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OPTIMIZATION OF PRODUCTION OF BREAD ENRICHED WITH PEARL MILLET BASED COMPOSITE FLOUR

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ABSTRACT

The optimal design of response surface methodology (Design Expert Version 10) was used, to study the effect of the level of inclusion of pearl millet based composite flour, mixing time and proofing time, on the weight and volume of bread made from composite flour. The study revealed all the parameters studied were significant in producing high quality and nutritionally enriched bread. The feasibility of partially replacing wheat flour with pearl millet based composite flour in bread making was evaluated in several formulations, aiming to find a formulation for the production of wheat bread with better nutritional quality and consumer acceptance. The composite flour comprising of pearl millet (85%), kidney beans (10%), tiger nut (5%) and xanthan gum is used. The study found out the combinations of the parameters; level of composite flour inclusion; 20%, proofing time: 90 minutes and mixing time: 4 minutes were the optimal conditions for the productions of high quality bread enriched with pearl millet based composite flour.

KEYWORDS: Pearl Millet Based Composite Flour, Proofing Time, Mixing Time & Response Surface Methodology

INTRODUCTION

Bread is a baked product made from wheat flour. It is one of the most important staple foods in the world and the technology for its production has been in existence for long. There are evidences from food consumption survey in Nigeria of the astronomic rise in the consumption of this baked food. In addition to wheat flour, which is the basic ingredient in bread, yeast, butter, salt, sugar and water are also important ingredients. Other food materials like beverages can also be added based on individual delight. Each of the ingredients has its peculiar purpose in improving the physical characteristics of the final product. Bread, despite lack of some basic nutrients, it is generally accepted and of as such belong to class of food people called ‘convenience food.

The use of cereals, tubers with or without legumes and fibres as viable sources of functional composite flours keeps on increasing (Bamigbola et al., N2016; Awolu et al., 2016b; Awolu et al., 2016a). Partial utilization or non-utilization of wheat in flour production, are meant to mitigate gluten-related celiac disease, diversify raw materials for flour production especially using local and nutritionally rich crops, and reduce high cost of importing wheat by developing countries. Cereals(rice, amaranth, tigernut), tubers(cocoyam, sweet potatoes), legumes(soybeans, African oil bean, bambara groundnut, kersting’s groundnut) and fibers sources (rice bran, brewer’s spent grains) have been utilized as credible sources of composite flours (Bamigbola et al.,2016; Awolu et al.,2016b; Awolu et al.,2016a; Awolu et al., 2015).

Pearl millet is a species of millet widely grown in Nigeria; Nigeria being the world's third largest producer after India and Niger (FAO, 1995). Millets generally have been discovered to be rich in dietary fibre, minerals, phyto chemicals (especially phenolic compounds)and vitamins, which make them to be health promoting (Saleh et al.,2013). Pearl millet (*Pennisetum typhoideum*) is the most widely grown type of millet. Because of its tolerance to difficult growing conditions such as drought, low soil fertility and high temperature, it can be grown in areas where other cereal crops, such as maize (*Zeamays*) or wheat (*Triticum aestivum*), would not survive. Millets have been incorporated into wheat in the production of bread, biscuits, and ready-to-eat snacks (Saha et al., 2011).

Kidney beans are an underutilized tropical legume rich in protein, ash, soluble and insoluble fibres, and linoleic acid (Manonmani et al., 2014). It has been used to complement cereals and wheat in the production of composite flours rich in protein. Tigernut on the other hand is also an underutilized crop rich in calcium, magnesium, iron, dietary fibre, protein and carbohydrates (Oladele and Aina, 2007). It has been widely used in food formulations and composite flours production (Awolu et al., 2016b; Ade-Omowaye et al., 200811).

Recently, efforts are being made towards improving the quality of wheat bread through wheat flour substitution, probably due to perceived loss in some of nutrient of the wheat flour during milling. Composite flour is a partial replacement of wheat flour with other food materials such as vegetable flour, millet flour. However, in a bid to enrich the nutrient base of this bread with millet flour, some physical characteristics must not be compromised. In preserving the physical characteristics, such as loaf volume and weight of bread enriched with pearl millet based composite flour, unit operations such as mixing time, level of flour inclusion and proofing time need to be optimized.

