MODELING THE EFFECT OF RELATIVE HUMIDITY AND PROXIMATE COMPOSITION ON THE SHELF-LIFE OF BAMBARA NUT FLOUR

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Abstract: Bambara nut samples were obtained, milled, packaged in HDPE and stored for a period of 24 weeks under controlled temperatures of 20°C, 30°C and 40°C respectively. At weekly intervals, the flours were analyzed for proximate composition and sorption isotherms (Relative Humidity). The data obtained from the study were analyzed using the Design-Expert software (Version 7.0.0, Stat-Ease Inc., and Minneapolis, USA). The experimental data generated was fitted to a polynomial regression model for predicting maximum shelf-life. In order to correlate the response variables to the independent variables, multiple regressions were used to fit the coefficient of the polynomial model. The quality of fit of the model was evaluated using analysis of variance (ANOVA). The suitability of the models was compared and evaluated using correlation coefficient (R^2). The study showed that all the parameters studied were significant in predicting the shelf-life of Bambara nut flour. The results obtained in the study showed that the response surface model developed is a good one. The model correlation coefficient (R^2) of the responses was found to be 0.9983, 0.9862 and 0.9138 for the flour moisture, fat and fibre contents, respectively. Levels of significance obtained were 0.001, 0.01 and 0.03 for the flour moisture, fat and fibre contents which were high and attested to the fitness of the model in evaluating the responses. Optimum moisture content and storage time were found to be 6.32% (wb) and 23.62 weeks. The study confirmed that the model developed is adequate to optimize these process conditions.

Key Words: Model, Shelf-life, Sorption Isotherms, Proximate composition, Bambara nut

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Introduction

The global concern for the diversification of the uses of plant foods to improve normal and the paretic nutrition for diabetes control has shifted research interest to enhancing the potential sources of beneficial constituents in plant foods. Studies have shown that the fibre and protein contents of Bambara nut can weaken the absorption of sugar, reduce sugar response and increase insulin sensitivity and therefore recommended as a supplement for type II diabetes. Ngabea, 2022 reported that Diabetic patients in Nigeria rely on Bambara nut flour as food because of its insulin building ability in the body system, but the challenge is its unavailability all the year round in the market outlets when needed. Presently, there is paucity of information on the storage techniques of Bambara nut flour that can prolong the shelf-life for later usage.

Temegne et al, (2018) reported that Bambara nut is now widely cultivated throughout tropical Africa, Indonesia, Malaysia, India, Sri Lanka, Philippines, South Pacific, parts of Northern Australia, Central and South America. Nigeria is one of the major producers of the crop and it is locally called Fyegbankpo (Jukun), Okpa (Ibo), Epiroro (Yoruba) and Gurjiya (Hausa). It is the third most important grain legume after ground nut and cowpea in Nigeria (Lacroix et al., 2003; Ngabea, 2022). Beyond Africa, Bambara nut is cultivated in Brazil where it is known as Mandubi d‟Angola‟ as well as in West Java and southern Thailand. Other tropical locations such as Middle East, Syria and Greece could also grow Bambara nut. Small-scale cultivation trials of Bambara nut have been successful in Florida, United States (Ferry, 2002; Ngabea et al., 2021) Bambara nut is extensively cultivated in West Africa, Nigeria produced over 100,000 metric tons, follow closely by Niger with 30,000 metric tons and Ghana 20,000 metric tons annually (Asiedu, 1989). The seeds are ground into powder, which is used for bread making or prepared into stiff porridge, a very popular semi-fluid food in some parts of Nigeria (Ngabea et al., 2020).

Shelf life is defined as the period of time, established under intended conditions of distribution, storage, retail and use, that the food would remain safe and suitable. Ngabea et al., (2019) reported that shelf-life is the length of time food can be held without loss of nutritive value and quality. The shelf life of many foods can be extended through various means including controlled storage. It may be possible to manipulate certain factors to extend the shelf life. Although the composition, formulation, processing or packaging may inadvertently lead to a decrease in the shelf life or make the food more susceptible to the growth of spoilage or even pathogenic microorganisms.

