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Research Article
Optimization of Temperature, Packaging Materials and Time on the Proximate Compositions of Bambara Nut Flour

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Abstract
Background and Objective: Most 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-year-round in the market outlets when needed. The objective of this study was to use response surface methodology to optimized temperature, packaging material and storage time for Bambara nut flour storage. **Materials and Methods:** Bambara nut was grounded to the flour and packaged in a high-density polythene bag, paper bag and plastic container. The flour samples were stored in each of the packaging materials for 7 weeks under controlled temperatures of 20, 30 and 40°C, respectively. At weekly intervals, the flours were analyzed for proximate composition. The central composite design was used to study the effect of temperature, packaging materials and storage time on the proximate composition of Bambara nut flour. Data obtained were evaluated using regression analysis. **Results:** The study showed that all the parameters studied were significant in producing high-quality Bambara nut flour. The coefficients of determinations (R^2) were 0.8693, 0.8839 and 0.9750 for moisture, fat and carbohydrate contents, respectively and were good for the second-order quadratic model. The study showed that the optimum temperature is 37.58°C, time is 4.62 weeks and the flour packaged in the plastic container had the lowest moisture content of 11.17%. **Conclusion:** The study confirmed that the model is adequate to optimize these process conditions and the flour packaged in a plastic container would be most effective for shelf-life stability of Bambara nut flour stored at ambient condition.

Key words: Bambara nut flour, storage conditions, shelf-life, proximate composition, response surface methodology

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Bambara nut (*Vigna subterranea*) is an indigenous crop grown widely in the African continent. It is the third most important grain legume after groundnut and cowpea in Nigeria as reported[1]. Fery[2], reported that in Nigeria, it is locally called "Okpa (Ibo), Epiroro (Yoruba) and Gurjiya (Hausa)". Although Bambara nut is grown excessively in Nigeria, it is one of the under research legumes in the country. Bambara nut contains 63% carbohydrate, 19% protein and 6.5% fat[3]. The protein content of Bambara nut is reported to be high in essential amino and methionine than other legumes. The seeds are eaten locally in a number of ways. In eastern Nigeria, the seeds are milled into flours and used as a major ingredient for the preparation of Okpa. In Northern Nigeria, the seeds are boiled and eaten with cereals or roasted, flavored with salt and eaten as snacks[4]. In the western part of Nigeria, the seeds are milled into flour and used for the preparation of fufu.

Despite the nutritional and economic importance of Bambara nut, there is no industrial use of the crop in Nigeria and most of the African countries. For the use of Bambara nut in the production of flours, the flour needs to be stored properly prior to utilization in order to maintain quality, safety and storage stability. In determining the optimal storage conditions, two important external factors to consider are temperature and packaging materials. Temperature is the major postharvest challenge limiting the shelf-life and quality of food. The lower the temperature, the longer the storability, the temperature depends not only on climatic conditions but also on the biochemical changes that are produced inside a mass of the food product. The packaging is also essential in food systems because it helps to reduce losses, add value, extend shelf-life, maintain quality and wholesomeness of products, improve the market standard and food safety. Food packaging offers the benefit of containment, easy communication, convenience and protective measures from contamination associated with post-harvest handling.

The optimization of process parameters can be done using numerous techniques.Ferruh[5]reported that, the increase in the availability of higher computing abilities, promoted significant developments in the optimization methodologies with various statistical and mathematical techniques for different objectives. 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[6].

To realize the full potential of Bambara nut flour in food applications, alone or in combination with other raw materials, knowledge of optimizing the effects of temperature, relative humidity, packaging materials and other storage conditions on the quality and shelf-life stability of Bambara nut flour is imperative. However, improper use of raw materials and non-optimal unit operations such as milling and particle size can affect the physical characteristics of the flour and hence, attractions of the flour to consumers. The optimization method could be a viable tool in determining the best temperature, packaging materials and other conditions for the flour storage.

The objective of this study was to use the response surface methodology to optimize the process variables for maximum shelf life, appropriate temperature and the best packaging material for storing Bambara nut flour.

MATERIALS AND METHODS

Research materials: The materials used for this study were: Bambara nuts *(Vigna subterranean)* flour, paper bags, high-density polythene bags, plastic containers, food-grade chemicals and water.

