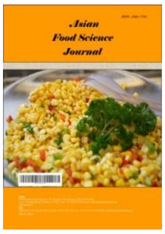

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Effect of Slice Weight and Soaking Time on the Physico-Chemical Properties of Cassava Flour (*Manihot esculentus*) used for Bakery Products

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Authors' contributions

This work was carried out in collaboration among all authors. Author CRA designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors CNI and JEO managed the analyses of the study. Authors EFO and CSA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Quality cassava (*Manihot esculentus*, Crantz) flour is often influenced by process variables such as slice weight and soaking time which may affect its nutritional quality. In this study, the effect of process variables (slice weight and soaking time) on quality of cassava flour was carried out. Cassava root was peeled, washed and cut into varied sizes (25.86 - 54.14 g) and soaked at varied time (7.03 - 40.97 h). The proximate composition, physical and chemical properties of the flour were carried out using standard methods. The result in our findings showed that slice weight and soaking time had significant increase ($p<0.05$) on the proximate and physico-chemical properties of the flour.The amylose and amylopectin content of the flour increased with increasing soaking time while the hydrogen cyanide content decreased with increase in soaking time. Overall, the quality cassava flour displayed desirable properties for its incorporation into baked goods.

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Keywords: Quality cassava flour; soaking time; slice weight; bakery products.

1. INTRODUCTION

Root and tuber crops such as yam and cassava are important source of carbohydrates globally after cereals [1]. However, cassava is the second most important tropical root crop in West Africa [2, 3]. Cassava (*Manihot esculenta*) is a root crop that is consumed in many parts of the world. It is drought tolerant and can withstand harsh climatic conditions and can thrive well on poor soils and marginal lands [4]. Cassava root is a starchy crop that has been processed into various forms for utilization. For instance, it may be processed into quality cassava flour (QCF). QCF is an unfermented cassava product that has been successfully used as a partial and complete replacement for wheat flour in processing of bread, cookies, and other confectioneries [5]. In Nigeria and some parts of the tropics, cassava roots are processed into traditionally fermented food products such as gari, fufu, elubo and tapioca [6]. Furthermore, cassava is considered a good source of dietary fibre which may be used to increase bulkiness and facilitate digestion. More importantly, cassava is also a good source of starch for various industrial applications. Several factors such as processing methods and variables, growing conditions and genotypic differences may influence the composition and physicochemical properties of cassava flour and starch. For instance, Janket et al.[7] studied the effect of varying seasons on starch accumulation and starch granule size in cassava genotypes grown in tropic Savannah climate. These authors reported that amylose content of the extracted starch was greatly influenced by genotype. Furthermore, higher temperature and solar radiation received during October and December of the growing period resulted in significantly higher starch yield and starch content compared to those planted in other periods of the year. Other factors such as growing season and period of harvest may also influence starch granule size and amylose content, which may influence starch physicochemical properties and functionality. Asaoka et al., [8], found variation in granule size of starch extracted from cassava root grown at different seasons. In addition, the period of harvest reportedly altered the proportion of amylose in cassava starch [9]. Different process variables such as soaking time, slice weight and drying temperature have been said to influence the physicochemical properties of cassava flour [7]. It is therefore important to evaluate the effect of these factors on quality cassava flour. Thus, this study was aimed at evaluating the effect of slice weight and soaking time on the physico-chemical properties of cassava flour.

2. MATERIALS AND METHODS

2.1 Source of Materials

Fresh cassava roots of *Manihot spp* (white variety) was obtained from the Faculty of Agriculture farm, Nnamdi Azikiwe University Awka, Anambra State, at about 12 months old after planting.

2.2 Experimental Design

Statistical software Design Expert version 7.0 was used. The experiment is a response surface methodology, designed in rotatable Central Composite design (RCCD). It has two independent variables (slice weight 25.86 – 54.14 g) and soaking time (7.03 - 40.97 h).