Aris, (1994) opined that a model is a simplified representation of a system at some particular point in time or space intended to promote understanding of the real system. Modeling involves identifying and selecting relevance features of a real work situation, representing those features symbolically, analyzing and reasoning about the model and characteristics of the situation and considering the accuracy and limitation of the model.

Fangchao et al.,(2023) reported in a review and classified shelf life models, detailed the application background and characteristics of commonly used models to better understand the different uses and aspects of the commonly used models. In particular, the structural framework, application mechanisms, and numerical relationships of commonly used models were elaborated. In addition, the study focused on the application of commonly used models in the food field. Besides predicting the freshness index and remaining shelf life of food, the study addressed aspects such as food classification (maturity and damage) and content prediction.

Stephanie *et al.* (2013) also developed a model for predicting the safe storage of fresh fish under modified atmospheres with respect to *Clostridium botulinum* toxigenesis by modeling length of the lag phase of growth.

Many models for monitoring food quality have been developed and applied to predict food shelf life. Most of the studies on shelf-life prediction models in the literature are on the composition of the stored materials. No study has been reported considering both the compositions and the environmental parameters. In this study, both the compositional and environmental conditions (relative humidity) are put into consideration. This study is the first to be carried out on modeling the effect of relative humidity on shelf-life of Bambara nut flour considering its hygroscopic nature and sorptive behavior under controlled storage conditions; all the equations used in this study were formulated, and first used in this study.

The objective of this study was to use sorption isotherms and response surface methodology to optimize the process variables for predicting maximum shelf life, appropriate temperature and relative humidity for storing Bambara nut flour.

The objective of this study was to use RSM to model the effect of relative humidity and proximate composition on the shelf-life of Bambara nut flour.

Materials and Methods

Study and Experimental Locations

The study was conducted at the Department of Agricultural Engineering, Federal University Wukari while the experiments were carried out at the laboratories of the Departments of Food Science and Technology, University of Nigeria Nsukka and Modibbo Adama University of Technology Yola, respectively.

Research Materials

The materials used for this study were Bambara nuts- *Vigna subterranean,* High density polythene bags, food grade chemicals and water.

Source of Bambara nut

Bambara nut was purchased from a local market in Donga township, Taraba State. North-eastern Nigeria. To remove foreign matter, immature and damaged seeds, the seeds were manually washed.

Chemicals and reagents

All the chemicals used were of analytical grade (Distilled water, sulphuric acid, sodium Hydroxide, Selenium tablets, Boric acid, Methyl red, Hydrochloric acid and Refined Vegetable oil). Some were purchased from Nsukka market while others from VEKO Scientific Chemical Shop, Jimeta-Yola.

Methods

The experiment was in two stages, the first stage was conducted for the determination of Bambara nut flour Moisture Sorption Isotherms (Relative Humidity). The second stage involved the determination of Proximate Composition of the stored packaged Bambara nut flour.

Preparation of experimental samples

The Bambara seeds were milled into flour using a magnetic sieve grinding machine as described by Ngabea et al, (2015). Particle size distribution using sieve analysis was carried out to separate the flour at a range of 20 - 100 mesh numbers (850 - 150µm) as designed in the face central composite design (FCCD) response surface methodology of Design Expert 7.0.0 software.

