specific volume of bread

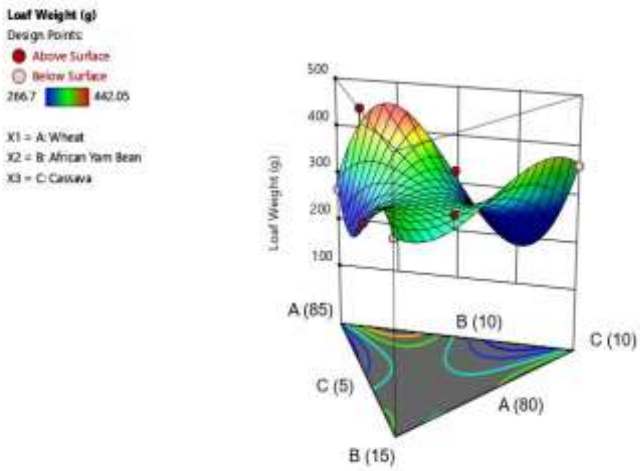

Figure 4: 3D plot for loaf weight

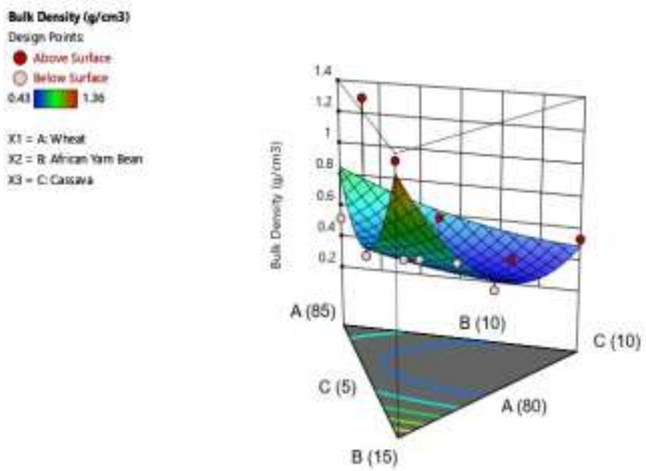

Figure 7: 3D plot for bulk density of bread

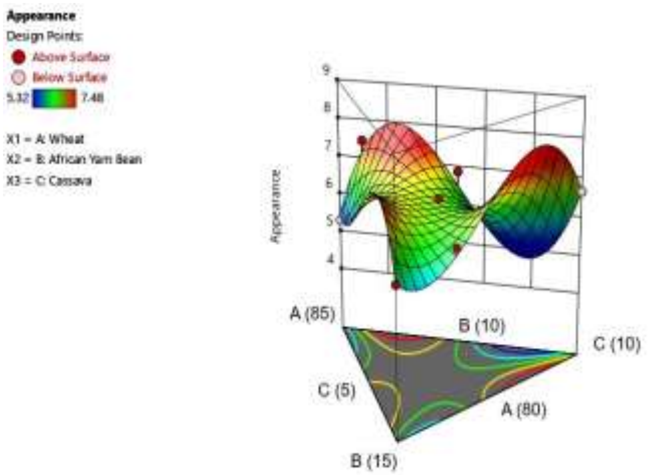

Figure 8: 3D plot for the appearance of bread

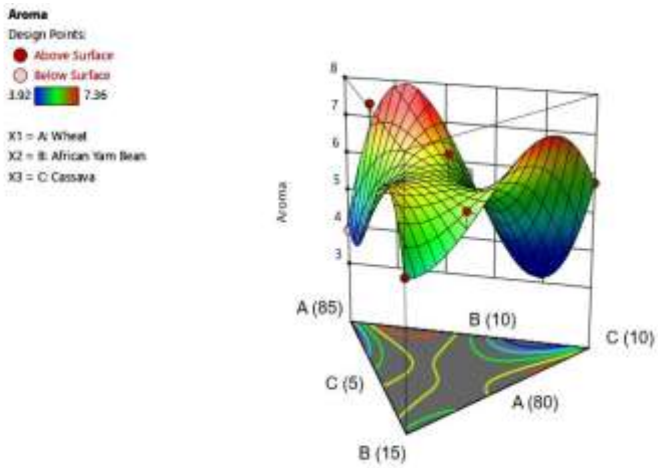

Figure 11: 3D plot for the aroma of bread

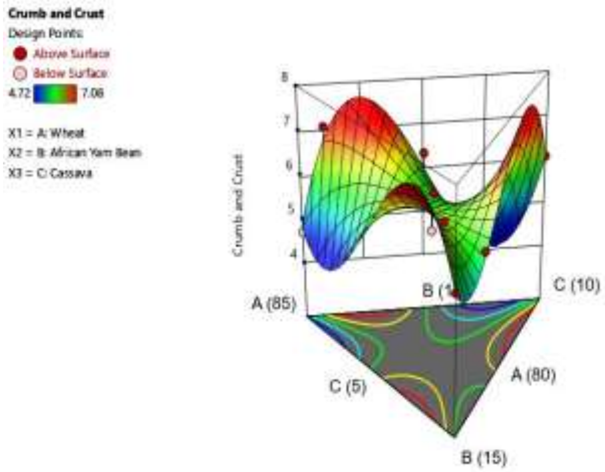

Figure 9: 3D plot for the crumb and crust of bread

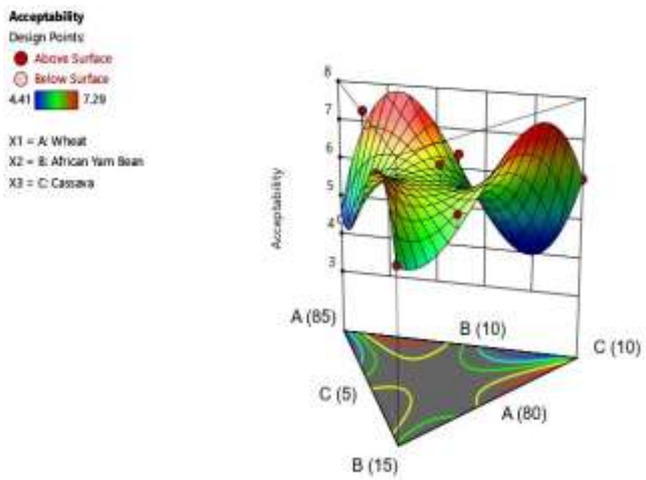