2.3 Sample Preparation

Cassava flours were produced from the cassava root in the Department of Food Science and Technology, Nnamdi Azikiwe University Awka, Anambra State Nigeria following the method of Ogbonnaya et al. [10] with slight modification. The fresh roots were peeled manually and cut into cylindrical pieces of different weight (25.86 - 54.14 g). The cassava roots were soaked by submerged in water at ambient temperature (30±3 ^{0}C) at different soaking time (7.03 - 40.97 h) with changing the steep water after every 6 h. The soaked slices were drained and dried using solar dryer at a constant temperature and milled to a particle size of 3.0 mm using attrition mill (2A premier grinding mill, Hunt and Co., United Kingdom). Sieving was done manually with muslin cloth to obtain fine cassava flour. The cassava flours obtained were properly packaged and stored at room temperature (28±2 ^{0}C) until ready for analysis.

2.4 Sample Analysis

2.4.1 Proximate analysis

Moisture content, crude fibre, crude fat, crude protein and Ash content were determined using the gravimetric method of the Association of Official Analytical Chemists, AOAC, [11].

Total carbohydrate content was determined by the method of Yerima and Adamu [12].

2.5 Determination of Physical Properties

2.5.1 Determination of particle size distribution

The particle size of flour samples will be determined using a set of eight Endicott test sieves (Endicott Ltd., London, UK) ranging from 600 µm to 53 µm sieve sizes arranged in decreasing order of pore size. About 100 g of each sample will be sieved for 15 min on an Endecott's sieve shaker (Endicott Ltd.). The flour retained on each sieve and in the receiver, pan was weighed and expressed as the percentage of total flour. Appropriate calculations were made; cumulative graphs and histograms were drawn to obtain the average particle size and the most common particle size of each flour sample.

2.5.2 Determination of colour

Colour was measured using Disk-spinning method with Macbeth Munsell colorimeter. Appropriate Munsell colour disks were selected and their nominal values were noted. The five disks were arranged in an interwoven mesh placed on one side of the instrument against the flour sample on the other. Munsell light was turned on and the arranged disks spun by a motor at high speed. Visual colour match was observed between the sample and the spun disks. The exposed portion of each disk was adjusted until the colour match was observed. Each measurement was in triplicate and the average was employed in obtaining the CIE Chromaticity coordinates x, y and reflectance Y. These values were converted to Munsell notation using appropriate graphs and tables. The results were expressed as Hue, Value and Chroma.

2.5.3 Data analysis

Data generated were analyzed using statistical package for social sciences (SPSS version 22) and Design Expert version 7.0. The SPSS was used to compare the means of the response variables and identify the sample that differed significantly ($P<0.05$).

The Design Expert was used to regress the response variables and draw the necessary graphs (3-D Surface plots and Contour plots) and also form the mathematical model where the conditions for model adequacy were certified and optimize the process variables.

3. RESULTS

The results of our findings are discussed Tables 1-5.

4. DISCUSSION

4.1 Moisture

The general ideal polynomial quadratic model is as equation 1.

$$Yi = \beta_0 + \sum_{i=1}^{3}\beta_i X_i + \sum_{i=1}^{3}\beta_{ii} X_{ii}^2 + \sum_{i=1}^{3}\sum_{j=i+1}^{3}\beta_{ij} X_i X_j \quad (1)$$

where Yi is the response variable for cassava, X_1 is the slice weight, X_2 is the soaking time,β_o isthe coefficient of the constant term. β_i is the coefficient of the linear term, β_{ij} is the coefficient of the interactive term while β_{ii} is the coefficient of quadratic term.