Bread, a basic food for human, has no negative health effects when produced in appropriate conditions using appropriate materials. However, improper use of raw materials and non-optimal unit operations such as proofing time, mixing time can affect the physical characteristics of the product and hence, attractions of this product to consumers. Over-mixing or under-mixing of dough during baking process would have negative effect on the quality of the product. Over proofing or under-proofing also has effect on the actions of the yeast which affect the quality of the final product. Optimization method could be a veritable tool in determining the favorable production conditions for bread enriched with leafy vegetable powder.

The optimization of process parameters can be done by various techniques; one of the effective and commonly used techniques for this purpose is Response Surface Methodology, which is a collection of statistical and mathematical techniques useful for developing, improving and optimizing processes. This technique is a faster and economical method for gathering research results than classic one variable at a time or full factors experimentation. This statistical tool has been used in the optimization of bread by varying the amount of bran, the amount of yeast and the fermentation time on the amount of phytic acid in bread. Mohammed and Sharif optimized composite flour for the production of enhanced storability of leavened flat bread using response surface methodology.

This present study aims at optimizing some critical unit operations in the production of bread enriched with pearl millet based composite flour such as mixing and proofing time and the level of inclusion of the millet based flour on the loaf volume and weight of the product**.** This would ultimately help the industry to gain economic advantage with increased production of high quality and nutritionally enriched bread.

MATERIALS AND METHODS

Preparation of Pearl Millet based Composite Flour Blends

Pearl millet seeds (1Kg), was sorted and thoroughly washed using warm (65°C) water. It was later oven-dried (thermo stated oven, Model MC-1959K, China) at 50°C for 24h, milled using locally fabricated attrition mill and passed through 200 µm sieve, in order to obtain fine pearl millet flour. Similarly, tiger nut flour and kidney beans flour were prepared by using suitable milling process. Wheat flour was blended with 85%:10%:5% of pearl millet –kidney beans – tiger nut composite flour. The composite flour was mixed together to produce suitable blends of flour.

Baking of Bread Enriched with Composite Flour

Dough from the composite flour blends were baked using the straight-dough method of Greene and Bovell with some modifications. The formula used in this process is: 200 g of composite flour blends (wheat flour and vegetable powder in different proportions), 6 g yeast, 4.0 g salt, 10 g shortening, 6 g sugar, and 120 ml water. All dry ingredients were weighed and placed in a Kenwood dough mixer (Model a 907 D) set at highest speed and mixed for 50 seconds. Then a suspension of the yeast in water was added. The mixture was further run at high speed for 50 seconds. Water was added to the mixture to make up the required water for the process for the process and the mixture was further mixed for the required length of time. The dough was later kneaded on the kneading table, rounded into balls by hand and placed in lightly greased fermentation bowl and placed in fermentation cabinet (National Company, Lincoln, NE). The dough was then proofed for the required length of time. Baking was done at 250°C for 15 minutes. The baked bread was allowed to cool at room temperature before measurements were taken. The weight of the loaf was determined using a sensitive weighing balance and volume was also determined.

EXPERIMENTAL DESIGN

The optimal design of Response Surface Methodology was used (Design Expert Version 10). The process was optimized on the basis of three input variables whose interactions were studied as two major responses. The independent variables were level of inclusion of composite flour, mixing time and proofing time. The selected responses evaluated include; loaf volume and loaf weight. The levels of various input variables selected are as follows;

Table 1: Levels of Various Input Variables

Variables	Units	Low level	High level
Level of inclusion of composite flour	%	10	30
Mixing time	Minutes	3	5
Proofing time	Minutes	60	120

Statistical Analysis

Statistical analysis was carried out using the Response Surface Methodology so as to fit the quadratic polynomial equation generated by the Design-Expert software version 10. In order to correlate the response variable to the independent variables, multiple regressions was used to fit the coefficient of the polynomial model of the response. The quality of the fit of model was evaluated using analysis of variance (ANOVA).

RESULTS AND DISCUSSIONS

Twenty runs (Table 2) were evaluated to select the best combination of processing conditions that produced the best quality of loaf of bread made from the composite flours.