Determination of Moisture Sorption Isotherm

The adsorption isotherms of the samples were obtained using static gravimetric method as described by Labuza, (1984). An incubator was used as temperature control chamber. The experimental set up consists of saturated salt of lithium chloride, potassium acetate, Mgcl, KCO_2, MgN_2, sodium nitrate, Nacl, ammonium sulphate and barium chloride solutionswhich created different relative humidity environmental storage conditions with the corresponding water activities of 0.11, 0.21, 0.33, 0.43, 0.50, 0.67, 0.76, 0.86 and 0.90, respectively. The samples were arranged in dessicators. The duplicate flour samples of 3g each were placed on the saturated salt solutions in the dessiators and kept in a cabinet at a controlled temperatures of 20, 30, 40ºC, respectively. The weight of the samples was taken after every 24 hours with a digital weighing balance until constant weight is attained. Each of the samples was oven dried at 110ºC to a constant weight to obtained the equilibrium moisture content (dry basis). Graph of equilibrium moisture content against water activities (relative humidity) was plotted.

Determination of equilibrium moisture content

Equilibrium moisture content was determined by calculating the original moisture content and the known change in weight on dry basis (Akubor and Egbekun, 2017). The relation below is used in calculating the equilibrium moisture content (EMC) of the samples.

$$\text{EMC}=\left(\frac{Adsorbed\ moisture}{Weight\ of\ sample}\right) \text{X } 100 \qquad (1)$$

Determination of water activity

The water activity a_w of the sample was determined from the relative humidity of the air surrounding the sample when the air and the sample are at equilibrium which is equilibrium relative humidity. The equilibrium relative humidity value was divided by 100 to get the water (aw) value.

Determination of Proximate Composition of Bambara nut flour

The crude fat, moisture and crude fibre contents of the Bambara nut flour were determined using the methods of AOAC (2010), (Egan *et al.,* 1981).

Determination of moisture content

Five grams of each sample were weighed into pre-weighed aluminium drying dish. The sample was dried to a constant weight in an oven at 105ºC for four hours (AOAC, 1990). The moisture content was determined as follows:

$$\frac{M1 - M2}{M1 - M0} \times 100 \qquad (2)$$

Where

M_0 = Weight of aluminium dish

M_1 = Weight of fresh sample + dish
M_2 = Weight of dried sample + dish

Determination of crude fibre

Defatted sample (2g) was placed in a 600 ml conical flask, 1.25% sulphuric acid solution was added to 160 ml boiling. The sample was digested for 35 min and washed with boiling distilled water after when the acid was drained out. Then, 1.25% sodium hydroxide solutions (160 ml) were added. The sample was then digested for 35min, thereafter the sodium hydroxide solution was drained out and the sample was then washed with boiling distilled water. Lastly, the sample was placed in a dried crucible and oven dried at 120ºC overnight. The sample was allowed to cool in a desiccator and then weighed (W_1). The sample was ashed at 550ºC in a muffle furnace for two hours, cooled in a desiccator and then reweighed (W_2). Extracted fibre was articulated as percentage of the original sample and calculated according to the formula:

$$\textit{Crude Fibre (\%)} = \frac{Digested\ sample\ (W1) - Ashed\ sample (W2)}{Weight\ of\ sample} \times 100 \qquad (3)$$

Determination of crude fat content

Five grams of the sample was weighed in a thimble and plugged with cotton wool. The thimble was then inserted in a soxhlet apparatus. A formerly weighed clean dried 250 ml flask was filled with 180 ml of petroleum ether of 45 – 65ºC boiling points.

Plate 1: Soxhlet apparatus for fat determination (DHG-9023A, England**)**

The soxhlet apparatus (plate 2) were assembled and allowed to reflux for 6.5 hours, the solvent was recovered and the flask with the extract was dried in the oven (DHG-9023A, England) at 105ºC for 30 minutes. It was then cooled in the dessicator and weighed. The crude fat was calculated as stated in equation 4.

$$\% \text{ Fat} = \frac{W3\ - W2}{W1} \times 100 \qquad (4)$$

Where:
W_1 = weight of sample
W_2 = weight of empty flask
W_3 = weight of flask extracted oil

Experimental design and data analysis

A face central composite design (FCCD) of Response Surface Methodology (RSM) was used for the experimental design. The factors or independent variables were storage time and particle size, while the responses were the proximate composition (moisture, fat and fibre contents).