The proximate composition of the cassava flour samples is shown in table 1.0. The moisture content of the samples ranged between 5.05 and 9.04 % with sample 9 having the lowest value (5.05 %) and sample 1 having the highest value (9.04 %). This is consistent with the findings of Onitilo et al. [13] and slightly lower than the moisture content of wheat flour (11.90 ± 0.71 %) as reported by Iwe et al. [14]. This result is also an indication that the flour samples will keep well if properly stored under good conditions in other to discourage moisture absorption from the atmosphere which may eventually lead to caking [15]. The moisture content of any food is an index of its water activity and it is used as a measure of storage stability and susceptibility to microbial contamination. Hence, the lower the moisture contents of a food, the higher the storage stability.

$$\text{Moisture} = a + b_1X_1 + b_2X_2$$
$$\text{Moisture} = 7.37 + 0.015X_1 + 1.28X_2 \quad (2)$$

Moisture content was modeled as shown in Eq. 2. Linear model was suggested from the ANOVA $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ had p. value <0.05. Therefore, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are the only terms used in fitting the model. Fig. 1a shows the 3D Surface plot of moisture content. From this figure and equation above, the moisture content of the flour is increased by both slice weight and soaking time, since the coefficients of $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are positive. However, increasing the soaking time showed greater increase in the moisture content than the slice weight (Fig. 1a).

Table 1. Proximate composition of cassava flour

Sample	Slice weight X_1 (g)	Soaking time X_2 (h)	Moisture content (%)	Crude fibre (%)	Crude fat (%)	Crude protein (%)	Ash content (%)	Carbohydrate content (%)
1	40	24	7.24±0.02 [b]	0.05±0.01[cd]	0.42±0.02 [c]	3.24±0.03 [c]	0.62±0.01 [d]	80.24±0.03 [d]
2	40	24	7.25±0.01 [b]	0.07±0.01[bc]	0.40±0.02 [c]	3.20±0.02 [c]	0.64±0.02 [d]	82.28±0.04 [c]
3	25.86	24	7.25±0.01 [b]	0.05±0.02[cd]	0.42±0.03 [c]	3.18±0.02 [d]	0.62±0.01 [d]	82.24±0.04 [c]
4	40	24	7.28±0.04 [b]	0.05±0.00[cd]	0.43±0.01 [c]	3.30±0.04 [a]	0.62±0.01 [d]	81.88±0.05 [c]
5	30	12	6.54±0.02 [c]	0.04±0.00 [d]	0.28±0.01 [d]	3.08±0.01 [e]	0.74±0.03 [b]	85.54±0.06 [b]
6	50	12	6.57±0.02 [c]	0.04±0.00 [d]	0.25±0.01 [d]	3.10±0.01 [e]	0.70±0.02 [c]	84.90±0.05 [b]
7	40	24	7.23±0.03 [b]	0.07±0.02[bc]	0.48±0.03 [c]	3.20±0.02 [c]	0.60±0.01 [d]	82.08±0.04 [c]
8	54.14	24	7.32±0.03 [b]	0.06±0.01 [c]	0.45±0.03 [c]	3.22±0.02 [c]	0.68±0.02 [b]	81.86±0.05 [c]
9	40	7.03	5.05±0.00 [d]	0.03±0.01 [e]	0.18±0.01 [e]	3.02±0.01 [f]	0.82±0.04 [a]	90.02±0.06 [a]
10	40	24	7.25±0.03 [b]	0.06±0.02 [c]	0.44±0.04 [c]	3.18±0.02 [d]	0.66±0.02 [d]	83.02±0.04 [b]
11	50	36	8.86±0.04 [a]	0.09±0.03 [b]	0.48±0.03 [b]	3.26±0.03 [b]	0.78±0.04 [a]	80.06±0.02 [d]
12	40	40.97	9.04±0.06 [a]	0.12±0.04 [a]	0.52±0.04 [a]	3.28±0.04 [a]	0.73±0.03 [b]	79.18±0.02 [d]
13	30	36	8.87±0.04 [a]	0.10±0.04 [a]	0.47±0.02 [b]	3.26±0.03 [b]	0.72±0.03 [b]	81.06±0.05 [c]
14	control							

Values are means ± standard error of mean. Values on the same column with different superscript are significantly different at $P< 0.05$.