Figure 12: 3D plot for the acceptability of bread

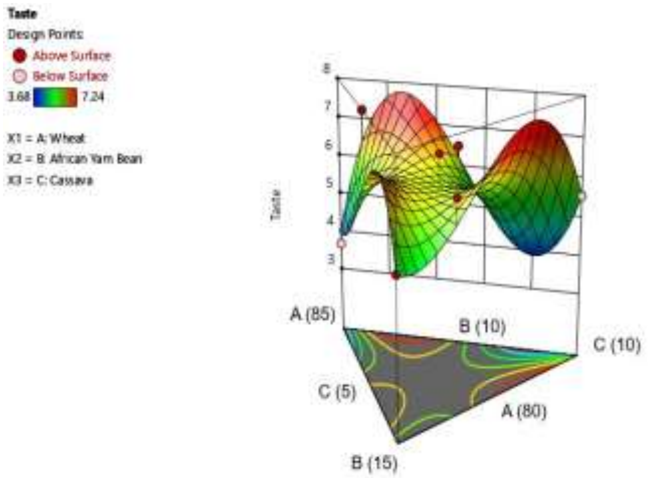

Figure 10: 3D plot for the taste of bread

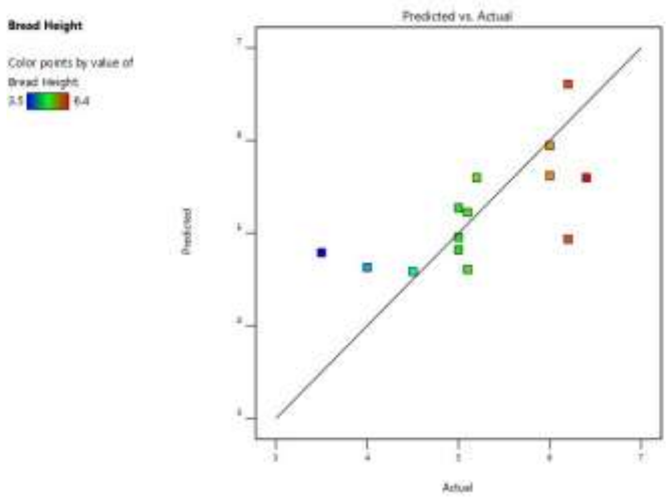

Figure 13: Plot of predicted againstactual value for the bread height

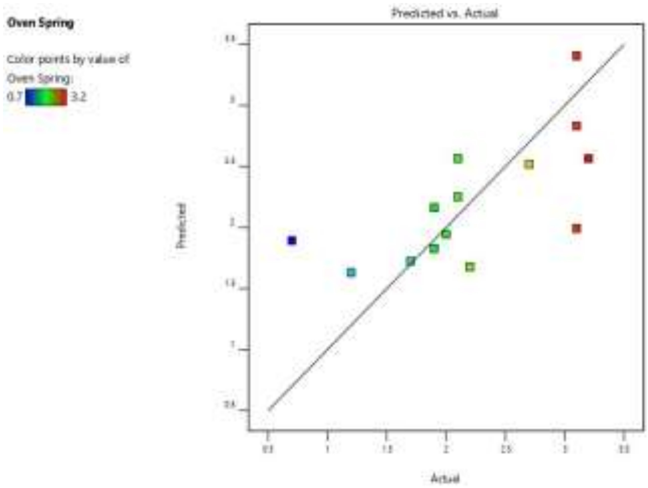

Figure 14: Plot of predicted against actual value for the oven spring of bread

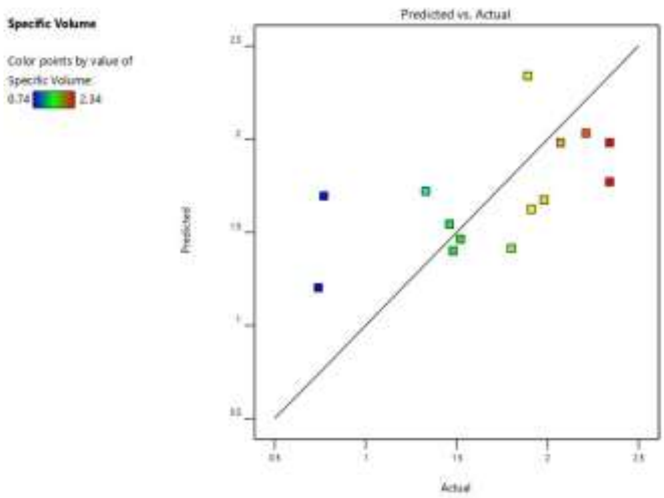

Figure 17: Plot of predicted against actual value for the specific volume of bread