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

Source of bambara nut: Bambara nuts were purchased from a local market in Mu-Baka village, Donga LGA, Taraba State. Nigeria and the seeds were manually cleaned to remove foreign matters, immature and broken seeds.

Preparation of experimental samples: The Bambara seeds were milled into flour using a magnetic sieve grinding machine as described by Ngabea et al.[7], flour was packaged in three different packaging materials. Thus, high-density polythene bag (HDPE), paper bag and plastic containers. The flour samples were stored in each packaging material for a period of 7 weeks (3rd week of October to 2nd week of December 2018) at a controlled temperature of 20, 30 and 40°C, respectively. At weekly intervals, the flours were analyzed for proximate composition.

Experimental design and data analysis: A Face Central Composite Design (FCCD) of Response Surface Methodology was used for the experimental design. This generated 21 experimental runs. The independent variables were temperature, time and packaging materials. The packaging materials were coded 1, 2 and 3 for high-density polythene bags, paper bags and plastic containers, respectively while the responses were the proximate composition (moisture, fat and carbohydrates contents). The outline of experimental design (21 runs) with the coded levels is given on Table 1.

Determination of the responses: The moisture and crude fat contents of the Bambara nut flour were determined. The carbohydrate content was calculated by difference as[8]:

100-(Moisture (%)+Fat (%)+Protein (%)+Ash (%)+Fibre (%))

Determination of moisture content: Five grams of each sample was weighed into a pre-weighed aluminum drying dish. The sample was dried to a constant weight in an oven at 105°C for four hours[9].

The moisture content was determined as follows:

$$\frac{M_1 - M_2}{M_1 - M_0} \times 100 \quad (1)$$

Where

M_0 : Weight of aluminum dish

M_1 : Weight of fresh sample+dish

M_2 : Weight of dried sample+dish

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 system. A previously weighed clean dried 250 mL flask was filled with 200 mL petroleum ether (boiling point 40-60°C).

The Soxhlet apparatus were assembled and allowed to reflux for about 6 hours, the solvent was recovered and the flask with the extract was dried in the oven (DHG-9023A, England) at 105°C for 30 min. It was then cooled in the desiccator and weighed[10]. The crude fat was calculated as stated in Eq. 2:

$$\text{Fat}(\%) = \frac{W_3 - W_2}{W_1} \times 100 \quad (2)$$

Where:

W_1 : Weight of sample

W_2 : Weight of empty flask

W_3 : Weight of flask extracted oil

Modeling of the flour shelf-life: Each design point was performed in duplicates, except the center 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

Table I: Effect of packaging materials and storage time on the proximate composition of Bambara nut flour stored for a period of seven weeks

Month	Packaging material	Moisture	Ash	Protein	Fat	Fibre	Carbohydrate
1st week	LDPE	12.00	2.67	21.01	5.67	2.67	56.81
	PC	11.17	3.00	20.13	4.67	2.33	57.87
	LPB	11.67	3.00	21.01	5.33	2.00	56.99
2nd week	LDPE	12.00	2.67	22.76	5.33	2.67	56.36
	PC	9.33	3.00	20.13	4.67	2.33	57.87
	LP	11.69	3.00	21.01	5.33	2.00	56.12
3rd week	LDPE	9.67	3.33	21.01	5.67	3.00	58.99
	PC	8.00	3.33	27.13	6.33	3.33	50.54
	LPB	9.67	3.33	27.13	6.00	3.33	50.54
4th week	LDPE	9.33	3.30	21.01	8.00	3.33	56.69
	PC	7.67	3.30	20.13	7.67	2.67	56.23
	LPB	9.00	3.00	19.26	7.33	3.00	58.08
5th week	LDPE	9.00	3.33	28.89	8.00	3.00	49.78
	PC	7.00	3.33	21.88	7.59	2.56	55.64
	LPB	8.33	2.84	26.26	7.00	3.01	52.56
6th week	LDPE	8.00	3.33	36.76	8.10	2.95	42.53
	PC	6.33	3.33	29.76	7.50	2.66	48.75
	LPB	7.33	2.67	33.26	7.00	3.00	46.74
7th week	LDPE	8.67	3.33	26.63	7.80	2.67	50.90
	PC	9.00	3.33	25.01	7.60	2.58	42.48
	LPB	8.67	3.00	25.38	7.77	2.72	53.23