The independent variables and the responses are detailed in Table 1. The outline of experimental design with the coded levels is given on Table 1

Table 1: Variation of parameter for two (2) numerical factors design in surface response

Numerical Factor		
Variable	Low level (-1)	High level (+1)
Time (weeks)	8	24
Particle size	20 mesh number	100 mesh number

Note that, the low level and high level interval of 8 and 24 for the time (weeks) was obtained from the result of the preliminary investigation conducted to study the changes of the values of proximate composition of Bambara nut flour under ambient storage condition.

Modeling of the flour shelf-life with respect to particle size and time

Each design point was performed in duplicates, except the centre points that were performed four times. The experiment was carried out according to design. The data obtained were analyzed using the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA). The experimental data generated was fitted to a polynomial regression model for predicting maximum shelf-life. In order to correlate the response variables to the independent variables, multiple regressions were used to fit the coefficient of the polynomial model of the response. The quality of fit of the model was evaluated using analysis of variance (ANOVA).

Validation of the regression model

The model developed was examined for Test for significance, lack-of-fit and coefficient of determination (R^2) which was integrated into the analysis of variance (ANOVA) to examine the adequacy of the regression model while response surface and contour plots were designed with the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA). R^2 was calculated as:

$$R^2 = \frac{\text{Sum of square residual}}{\text{Model sum of square +sum of square residual}} \qquad (5)$$

$$R^2\text{adj} = 1 - \frac{n-1}{n-p}(1 - R^2) \qquad (6)$$

Process Optimization

To optimize the response variables, contour and surface plots were plotted using the Design Expert software as described by Floros and Chinnan (1988). A second order polynomial was used to predict the experimental behavior (Equation 7).

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_1 X^2{}_1 + \beta_2 X^2{}_2 + \beta_{11} X_1 X_2 + \beta_{12} X_1 X_2 + \varepsilon \qquad (7)$$

Where,
X_1, and X_2 are the factors: storage time and particle sizes
β is a constant coefficient of linear, interaction and square terms respectively
ε is the random error term.

Pearson correlation analysis ($p = 0.05$) was performed using the Design-Expert software (Version 7.0.0, Stat-Ease Inc., Minneapolis, USA).

Results and Discussions

The experimental results for the equilibrium moisture content of Bambara nut flour at each water activity (a_w) at temperatures 20°C, 30°C and 40°C are given in Table 2. The results showed that the equilibrium moisture content of all samples increased with water activity at selected temperatures.

Table 2: Experimental results for the adsorption sorption isotherms of Bambara nut flour at each water activity (a_w)

Conc. Salts Solutions at different a_w	**Temperatures** **20°C**	 **30°C** **EMC**	 **40°C**
0.1 Lithium chloride	0.867	0.832	0.867
0.2 Potassium acetate	0.814	0.811	0.819
0.3 Magnesium chloride	0.739	0.712	0.741
0.4 Potassium carbonate	0.674	0.636	0.678
0.5 Magnesium nitrate	0.549	0.522	0.534
0.6 Sodium nitrate	0.452	0.416	0.461
0.7 Sodium chloride	0.364	0.365	0.369
0.8 Ammonium sulphate	0.261	0.259	0.274
0.9 Barium chloride	0.172	0.174	0.182

Table 2 showed the Equilibrium moisture content data obtained for Bambara nut flour at different water activities and temperatures. The results showed that temperature depended on the behavior of the sorption isotherm; increase in temperature causes the capacity of the sorption to increases also. The decrease in the equilibrium moisture content with increase in water activity makes the flour more susceptible to microbial spoilage. Therefore, Bambara nut flour requires careful handling and proper storage environment to make it stable over long period of time.