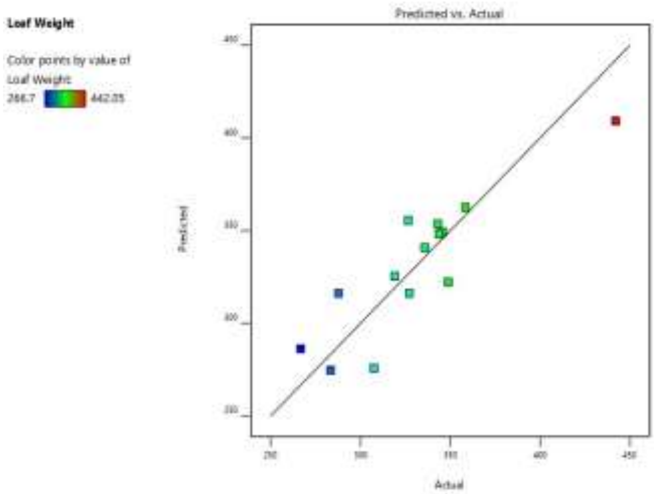

Figure 15: Plot of predicted against actual value for the loaf weight

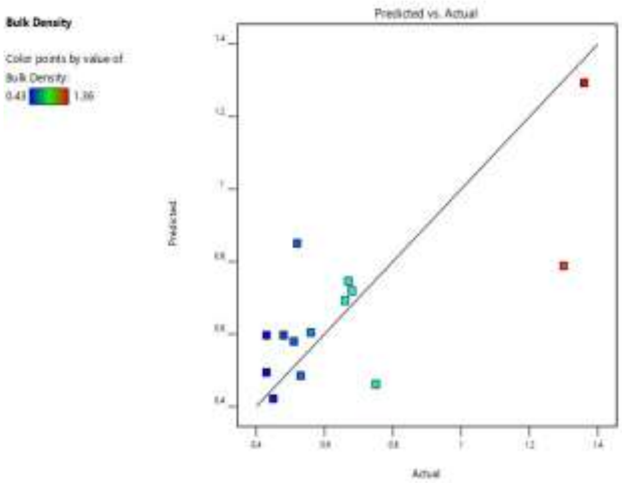

Figure 18: Plot of predicted against actual value for the bulk density of bread

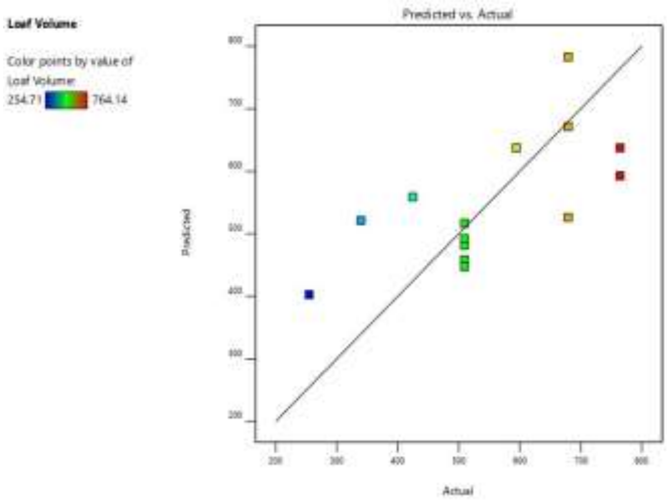

Figure 16: Plot of predicted against actual value for the loaf volume

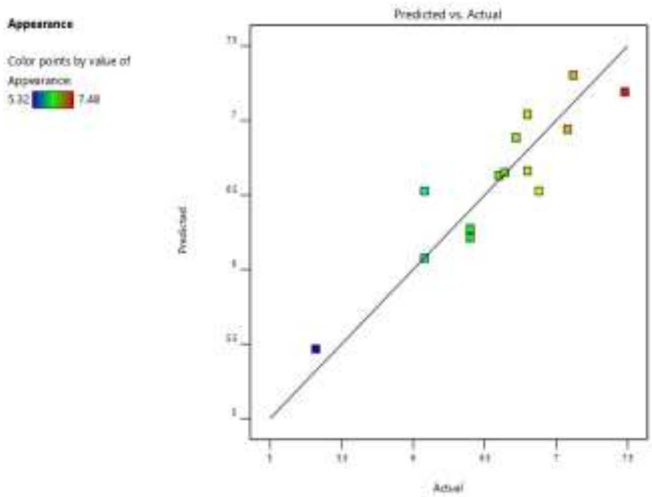

Figure 19: Plot of predicted against actual value for the appearance of bread

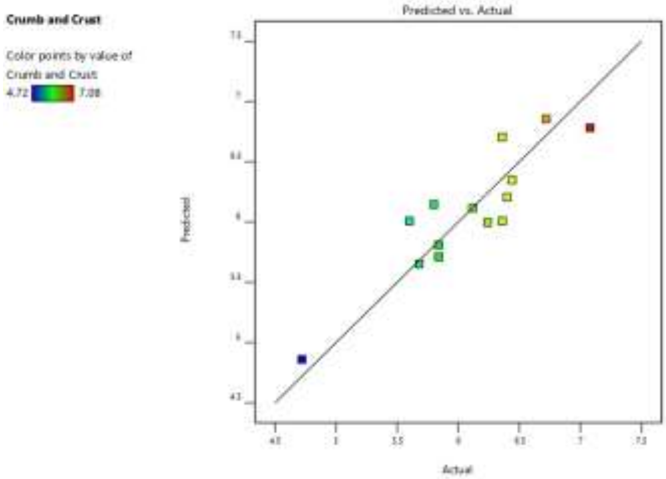

Figure 20: Plot of predicted against actual value for the crumb and crust of bread