LDPE: Low density polythene bag, PC: Plastic container, LPB: Laminated paper bag, respectively 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:

$$R^2 = \frac{\text{Sum of square residual}}{\text{Model sum of square+Sum of square residual}} \quad (3)$$

$$R^2 \text{ adj} = 1 - \frac{n-1}{n-p}\left(1-R^2\right) \quad (4)$$

Where:

R^2	:	Coefficient of determination
R^2 adj	:	Adjusted coefficient of determination
p	:	Number of the regression coefficient
n	:	Total numbers of observations

Process optimization: To optimize the response variables, contour and surface plots were performed using the Design-Expert software package[11]. A second-order polynomial was used to predict the experimental behavior (Eq. 3):

$$Y = \beta o + \beta_1 X_1 + \beta_2 X_2 + \beta_1 X_{21} + \beta_2 X_{22} + \beta_{11} X_1 X_2 + \beta_{12} X_1 X_2 + \varepsilon \quad (5)$$

where, X_1, X_2 and X_{21} are the factors: temperature, packaging materials and time, B's are the 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 same software.

RESULTS AND DISCUSSION

Table 1 showed the effects of packaging materials and storage time on the proximate composition of Bambara nut flour stored for a period of seven weeks. Packaging material and time has an impact on the composition of Bambara nut flour ($p<0.05$). The result showed that Bambara nut flour packed and kept in different packaging materials had an influence on the proximate compositions. Table 2 shows the variation of parameters of 2 numerical factors design in Response surface methodology for the temperature, packaging materials and storage time at high and low levels. The result shows that, storage time, packaging material and temperature ranges from 1-7 weeks, 1-3 and 20-40°C respectively.

Modeling of parameters: 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. Using the experimental data in Table 4, second degree polynomial models for the flour moisture, crude fat and carbohydrate contents were regressed and the equations are shown below:

$$\text{Moisture} = +9.94+0.066A+0.45B-1.42C-0.10AB-0.19AC -0.27BC+0.39A^2-1.36B^2+0.64C^2 \quad (6)$$

$$\text{Fat} = +7.43-0.19A-0.17BB+1.45C+0.041AB+ 0.22AC+0.20BC-0.57A^2+0.60B^2-0.93C^2 \quad (7)$$

$$\text{Carbohydrate} = +56.11-2.81A-0.054B-6.54C-0.14AB- 3.01AC+0.88BC+0.1A^2+1.46B^2-5.75C^2 \quad (8)$$

Model evaluation: The model analysis results (Table 4) showed that the following model, which is a quadratic equation, appears to be the most accurate with no significant lack of fit. The coefficient of the regression equations for the measured responses, the linear, quadratic and interaction terms of the selected variables was evaluated and values shown in Table 4. The results of the effect of temperature showed that two linear (A, B), three quadratic (A^2, B^2, C^2) parameters and one interaction (BC) terms were significant at $p<0.05$ as shown in Table 4. For the packaging materials, it was observed from the analysis that two linear (A, C) parameters, three quadratic (A^2, B^2, C^2) and one interaction

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

Variables	Numerical Factors Low Levels (-1)	High Levels (+1)
Temperature (°C)	20	40
Packaging materials (No.)	1	3
Time (weeks)	1	7

Table 3: Variables, levels and experimental data for proximate analysis of Bambara nut flour

Factors				Responses		
Treatments (°C)	Temperature	Packaging Materials (No.)	Time (weeks)	Moisture Content (%)	Fat content (%)	Carbohydrate Content (%)
1	40	2	4	11.5	5.33	55.41
2	30	2	4	10.0	7.67	56.21
3	20	3	1	12.0	5.00	57.20
4	30	2	7	9.00	7.60	42.48
5	30	2	4	10.0	7.67	56.23
6	30	2	4	10.0	7.67	56.23
7	30	2	1	12.0	4.67	57.87
8	40	1	1	10.67	5.33	58.74
9	40	3	1	11.33	4.67	56.99
10	20	2	4	9.00	7.67	56.65
11	40	3	7	8.00	8.49	39.45
12	30	2	4	10.0	7.67	56.23
13	40	1	7	7.67	8.20	39.24
14	30	2	4	10.0	7.67	56.23
15	20	3	7	8.67	7.77	53.23
16	20	1	7	8.67	7.80	50.90
17	20	1	1	10.17	5.67	59.92
18	30	2	4	10.0	7.67	56.23
19	30	3	4	9.33	7.33	58.08
20	30	1	4	7.67	8.00	56.69