Sorption Isotherms

The adsorption moisture sorption isotherms of Bambara nut flour at 20°C, 30°C and 40°C are presented in fig.1

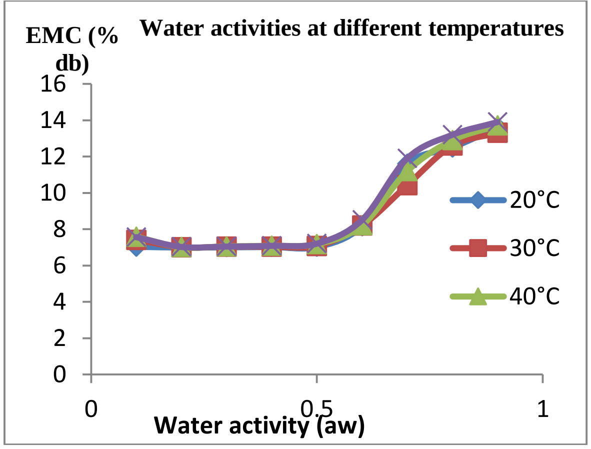

Fig. 1: Adsorption Moisture Sorption Isotherms of Bambara nut flour at 20°C,30°C and 40°C

The adsorption moisture sorption characteristics of Bambara nut four at 20°C, 30°C and 40°C are shown in Figure 1. Each point on the curve of sorption isotherms showed the average of two replications. The four curves of isotherms exhibited a sigmoid shape (type II) isotherm which is common for many hygroscopic products like the Bambara nut flour as described according to the classification of Brunauer in Aqua Lab University application note (2018). This type of curve is typical of many food materials. At low and intermediate water activities (relative temperature) the equilibrium moisture content of Bambara nut flour of the three temperature study increased slowly at the initial stages (0.1 – 0.6 a_w), and a steep rise with increase in water activity (0.6 – 0.9 a_w) was noticed on the curve. This behavior was reported for African locust bean pulp flour (Akubor, 2017). Similar result was reported for ginger slices (Alkali et al., 2009). This behavior and characteristics of Bambara nut flour could be attributed to physical adsorption of moisture on polymeric molecules at low water activities. The forces involve in physical adsorption of moisture are mainly those of molecular interaction which induced quara-pole and dipole attractions. These are the types of forces responsible for non-ideal behavior of gases and vander waal forces of attraction of water molecules to the flour. The time taken for the Bambara nut flour to reach equilibrium varied from 7 to 14 days and was shorter at lower water activities than at higher temperature.

Influence of temperature on moisture sorption isotherm of Bambara nut flour

Figure 1 also indicated that the equilibrium moisture content of Bambara nut flour at water activities of 0.1 – 0.6 remained stable with increase in temperature. However, at higher water activities (0.7 – 0.9), the equilibrium moisture content increased with increase in temperature. This is similar to the one reported by Nutama, (2010) on taro flour. This showed that the Bambara nut flour within the water activities of 0.1 - 0.6 became less hygroscopic with increase in temperature. This is in total agreement with the result reported for ginger slices (Alkali et al., 2009). This behavior is compelled with the thermodynamic relationship according to Tarik Al-Shemmeri (2010). $\Delta G - \Delta H = T\Delta S$ where ΔH, $T\Delta S$ and ΔG are changes in the enthalpy, entropy and free energy, respectively. Therefore, increase in temperature represents an unfavorable environmental storage conditions for Bambara nut flour.

Modeling the effect of storage time and particle size on the proximate composition of Bambara nut flour

The descriptive statistics, experimental ranges and levels of the independent variables for the experimental design for proximate analysis of Bambara nut flour are summarised in Table 3

Table 3: Experimental ranges and levels of the independent variables for the proximate analysis of Bambara nut flour