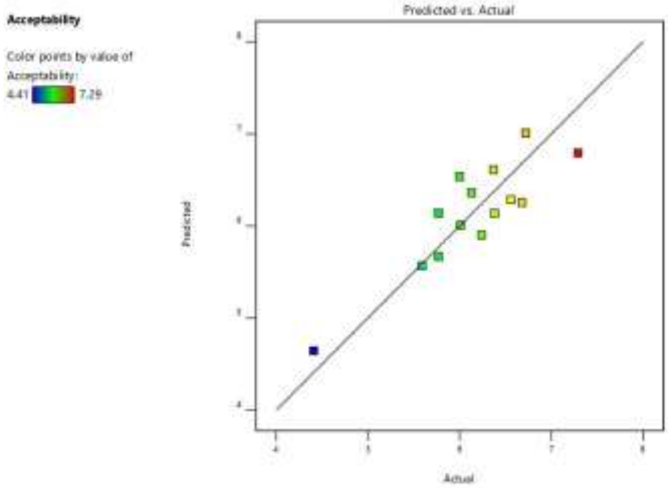

Figure 23: Plot of predicted against actual value for the acceptability of bread

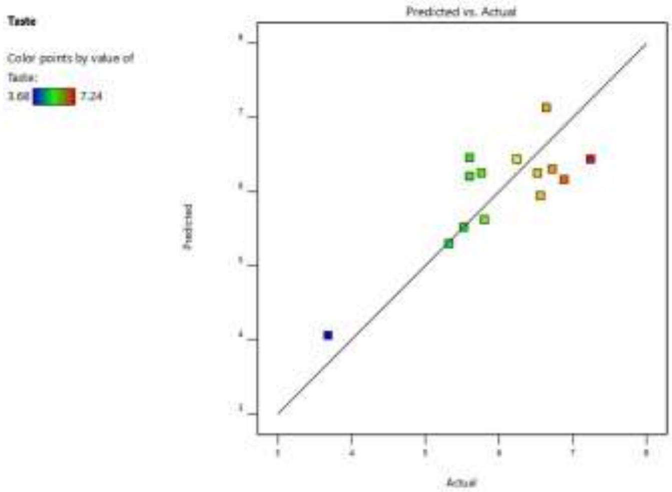

Figure 21: Plot of predicted against actual value for the taste of bread

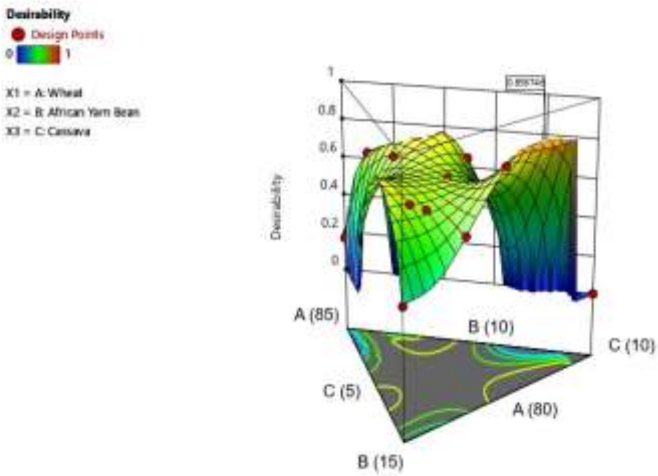

Figure 24: 3D plot for the desirability (0.86) of the bread

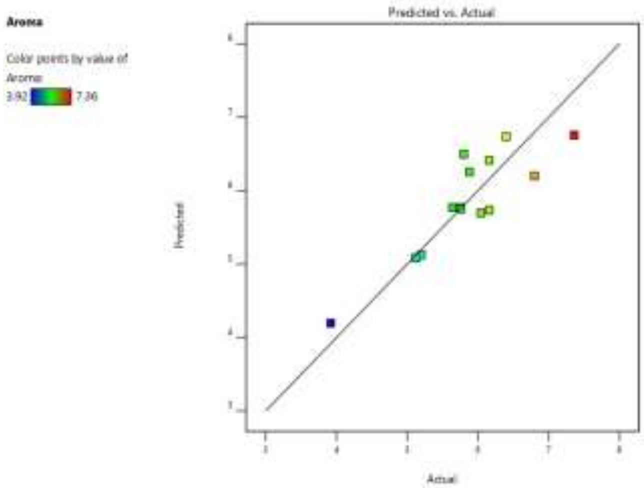

Figure 22: Plot of predicted against actual value for the aroma of bread

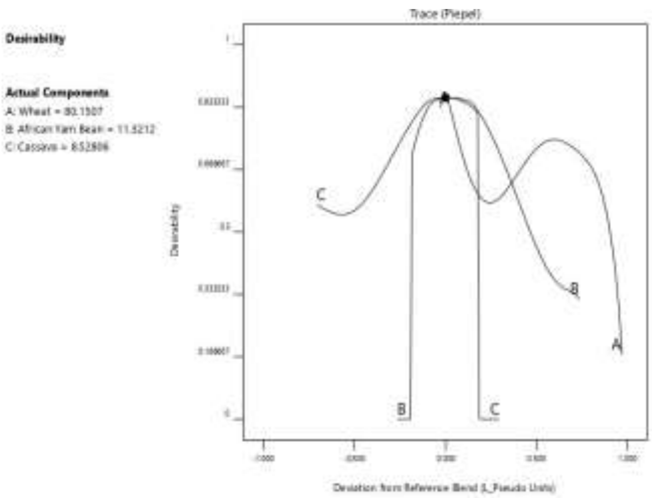

Figure 25: Trace (Piepel) plot for the desirability (0.86) of the bread

Table 1: Three component D – optimal mixture design for the evaluation and optimization of the sensory and physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava

Design points	Independent variables			Dependent variables										
	x_1 (g)	x_2 (g)	x_3 (g)	Bread Height (cm)	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Volume (cm^3/g)	Bulk Density (g/cm^3)	Appearance	Crumb and Crust	Taste	Aroma	Acceptability
1	80	10	10	6.2	3.1	358.46	679.24	1.89	0.53	6.64	6.12	5.52	5.76	6.01