1: high density polythene bag, 2 = paper bag and 3 = plastic container, respectively

Table 4: Model summary statistics

Parameter	Coefficient estimate	Degree of freedom	Standard error	95% CI Low	95% CI High	VIF
Moisture content						
Intercept	9.94	1	0.22	9.44	10.44	-
A	0.066	1	0.21	-0.39	0.52	1.00
B	0.45	1	0.21	-0.011	0.91	1.00
C	-1.42	1	0.21	-1.87	-0.96	1.00
AB	-0.10	1	0.23	-0.62	0.41	1.00
AC	-0.19	1	0.23	-0.70	0.33	1.00
BC	-0.27	1	0.23	-0.78	0.24	1.00
A^2	0.39	1	0.39	-0.48	1.27	1.82
B^2	-1.36	1	0.39	-2.23	-0.48	1.82
C^2	0.64	1	0.39	-0.23	1.52	1.82
Fat content						
Intercept	7.43	1	0.21	6.96	7.89	-
A	-0.19	1	0.19	-0.62	0.24	1.00
B	-0.17	1	0.19	-0.60	0.25	1.00
C	1.45	1	0.19	1.02	1.88	1.00
AB	0.041	1	0.21	-0.44	0.52	1.00
AC	0.22	1	0.21	-0.25	0.70	1.00
BC	0.20	1	0.21	-0.28	0.68	1.00
A^2	0.57	1	0.37	-1.38	0.25	1.82
B^2	-0.60	1	0.37	-0.22	1.41	1.82
C^2	-0.93	1	0.37	-1.75	-0.12	1.82
Carbohydrate content						
Intercept	56.11	1	0.46	55.07	57.14	-
A	-2.81	1	0.43	-3.76	-1.86	1.00
B	-0.054	1	0.43	-1.00	0.90	1.00
C	-6.54	1	0.43	-7.49	-5.39	1.00
AB	-0.14	1	0.48	-1.21	0.92	1.00
AC	-3.01	1	0.48	-4.07	-1.94	1.00
BC	0.88	1	0.48	-0.19	1.94	1.00
A^2	0.10	1	0.81	-1.71	1.91	1.82
B^2	1.46	1	0.81	-0.35	3.27	1.82
C^2	-5.75	1	0.81	-7.56	-3.94	1.82

A, B and C: Model parameters for the linear, AB, AC and BC: Model parameters for the Interaction; A^2, B^2 and C^2: Model terms for square terms

terms were significant at $p<0.05$ and two of the interaction terms were not significant. In the case of the storage time, all the linear (A, B, C) terms and the quadratic terms were significant terms. One interaction term (BC) was also significant. Just like the temperature and packaging material, two of the interaction terms were not significant.

Fitting of the quadratic model: The quadratic models fitting are shown in Table 5. From the Analysis of Variance (ANOVA), it was clear that the models were significant ($p<0.05$) for the predicted moisture, fat and carbohydrate contents of Bambara nut flour. The correlation coefficient (R^2) 0.8693, 0.8839 and 0.9750 for the flour moisture, crude fat and carbohydrate contents, respectively were obtained. R-squared value is an indication of the level of responses that can be explained by a particular model. From these results, it could be shown that 86.93,88.93 and 97.50% of the responses could be explained by the model. Statistically, the significant levels obtained were