Run	Storage Time (Weeks)	Particle Size (Mesh.number)	Moisture (%)	Ash (%)	Protein (%)	Fat (%)	Fibre (%)	Carbohydrate (%)
1	24.00	20.00	6.33	3.33	36.76	8.10	2.96	42.53
2	8.00	60.00	12.0	3.00	20.13	4.67	2.33	57.87
3	8.00	100.0	11.67	3.00	21.01	5.33	2.00	56.12
4	8.00	20.00	9.33	2.67	22.76	5.33	2.67	56.36
5	16.00	100.00	9.33	3.00	19.26	7.33	3.00	58.08
6	16.00	20.00	7.67	3.30	21.01	8.00	3.33	56.69
7	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
8	24.00	60.00	8.00	3.33	29.76	7.50	2.66	48.75
9	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
10	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
11	24.00	100.0	7.33	2.67	33.26	7.00	3.00	46.74
12	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23
13	16.00	60.00	10.0	3.30	20.13	7.67	2.67	56.23

The coefficient of the regression equations for the measured responses, the linear, quadratic and interaction terms of the selected variables are presented in Table 4.The results of the proximate composition of the flour showed that the linear (A, B), interaction (AB) parameters and square (A^2,B^2) terms were all significant at $p<0.05$ as shown in Table 4.

Table 4: Regression coefficients of predicted quadratic model for proximate composition of Bambara nut flour

		Variables	
Coefficients	**Moisture**	**Fat**	**Fibre**
Intercept	9.98	7.62	2.72
A	-1.89	1.21	0.27
B	0.83	-0.30	-0.16
AB	-0.33	-0.27	0.18
A^2	0.080	-1.41	-0.34
B^2	-1.42	0.17	0.33
R^2	0.9983	0.9862	0.9138
Adj. R^2	0.9971	0.9763	0.8522
C.V (%)	0.95	2.51	4.61
Adeq. Precision	94.538	26.362	12.962
Mean	9.36	7.05	2.71
Std. Dev.	0.089	0.18	0.13

A = Storage time, B = Particle size

Fitting of the quadratic model

The quadratic model fittings are shown in Table 5. The analysis of variance (ANOVA) showed in Table 6-8, that the model was significant ($p<0.05$) for the predicted flour moisture, fat and fibre contents. The correlation coefficient (R^2) 0.9983, 0.9862 and 0.9138 for the flour moisture, fat and fibre contents, respectively were obtained. The R-squared value is an indication of the level of responses that can be explained by a particular model. These results showed that 99.83%, 98.62% and 91.38% of the responses could be explained by the model. Levels of significance obtained were 0.001, 0.01 and 0.03 for the flour moisture, fat and fibre contents, respectively. These levels were high and attested to the fitness of the model in evaluating the responses.

Table 6: Moisture content ANOVA for Response Surface Quadratic Model

Source	SS	Df	MS	F - Value	P - Value
Model	32.31	5	6.46	820.75	<0.0001
A	21.43	1	21.43	2722.38	<0.0001
B	4.17	1	4.17	529.25	<0.0001
AB	0.45	1	0.45	57.02	0.0001
A^2	0.018	1	0.018	2.23	0.1793
B^2	5.57	1	5.57	707.73	<0.0001
Residual	0.055	7	7.873E-003		
Lack of fit	0.055	3	0.018		
Pure Error	0.000	4	0.000		
Total	32.36	12			
	$R^2 = 0.9983$	Adj. $R^2 = 9971$	Pred. R^2=0.9846		

Table 7: Fat Content ANOVA for Response Surface Quadratic Model

Source	SS	Df	MS	F - Value	P - Value
Model	15.57	5	3.11	99.91	<0.0001
A	8.81	1	8.81	282.58	<0.0001
B	0.52	1	0.52	16.75	0.0046
AB	0.30	1	0.30	9.70	0.0170
A^2	5.50	1	5.50	176.44	<0.0001
B^2	0.079	1	0.079	2.52	0.1561
Residual	0.22	7	0.031		
Lack of fit	0.22	3	0.073		
Pure Error	0.000	4	0.000		
Total	15.19	12			
		$R^2 = 0.9862$	Adj. $R^2 = 0.9763$	Pred. $R^2 = 0.8784$	