2	80.83	10.83	8.34	6	3.1	307.53	679.24	2.21	0.45	6.4	5.68	5.8	5.2	5.77
3	85	10	5	4.5	1.7	266.7	509.43	1.91	0.52	5.32	4.72	3.68	3.92	4.41
4	82.5	10	7.5	6.4	3.2	327.23	764.14	2.34	0.43	6.88	6.36	6.52	5.76	6.38
5	82.5	10	7.5	5.2	2.1	287.71	594.33	2.07	0.48	6.08	5.6	5.76	5.64	5.77
6	80	13.5	6.5	5.1	1.9	348.85	509.43	1.46	0.68	6.4	5.84	6.56	6.16	6.24
7	80.83	13.33	5.84	5	2	335.84	509.43	1.52	0.66	6.6	6.44	5.6	5.88	6.13
8	82.5	12.5	5	5.1	2.2	283.39	509.43	1.8	0.56	7.08	6.4	6.72	6.04	6.56
9	81.67	11.67	6.66	5	2.1	319.11	424.52	1.33	0.75	6.8	6.24	6.88	6.8	6.68
10	80	12.5	7.5	6	2.7	326.55	764.14	2.34	0.43	7.12	6.72	6.64	6.4	6.72
11	81	13.5	5.5	5	1.9	343.75	509.43	1.48	0.67	6.72	6.36	6.24	6.16	6.37
12	83.33	10.83	5.84	6.2	3.1	343.06	679.24	1.98	0.51	6.8	5.8	5.6	5.8	6
13	80	15	5	4	1.2	345.73	254.71	0.74	1.36	6.08	5.84	5.32	5.12	5.59
14	84.5	10	5.5	3.5	0.7	442.05	339.62	0.77	1.3	7.48	7.08	7.24	7.36	7.29

x_1- Wheat flour; x_2- *African yam bean* starch; x_3- cassava starch

Table 2: Regression equation coefficients for the evaluation and optimization of the sensory and physical properties of wheat bread enhanced