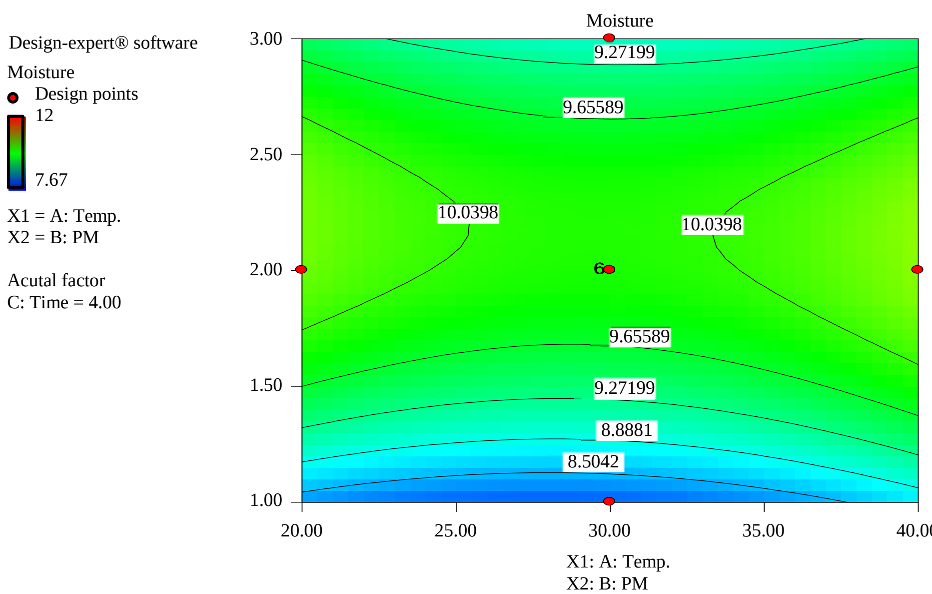
Table 5: Analysis of variance for Response surface model

Source	SS	Df	MS	F-value	p-value
Moisture					
Model	28.17	9	3.13	7.39	0.022
A	0.044	1	0.044	0.10	0.755
B	2.01	1	2.01	4.74	0.05
C	20.05	1	20.05	47.3	<0.001
AB	0.088	1	0.088	0.21	0.66
AC	0.28	1	0.28	0.66	0.43
BC	0.58	1	0.58	1.38	0.27
A^2	0.43	1	0.43	1.01	0.34
B^2	5.05	1	5.05	11.92	0.06
C^2	1.14	1	1.14	2.70	0.13
Residual	4.24	10	0.42		
Lack of fit	4.24	5	0.85		
Pure Error	0.00	5	0.00		
$R^2 = 0.8693$, Predicted $R^2 = 10.486$					
Fat					
Model	28.02	9	3.11	8.96	0.0013
A	0.36	1	0..36	0.97	0.3478
B	0.30	1	0.30	0.82	0.3857
C	21.08	1	21.08	57.29	<0.001
AB	0.014	1	0.014	0.037	0.8513
AC	0.40	1	0.40	1.09	0.3214
BC	0.32	1	0.32	0.86	0.3755
A	0.89	1	0.89	2.41	0.1517
B	0.98	1	0.98	2.67	0.1336
C	2.39	1	2.39	6.50	0.0289
Residual	3.68	10	0.37		
Lack of fit	3.68	5	0.74		
Pure Error	0.00	5	0.00		
$R^2 = 0.8839$, Predicted $R^2 = 5.78$					
Carbohydrate					
Model	708.61	9	78.73	43.33	<0.0001
A	78.79	1	78.79	43.36	<0.0001
B	0.029	1	0.029	0.016	0.0917
C	427.98	1	427.98	235.51	<0.0001
AB	0.17	1	0.17	0.091	0.7691
AC	72.30	1	72.30	39.79	<0.0001
BC	6.14	1	6.14	3.38	0.0958
A	0.029	1	0.029	0.016	0.9024
B	5.85	1	5.85	3.21	0.1033
C	91.01	1	91.01	50.08	<0.001
Residual	18.17	10			
Lack of fit	18.17	5			
Pure Error	3.33E-004	5			
$R^2 = 0.9750$, Predicted $R^2 = 59.02$					

A, B and C: Model parameters for the linear, AB, AC and BC: Model parameters for the Interaction, A^2, B^2 and C^2: Model terms for square terms

0.0037, 0.004 and 0.003 for the flour moisture, fat and carbohydrate contents, respectively. These levels were high and attested to the fitness of the model in evaluating the responses. The results obtained in this study revealed that the models employed are good and could be used for the prediction of the three selected responses (moisture, fat and carbohydrate contents) for the production and storage of Bambara nut flour.