Table 2: Experimental Data

Select	Std	Block	Run	Factor 1 A:Level of c... Percent	Factor 2 B:Mixing Time Minutes	Factor 3 C:Proofing Ti... Minutes	Response 1 Weight of loaf g	Response 2 Volume of loaf cm3
	10	Day1	1	20	4	90	125.67	471
	5	Day1	2	10	3	120	147.6	490
	3	Day1	3	10	5	60	128.8	395
	11	Day1	4	20	4	90	146.8	365
	1	Day1	5	10	3	60	126.51	402
	9	Day1	6	20	4	90	138.9	352
	2	Day1	7	30	3	60	142.16	425
	7	Day1	8	10	5	120	144.4	360
	6	Day1	9	30	3	120	140.51	445
	12	Day1	10	20	4	90	145.1	540
	4	Day1	11	30	5	60	159.6	675
	8	Day1	12	30	5	120	170.1	574
	20	Day 2	13	20	4	90	135.2	484
	13	Day 2	14	3.18207	4	90	169.8	675
	15	Day 2	15	20	2.31821	90	148.4	420
	18	Day 2	16	20	4	140.454	153.1	410
	14	Day 2	17	36.8179	4	90	142.3	370
	19	Day 2	18	20	4	90	140.1	349
	17	Day 2	19	20	4	39.5462	170.5	620
	16	Day 2	20	20	5.68179	90	168.2	655

Using the experimental data in Table 2, second degree polynomial equation model for the loaf weight and loaf volume were regressed and the equations are shown below:

- Y_1=+261.23174-2.35056A-37.73714B-0.81351C+0.59925AB.

  0.011600AC+0.027750BC+0.028383A²+3.63375B²+5.41243E-003C²
- Y_2=+433.76-3.00A+46.66 B-27.91 C+64.50 AB-16.75 AC-30.50BC+20.51A^2+25.82B^2+17.86 C^2

  Where

  Y□= Weight of loaf

  Y□=Volume of loaf
- A= Level of inclusion of composite flour
- B=Mixing Time
- C=Proofing Time

Design Summary											
File Version	10.0.5.0										
Design Wizar	Optimization > Factorial / RSM > No HTC > All Numeric > 3 factors, 20 runs, goal design										
Study Type	Response Surface		Subtype	Randomized							
Design Type	Central Composite		Runs	20							
Design Mode	Quadratic		Blocks	2							
Factor	Name	Units	Type	Subtype	Minimum	Maximum	Coded	Values	Mean	Std. Dev.	
A	Level of comp	Percent	Numeric	Continuous	3.18207	36.8179	-1.000=10	1.000=30	20	8.4781	
B	Mixing Time	Minutes	Numeric	Continuous	2.31821	5.68179	-1.000=3	1.000=5	4	0.84781	
C	Proofing Time	Minutes	Numeric	Continuous	39.5462	140.454	-1.000=60	1.000=120	90	25.4343	
Response	Name	Units	Obs	Analysis	Minimum	Maximum	Mean	Std. Dev.	Ratio	Trans	Model
R1	Weight of loaf	g	20	Polynomial	125.67	170.5	147.187	14.1594	1.35673	None	Quadratic
R2	Volume of loaf	cm3	20	Polynomial	349	675	473.85	111.799	1.9341	None	Quadratic

Figure 1: Design Summary

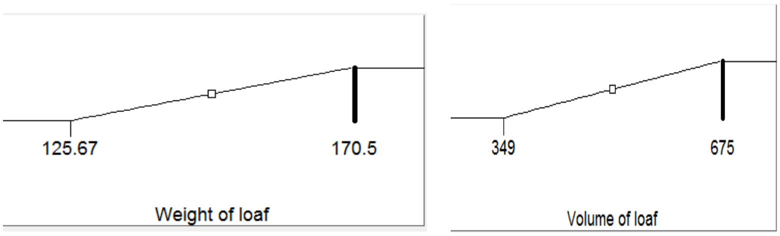

Figure 2: Optimized Parameters

Use your mouse to right click on individual cells for definitions.