Coefficients	Dependent variable										
	Bread Height (cm)	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Volume (cm^3/g)	Bulk Density (g/cm^3)	Appearance	Crumb and Crust	Taste	Aroma	Acceptability
Linear											
x_1 (p-values)	4.58851* (0.0314)	1.72547* (0.0348)	286.292* (0.0493)	492.149* (0.0342)	1.6233* (0.0278)	0.850483* (<0.0001)	5.468* (<0.0001)	4.85933* (0.0374)	4.05973* (0.0139)	4.19738* (<0.0001)	4.64611* (<0.0001)
x_2 (p-values)	4.63096* (0.0314)	1.63127* (0.0348)	349.188* (0.0493)	402.637* (0.0342)	1.20276* (0.0278)	1.29335* (<0.0001)	6.07634* (<0.0001)	5.80805* (0.0374)	5.29867* (0.0388)	5.08723* (<0.0001)	5.56757* (<0.0001)
x_3 (p-values)	6.6088* (0.0314)	3.40655* (0.0348)	362.567* (0.0493)	782.697* (0.0342)	2.33912* (0.0278)	0.485398* (<0.0001)	6.65105* (<0.0001)	6.11563* (0.0374)	5.52037* (0.0335)	5.75117* (<0.0001)	6.00955* (<0.0001)
Binary											
x_1x_2 (p-values)	-	-	-172.016 (0.3662)	-	-	-1.87107 (0.1026)	4.67699* (0.0461)	3.49025 (0.1652)	6.49874 (0.2148)	4.22114 (0.2618)	4.72178* (<0.0001)
x_1x_3 (p-values)	-	-	-32.865 (0.8314)	-	-	-0.284418* (0.0256)	1.87197 (0.3059)	2.08188* (<0.0001)	5.84027 (0.1971)	3.18401* (<0.0001)	3.24453 (0.2356)
x_2x_3 (p-values)	-	-	-1.4596 (0.9935)	-	-	-1.5808 (0.1650)	3.766* (0.0133)	3.57413 (0.1574)	6.8941* (0.0431)	5.27102 (0.1782)	4.87631* (0.0170)
Ternary											
$x_1x_2x_3$ (p-values)	-	-	419.882 (0.7201)	-	-	-	-14.8768 (0.2843)	-16.6478 (0.2789)	-25.3149 (0.4248)	-5.96225* (0.0375)	-15.7004 (0.4217)
$x_1x_2(x_1-x_2)$ (p-values)	-	-	-588.32* (0.0307)	-	-	-	-7.13129 (0.2354)	-13.3429 (0.0773)	-8.51429 (0.5205)	-10.9816 (0.2832)	-9.99252 (0.2509)
$x_1x_3(x_1-x_3)$ (p-values)	-	-	1641.99 (0.2730)	-	-	-	19.9654 (0.4226)	22.3543 (0.1200)	23.7021 (0.1446)	29.4154 (0.7895)	23.8593 (0.4016)
$x_2x_3(x_2-x_3)$ (p-values)	-	-	-364.442 (0.4781)	-	-	-	-9.82974 (0.1286)	-11.1991* (0.0215)	-10.34 (0.4436)	-7.82242 (0.4302)	-9.79782 (0.2613)
R^2	0.9671	0.8568	0.9712	0.8586	0.9448	0.9495	0.8277	0.8169	0.9547	0.8608	0.8459
Adj R^2	0.8702	0.7581	0.9565	0.7601	0.8256	0.7679	0.7400	0.7051	0.8223	0.7725	0.7680
LoF	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV (%)	13.09	27.33	10.94	21.99	26.61	10.33	6.06	7.25	15.76	11.84	9.49
Adeq Precision	6.3770	6.3370	4.3904	6.7660	5.4179	5.2117	5.4386	5.3497	4.8425	4.3678	4.7955
Model	0.0314*	0.0348*	0.0447*	0.0342*	0.0278*	<0.0001*	<0.0001*	0.0268*	0.0323*	<0.0001	<0.0001

Key: LoF -Lack of Fit; * Significant at the 5% confidence interval ($p<0.05$). NS - Not Significant; CV- Coefficient of Variation; Adj – Adjusted; Adeq – Adequate; x_1- Wheat flour; x_2- *African yam bean* starch; x_3- cassavastarch.