Figure 1 is the three dimensional contour and surface plots showing the effect of temperature, packaging material and storage time on the moisture content of Bambara nut flour. The figure shows that the temperature and packaging material contributed to the reduction of the flour moisture content. The progressive decrease in moisture content during the storage period was observed across all the packaging materials. The 3D contour and surface plots (Fig. 2) showed the effect of temperature, packaging material 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 weeks of storage. However, as the storage period increased from week 4 to week 7, a slight increase was noticed on the fat content. It could be as a result of the relative humidity of the storage environment and the microbial activities inside the packaging materials. The 3D surface and contour plots (Fig. 3) showed that there were significant ($p<0.05$) contributions on the temperature,



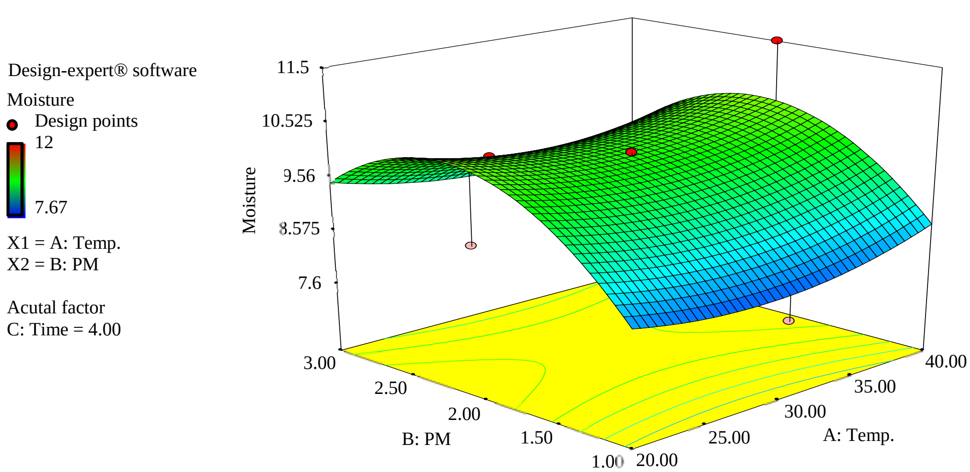


Fig. 1: 3D surface and contour plots showing the effect temperature and packaging materials on the moisture content of Bambara nut flour