Response 1 Weight of loaf

ANOVA for Response Surface Quadratic model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Block	522.92	1	522.92			
Model	1445.13	9	160.57	0.78	0.6380	not significant
A-Level of co	25.91	1	25.91	0.13	0.7301	
B-Mixing Tim	461.85	1	461.85	2.26	0.1672	
C-Proofing T	19.40	1	19.40	0.095	0.7651	
AB	287.28	1	287.28	1.40	0.2664	
AC	96.88	1	96.88	0.47	0.5087	
BC	5.54	1	5.54	0.027	0.8729	
A^2	116.00	1	116.00	0.57	0.4707	
B^2	190.14	1	190.14	0.93	0.3602	
C^2	341.69	1	341.69	1.67	0.2284	
Residual	1841.24	9	204.58			
Lack of Fit	1553.54	5	310.71	4.32	0.0906	not significant
Pure Error	287.70	4	71.92			
Cor Total	3809.28	19				

Use your mouse to right click on individual cells for definitions.

Response 2 Volume of loaf

ANOVA for Response Surface Quadratic model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Block	7696.01	1	7696.01			
Model	1.005E+005	9	11163.46	0.78	0.6435	not significant
A-Level of co	122.77	1	122.77	8.545E-003	0.9284	
B-Mixing Tim	29732.40	1	29732.40	2.07	0.1841	
C-Proofing T	10639.02	1	10639.02	0.74	0.4119	
AB	33282.00	1	33282.00	2.32	0.1623	
AC	2244.50	1	2244.50	0.16	0.7019	
BC	7442.00	1	7442.00	0.52	0.4900	
A^2	6059.91	1	6059.91	0.42	0.5323	
B^2	9598.13	1	9598.13	0.67	0.4348	
C^2	4594.55	1	4594.55	0.32	0.5856	
Residual	1.293E+005	9	14368.16			
Lack of Fit	96126.94	5	19225.39	2.32	0.2179	not significant
Pure Error	33186.50	4	8296.63			
Cor Total	2.375E+005	19				

The Model F-value of 0.78 implies the model is not significant relative to the noise. There is a 64.35 % chance that a F-value this large could occur due to noise.

Figure 3: Anova Tables

Response Surfaces Analysis

The graphical representation of 3 dimensional plots of response surface in Figures 1-2 show the relationships between the dependent and independent variables in the production of bread enriched with pearl millet based composite flour.

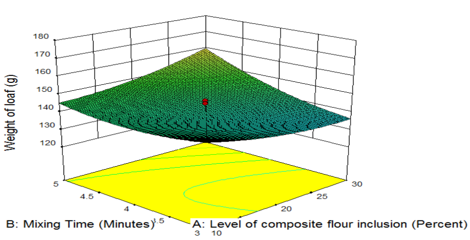

Figure 4: Weight of Loaf (G)

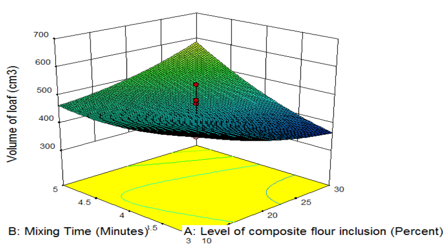

Figure 5: Volume of Loaf (Cm3)

Figures 4 -5 are three dimensional plots showing the influence of two of the variables: mixing time and level of composite flour inclusion on the weight and volume respectively of the loaves produced while the other variable, proofing time was kept constant. In Figure 4, increasing the mixing time of the process from 3-4 minutes and the level of vegetable inclusion in the composite flour from 10-20% positively affected the weight of the loaves produced.. In Figure 5, the effect of the mixing time and level of vegetable inclusion on the volume of the loaf is represented by three dimensional plots. The volume decreased as the mixing time approached 5.0 minutes. Mixing is an important stage in bread production.

RESULTS OF OPTIMIZATIONS

Table 3: Results of Optimization

Optimized parameter	Level	Responses	Value
Level of inclusion of composite flour	20	Loaf weight	140.44
Mixing time	4	Loaf volume	433.76
Proofing time	90		

Optimum level of Composite flour inclusion, mixing and proofing times were generated by the software and were found to be 20%, 4 minutes and 90 minutes respectively as shown in Table. With respect to these optimum conditions, the loaf volume and weight produced were 433.76cm3 and 140.44 g respectively.

CONCLUSIONS

Response Surface Methodology (Design Expert Version 10) was successfully used to optimize the process condition in the production of bread enriched with pearl millet based composite flour. It is used to determine the level at which the composite flour will be added to the flour, mixing time and the proofing time of the process that will not negatively affect the physical properties of the product. The optimal conditions of the process parameters can therefore be used in the production of bread which is nutritionally rich.

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