Table 3: Numerical optimization goals for the evaluation and optimization of the sensory and physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava

Variables	Goal	Lower Limit	Upper Limit	Lower Weight	Upper Weight	Importance
Independent variables						
Wheat (g)	is in range	80	85	1	1	3
African Yam Bean (g)	is in range	10	15	1	1	3
Cassava (g)	is in range	5	10	1	1	3
Dependent variables						
Bread Height (cm)	is in range	3.5	6.4	1	1	3
Oven Spring (cm)	is in range	0.7	3.2	1	1	3
Loaf Weight (g)	minimize	266.7	442.05	1	1	3
Loaf Volume (cm^3)	is in range	254.71	764.14	1	1	3
Specific Volume (cm^3/g)	maximize	0.74	2.34	1	1	3
Bulk Density (g/$cm^{3)}$	minimize	0.43	1.36	1	1	3
Appearance	maximize	5.32	7.48	1	1	3
Crumb and Crust	maximize	4.72	7.08	1	1	3
Taste	maximize	3.68	7.24	1	1	3
Aroma	maximize	3.92	7.36	1	1	3
Acceptability	maximize	4.41	7.29	1	1	3

Table 4: Optimization values, predictions and desirability index of the evaluation and optimization of the sensory and physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava

S/N	Wheat (g)	African Yam Bean (g)	Cassava (g)	Bread Height (cm)	Oven Spring (cm)	Loaf Weight (g)	Loaf Volume (cm^3)	Specific Volume (cm^3/g)	Bulk Density (g/cm^3)	Appearance	Crumb and Crust	Taste	Aroma	Acceptability	Desirability	
1	**80.151**	**11.321**	**8.528**	**6.025**	**2.887**	**364.249**	**673.510**	**2.017**	**0.394**	**7.695**	**7.267**	**7.263**	**6.821**	**7.261**	**0.859**	**Selected**
2	80.000	12.041	7.959	5.801	2.682	372.921	627.565	1.875	0.433	7.762	7.350	7.554	7.101	7.442	0.844	

Table 5: Confirmation for the optimization runs (Two - sided confidence = 95 %) for the evaluation and optimization of the sensory and physical properties of wheat bread enhanced with chemically modified starches from African yam bean and cassava

Response	Predicted Mean	Predicted Median	Observed	Std Dev	n	SE Pred	95% PI low	Data Mean	95% PI high
Bread Height	6.02527	6.02527	5.13847	0.684388	14	0.371774	5.207	5.22857	6.84354
Oven Spring	2.88677	2.88677	2.21539	0.605186	14	0.32875	2.1632	2.21429	3.61035
Loaf Weight	364.249	364.249	319.84	36.234	14	50.1187	225.097	331.14	503.4
Loaf Volume	673.51	673.51	547.235	121.346	14	65.9179	528.426	551.881	818.595
Specific Volume	2.01726	2.01726	1.50453	0.453095	14	0.246131	1.47553	1.70286	2.55899
Bulk Density	0.394201	0.394201	0.578277	0.255466	14	0.171174	-0.000527236	0.666429	0.788929
Appearance	7.69455	7.69455	5.9	0.399698	14	0.55286	6.15957	6.6	9.22954
Crumb and Crust	7.26675	7.26675	7.35376	0.441475	14	0.610647	5.57132	6.08571	8.96218
Taste	7.26317	7.26317	6.81533	0.946374	14	1.30902	3.62874	6.00571	10.8976
Aroma	6.82114	6.82114	5.92708	0.693447	14	0.959173	4.15805	5.85714	9.48423
Acceptability	7.2614	7.2614	5.82013	0.582674	14	0.805952	5.02372	6.13714	9.49908

Std Dev – Standard Deviation, SE Pred – Standard Error Predicted, PI – Prediction Interval, n- number of confirmations run

REFERENCES

[1] Akpa, J. G. & Dagde, K. K. (2012). Modification of Cassava Starch for Industrial Uses. International Journal of Engineering and Technology, 2 (2): 3-10

[2] AOAC (2005). Association of Official and Analytical Chemists. 19th Edn. Association of Official Analytical Chemists, Washington, D.C. USA.

[3] Araki, E., Ikeda, M.T., Ashida, K., Tanaka, K., Yanaka, M. & Iida, S. (2009). Effects of rice flour properties on specific loaf volume of one-loaf bread made from rice flour with wheat vital gluten. Journal of Food Science and Technology Research 15 (4): 439 – 448.

[4] Bates, D.M. (1985). Plant utilization: patterns and prospect. Economic Botany 39: 241 265.

[5] Da-Wen, S. (2008). Optimization in Food Engineering. Engineering series. CRC. Taylor and Francis Group. L.L.C. pp. 115 – 139.

[6] Delcour, J.A. & Hoseney, R.C. (2009). Principles of Cereal Science and Technology. AACC Int. Inc. Minnesota.

[7] Demiate, I.M., Dupuy, N., Huvenne, J.P., Cereda, M.P. & Wosiacki, G. (2000). Relationship between baking behaviour of modified cassava starches and starch chemical structure determined by FTIR spectroscopy. Carbohydrate Polymers, 42: 149-158.