Table 8: Fibre Content ANOVA for Response Surface Quadratic Model

Source	SS	Df	MS	F - Value	P - Value
Model	1.16	5	0.23	14.83	0.0013
A	0.43	1	0.43	27.60	0.0012
B	0.15	1	0.15	9.61	0.0173
AB	0.13	1	0.13	8.28	0.0237
A^2	0.31	1	0.31	20.01	0.0029
B^2	0.31	1	0.31	19.60	0.0031
Residual	0.11	7	0.016		
Lack of fit	0.11	3	0.037		
Pure Error	0.000	4	0.000		
Total	1.27	12			
		$R^2 = 0.9138$	Adj. $R^2 = 0.8522$	Pred. $R^2 = 0.3270$	

The results obtained in the study showed that the model employed is a good one and could be used for the prediction of the flour maximum shelf life, particle size and storage time in respect to the proximate composition of Bambara nut flour for the production, handling and storage of the flour.

Using the experimental data in Table 3, second degree polynomial equation model for the flour moisture, fat and fibre contents, respectively were regressed and the final equations in term of coded factor for the linear, interaction and square terms, respectively are shown in equations 8 – 10

$$\text{Moisture content} = +9.98 - 1.89A + 0.83B - 0.33AB + 0.08A^2 - 1.42B^2 \quad (8)$$

$$\text{Fat content} = +7.62 + 1.21A - 0.30B - 0.27AB - 1.41A^2 + 0.17B^2 \quad (9)$$

$$\text{Fibre content} = +2.72 + 0.27A - 0.16B + 0.18AB - 0.34A^2 + 0.33B^2 \quad (10)$$

Numerical Optimization of particle size and storage duration on the proximate composition of Bambara nut flour

The graphical representation of 3 dimensional surface and contour plots of response surface in Figures 2-7 show the relationships between the dependent and independent variables of the proximate compositions for handling and storage of Bambara nut flour.

Figure 2 showed 3D dimensional surface plots of moisture content and figure 3 plots contours. The function has the optimizer values 11.1972%, 10.2074%, 9.2176%, 8.2278% and 7.2971% with the maximum response moisture content value of 6.33%. The optimal particle size, moisture content and storage duration was estimated to be 120.12µm, 6.32% (wb) and 23.62 weeks, respectively. However, the optimized result from the moisture content is significantly influenced by particle size and storage time for Bambara nut flour handling and storage. The predicted result is in agreement with the recommended moisture content (6 – 14%) for storing food flour by Standard Organization of Nigeria (SON, 2013).

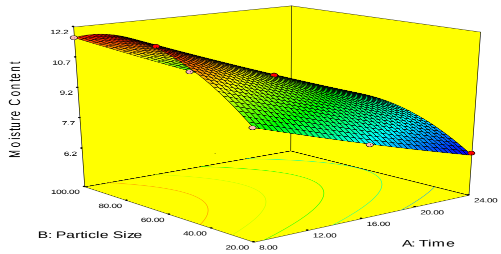

Fig. 2: 3D Surface plot of the effect of particle size and storage time on the moisture content of Bambara nut flour

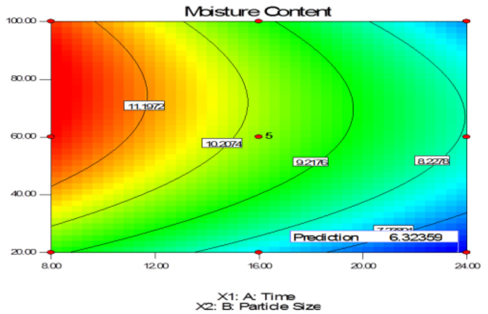

Figure 3: Contour plot of the effect of particle size and storage time on the moisture content of Bambara nut flour

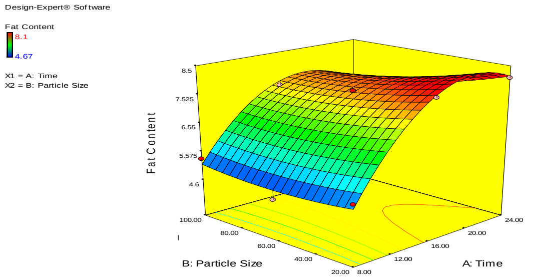

Figure 4: 3D surface plot of the effect of particle size and storage time on the fat content of Bambara nut flour