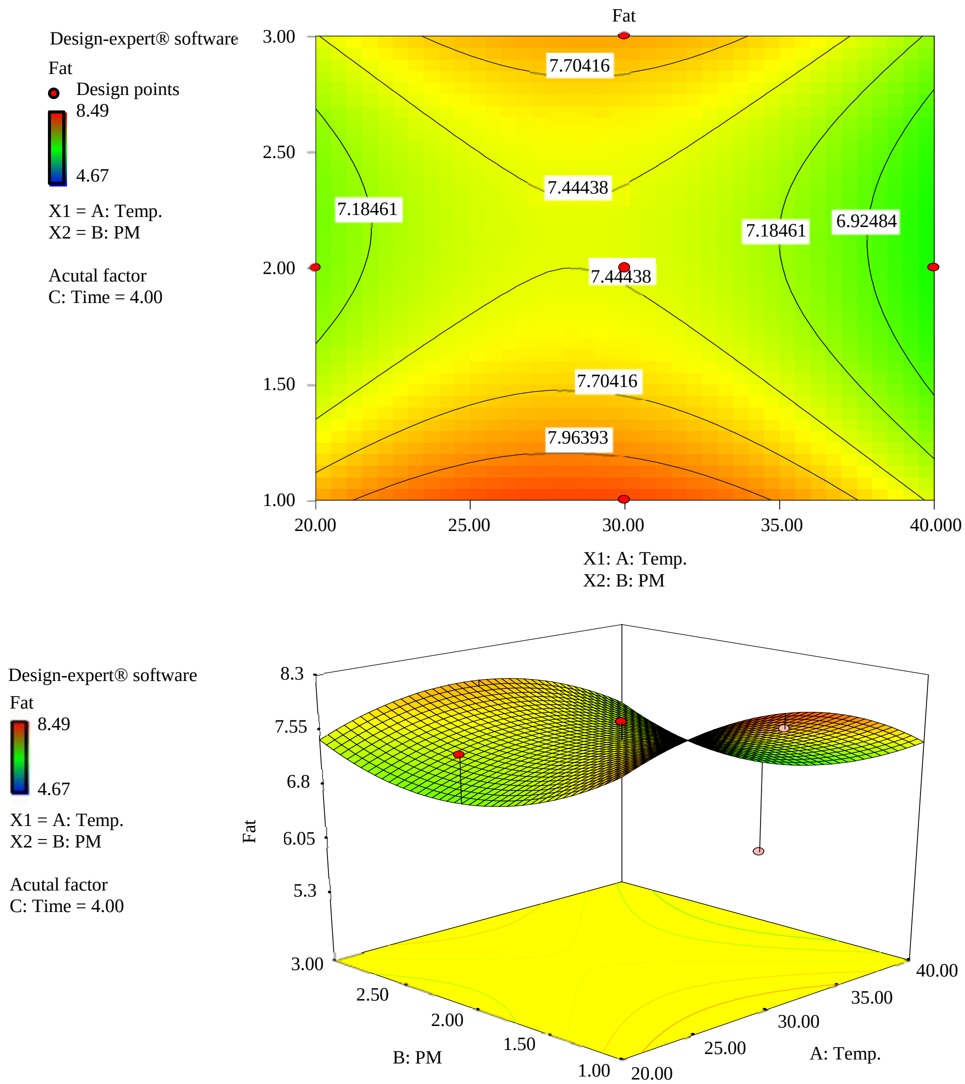


Fig. 2: 3D surface and contour plots showing the effect temperature and packaging materials on the fat content of Bambara nut flour

packaging material and storage time on the carbohydrate content from the beginning of the storage period to the end of the storage at week 7.

The flour moisture content values are related to the stability of food flours during storage since it corresponds with the recommended moisture content by standard organization of Nigeria (9-14%) for flour stability and in line with the reported range of moisture content of different cultivars of cassava flour[12]. The flours stored in plastics containers at ambient (30°C) did not significantly ($p<0.05$) affect its moisture content. However, moisture content was slightly higher for flours packaged in paper and polythene bags than for those in plastic containers. Similar findings have been reported by Mohammad Nasir *et al.*[13] for moisture content of wheat flour during storage in polypropylene bag for a period of 60 days.

The fat content increased with storage duration across samples. This increase might be due to possible proteolytic and lipolytic activities of the enzymes which in turn headed to the loss in nutrients. Previous studies on the storage of other flour products also stated an increase in fat content[14]. Ogiehor *et al.*[15] recounted that, the fat content is higher in the hull and pods while least in the nut. Furthermore, the increase could also be due to the microbial actions inside the packaging materials during storage which catalyzed the release of organic acids.