[8] Giami, S.Y., Amasisi, T. and Ekiyor, G. (2004). Comparison of breadmkaing properties of composite flour from kernels of roasted and boiled African breadfruit (Treculia africana) seeds. Journal of Raw Material Research, 1: 16-25.

[9] Grace, M. R. (1977), Cassava Processing, FAO Plant Production and Protection Series No. 3, 2.

[10] Huber, K.C. & BeMiller, J.N. (2010). Modified starch: Chemistry and properties. In: Bertolini AC (ed) Starches: Characterization, Properties and Applications. CRC Press, Florida, pp.145-203.

[11] Keswet, L. M., Ayo, J. A. & Bello, C. B. (2003). The Effect of Four Nigerian Wheat Flours on the Loaf Volume and Sensory Quality of bread. Nutrition and Food Science., 33 (1): 34 – 37. https://doi.org/10.1108/00346650310459554

[12] Lagrain, B., Wilderjans, E., Glorieux, C. & Delcour, J.A. (2013). Role of Gluten and Starch in Crumb Structure and Texture of Fresh and Stored Straight Dough Bread. Inside Food Symposium, 9-12 April, Leuven, Belgium.

[13] Makinde, F. M. & Akinoso, R. (2014). Physical, nutritional and sensory qualities of bread samples made with wheat and black sesame (Sesamum indicum Linn) flours. International Food Research Journal 21(4): 1635-1640.

[14] Miyazaki, M., Maeda, T. & Morita, N. (2008). Bread quality of frozen dough substituted with modified tapioca starches. Eur. Food Res. Technol. 227:503-509.

[15] Moorthy, S. N., Wenhem, J. P. & Blanshard, J. M. V. (1996). Effects of solvent extraction on the gelatinization properties of flour and starch of five cassava varieties, Journal of Science Food and Agriculture, 72, 329-336.

[16] Myers, R.H., Montgomery, D.C., & Anderson-Cook, C.M. (2009). Response Surface Methodology: Process and Product Optimization Using Designed Experiments. (4th edition) New York, USA, John Wiley & Sons

[17] Ndife, J., Abdulraheem, L.O. & Zakari, U.M. (2011). Evaluation of the nutritional and sensory quality of functional breads produced from whole wheat and soya bean flour blends. African Journal of Food Science 5(8): 466 – 472.

[18] Oluwale, B.A., Ilori, M.O., Ayeni, Y. & Ogunjemilua, E.M. (2018). Assessment of Cassava Composite Flour Inclusion in Bread Production in Southwestern Nigeria. Journal of Food Processing & Technology 9(11): 760. https://doi.org/10.4172/2157-7110.1000760

[19] Onoja, U.S., Akubor, P.I., Njoku, I., Atama, C.I., Onyishi, G.C., Ekeh, F.N., Eyo, J.E. & Ejere, V.C. (2014). Nutritional composition, functional properties and sensory evaluation of breads based on blends of 'orarudi' (Vigna spp.) and wheat flour. Academic Journals, 9 (24): 1119 – 1026.

[20] Onyekwere, O. O. (1977). Current Situations of Bread Baking Industries in Nigeria, Proceedings of the Launching and First Annual Conference of Nigeria Institute of Food Science and Technology, 5 May, Lagos.

[21] Rao, H.P. & Hemamalini, R. (1991). Effect of incorporating wheat bran on rheological characteristics and bread making quality of flour. Journal of Food Science and Technology 28: 92-97.

[22] Sathe, S.K. & Salunkhe, D.K. (1981). Isolation, partial characterization and modification of the Northern bean (Phaseous vulgarris L.) starch. Journal of Food Science. 46: 617-621.

[23] Singh, J. Kaur, L. & McCarthy, O.J. (2007). Factors Influencing the Physicochemical, Morphological, Thermal and Rheological Properties of some Chemically Modified Starches for Food Applications – A Review. Food Hydrocolloid. 21:1-22.

[24] Uguru, M.I., & Madukaife, S.O. (2001). Studies on the variability in agronomic and nutritive characteristics of African yam bean (Sphenostylis stenocarpa Hochst ex. A. Rich. Harms). Plant Production and Research Journal 6: 10-19.

[25] Vining, G. G., Cornell, J. A., & Myers, R. H. (1993). A graphical approach for evaluating mixture designs. Journal of the Royal Statistical Society. Series C, Applied Statistics, 42(1): 127. https://doi.org/10.2307/2347415

[26] Yeo, L.L. & Seib, P.A. (2009). White pan bread and sugar-snap cookies containing wheat starch phosphate, a cross-linked resistant starch. Cereal Chem. 86:210-220.

[27] Yue, P., Hetharachy, N. & D'Appolonia, B.L. (1991). Native and succinylated sunflower proteins use in bread making. Journal of Food Science 56: 992 – 998.