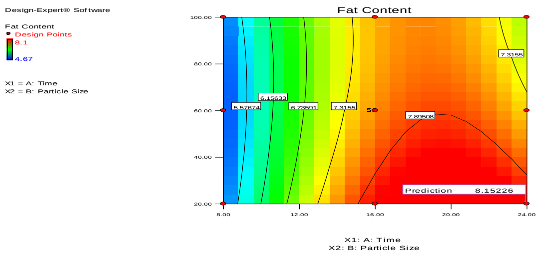

Fig. 5: Contour plot of the effect of particle size and storage time on the fat content of Bambara nut flour

Figures 4 and 5 showed the effect of particle size and storage time on the fat content of Bambara nut flour. There was no significant difference (P>0.05) in the fat content of the flour within the first three months of storage. At all the particle sizes (850 - 150µm) the fat content ranged between 5.0 – 6.3%.The 3 dimensional plots in figures 4 and 5 showed the effect of particle size and storage duration on the fibre content of Bambara nut flour. The fibre contents of the flour ranged from 2.00 – 3.33%. It was not significantly affected by the storage duration and particle size. The fibre content was slightly increased as the storage period progressed due to the decrease in moisture content of the flour. This is in agreement with result reported by Mpotokwane et al., (2008) for wheat flour during storage.

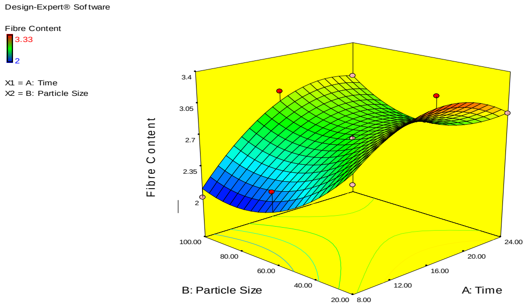

Fig. 6: 3D surface plot of the effect of particle size and storage time on the Fibre content of Bambara nut flour

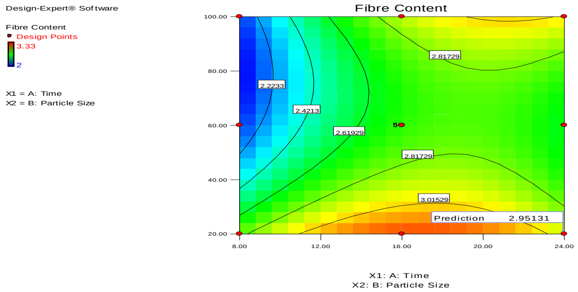

Fig. 7: Contour plot of the effect of particle size and storage time on the Fibre content of Bambara nut flour

Figures 6 and 7 showed the 3 dimensional plots of the effect of particle size and storage duration on the fibre content of Bambara nut flour. The fibre content has the optimizer values of 3.28%, 3.16%, 3.04%, 2.92% and 2.80% with the maximum response fibre content value of 3.39%. However, there were no significant differences on the fibre content. The fibre content slightly decreased with storage. The reduction could be as result of biochemical activities of microorganisms. This is in perfect agreement with the result of Awoyale et al, 2013.

Conclusion

Response surface methodology was successfully used to predict and optimize the process conditions for the storage of Bambara nut flour. The central composite design of Response surface methodology was found to be effective to determine the model parameter, sorptive behavior, particle size and storage duration for Bambara nut flour. The optimal storage conditions of the flour parameters can, therefore, be used for the storage and optimum shelf-life determination of Bambara nut flour. The results obtained in the study showed that the response surface model employed is a good one and could be used for the prediction of the responses (proximate composition) from the production and storage of Bambara nut flour.

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