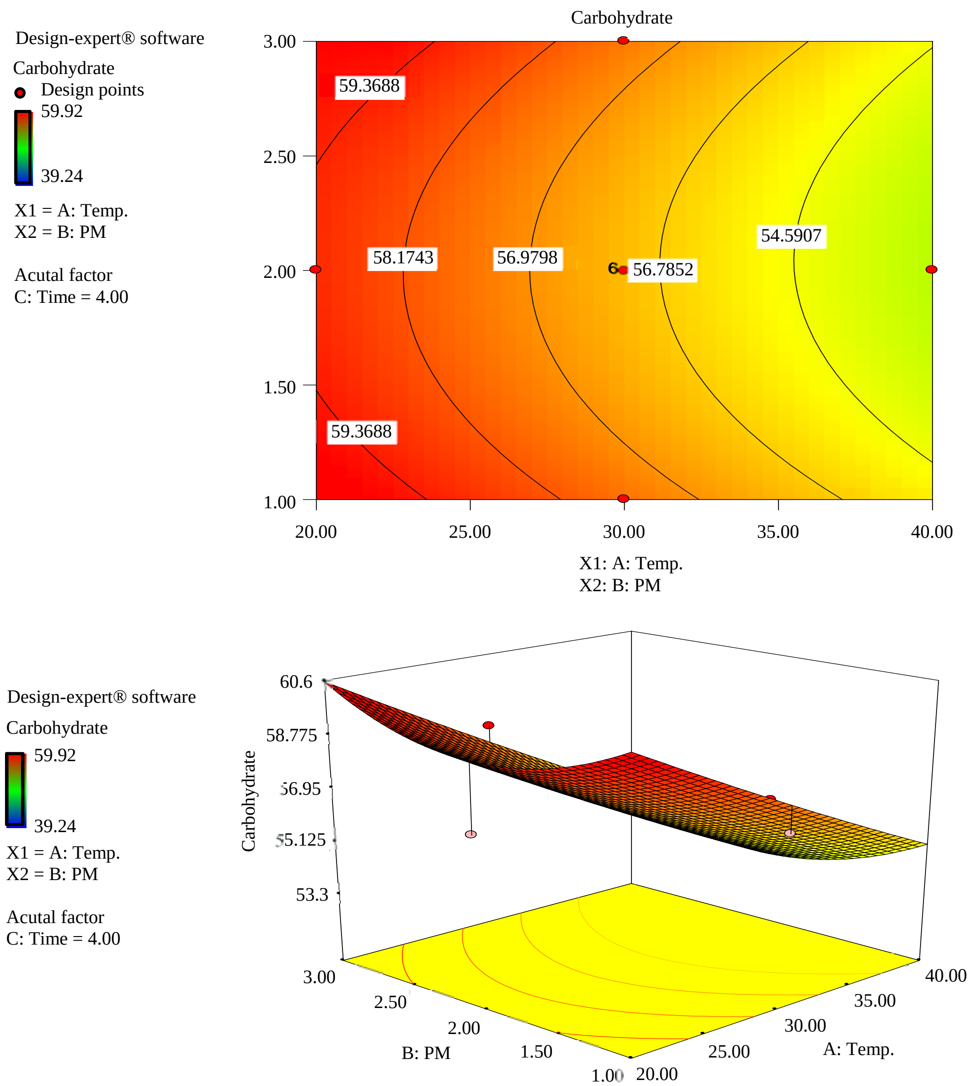


Fig. 3: 3D surface and contour plots showing the effect temperature and packaging materials on the carbohydrate content of Bambara nut flour

The result of the carbohydrate content of Bambara nut flour was in consistent with reports in the literature on the carbohydrate content of five different varieties of *Vigna subterranean* flour[16], the interaction between the materials used and then the time of storage had an impact on the percentage of carbohydrate content (Fig. 3).

The disparity in carbohydrate content might be due to the variation in the materials used for packaging as well as the moisture content of the flour. The flour with low moisture content probably may have higher carbohydrate content, because of the differences in the percentage of other proximate compositions[17].

It was noticed that packaging material with the highest moisture content barrier gave a consistent decrease in percentage carbohydrate and vice-versa. Therefore, Bambara nut flour packaged in plastic containers best maintained dry matter content, as well as the moisture content stability, which is a clear sign of longer shelf stability compared to paper bag storage and polythene bag. This finding suggests that at a lower temperature, the percentage of carbohydrates could increase. However, in this study, variation in carbohydrate was observed to have a strong negative relationship with the percentage of moisture content. This result suggests that at lower moisture content, the percentage carbohydrate could increase depending on the percentage of all other components (protein, fat and ash). This is in agreement with Butt *et al.*[18]. Bambara nut flour requires careful handling, proper packaging and favorable environmental storage conditions to make it stable over long period.

The study of obtaining the appropriate packaging material, optimum temperature and maximum shelf life of Bambara nut flour will bring about the desired knowledge of mass production of packaged Bambara nut flour in the market. The research study will increase the production and consumption of Bambara nut flour and invariably improves its commercial value. The flours are now available at market outlets mostly in the Northern part of Nigeria for diabetic patients. Flour packaged in plastic containers had the lowest moisture content.

This research work is limited to temperature, packaging materials and storage time. It is recommended that for future studies, the effect of other compositional and environmental storage conditions such as pH, microbial load, color, sensory attributes and foam stability should be investigated and the result compared with principal component analysis.

CONCLUSION

Response surface methodology was successfully used to 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 best temperature, packaging materials, 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.

SIGNIFICANCE STATEMENT

Despite the nutritional and economic importance of Bambara nut, presently there is a paucity of information on the storage techniques of Bambara nut flour that can prolong the shelf-life for later usage. This makes the study of the processing and storage of Bambara nut flour, the impacts of storage conditions on the proximate composition of Bambara nut flour as a product very vital. Like most agricultural products, Bambara nut flour is hygroscopic and the storage environment could adversely affect its quality. Consequently, the study of the optimization of the storage conditions of Bambara nut flour is imperative. Knowledge of the Bambara nut flour optimum storage condition is important for the shelf-life prediction, determination of best packaging material and the optimum temperature for the storage of the flour. This study discovered the storage conditions that can be beneficial for storing Bambara nut flour. This study will help researchers to uncover the critical challenges of storing food flours that many researchers were not able to explore. Thus a new theory on Bambara nut flour storage techniques may be arrived at.

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