Table 2. Particle size distribution of cassava flour

Sample	Slice weight (g)	Soaking time (h)	Particle Size Distribution (µm)
1	40	24	39.78± 0.02 ^{d}
2	40	24	39.67± 0.02 ^{d}
3	25.86	24	39.59± 0.01 ^{d}
4	40	24	39.48± 0.02 ^{d}
5	30	12	42.05± 0.03 ^{b}
6	50	12	43.10± 0.04 ^{b}
7	40	24	40.22± 0.00 ^{c}
8	54.14	24	41.08± 0.01 ^{c}
9	40	7.03	52.18± 0.04 ^{a}
10	40	24	41.10± 0.02 ^{c}
11	50	36	40.09± 0.03 ^{c}
12	40	40.97	40.02± 0.02 ^{c}
13	30	36	40.10± 0.02 ^{c}
14	Control		

Values are means ± standard error of mean. Values on the same column with different superscript are significantly different at P< 0.05.

Table 3.Colour of cassava flour

Sample	Slice weight (g)	Soaking time (hr)	Luminosity(L*)	a*	b*
1	40	24	60.45	59.55±0.04^{a}	10.05±0.03^{a}
2	40	24	60.66	59.35±0.04^{a}	10.44±0.02^{a}
3	25.86	24	56.33	55.54±0.03^{d}	8.88±0.01^{c}
4	40	24	59.66	58.88±0.04^{b}	9.65±0.01^{b}
5	30	12	60.55	58.66±0.04^{b}	9.55±0.01^{b}
6	50	12	63.33	61.12±0.06^{a}	10.04±0.03^{a}
7	40	24	60.45	59.22±0.04^{a}	9.55±0.02^{b}
8	54.14	24	60.85	58.88±0.04^{b}	9.88±0.02^{b}
9	40	7.03	58.87	57.77±0.04^{c}	9.67±0.03^{b}
10	40	24	59.75	58.45±0.02^{b}	10.07±0.03^{a}
11	50	36	61.13	59.85±0.03^{a}	10.18±0.03^{a}
12	40	40.97	60.66	59.44±0.02^{a}	10.18±0.3^{a}
13	30	36	57.77	56.55±0.01^{d}	9.44±0.02^{b}
14	control		60.33	59.44±0.03^{a}	10.22±0.03^{a}

Values are means ± standard error of mean. Values on the same column with different superscript are significantly different at P< 0.05.

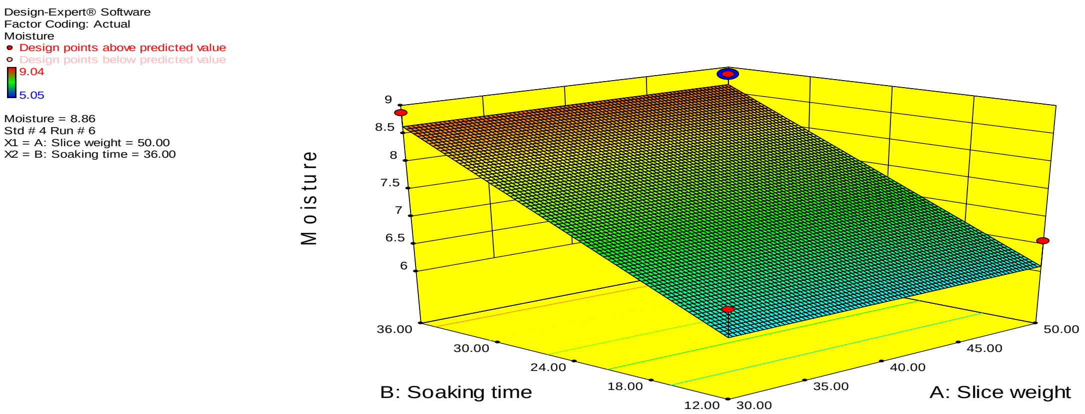

Fig. 1a. 3D surface plot of moisture content of cassava flour

Table 4. Cassava flour colour, amylopectin, amylose and hydrogen cyanide contents

Sample	Slice weight (g)	Soaking time (h)	Luminosity(L*)	a*	b*	Amylopectin (%)	Amylose (%)	Hydrogen Cyanide (mg/kg)
1	40	24	60.45	59.55±0.04[a]	10.05±0.03[a]	70.24±0.04[a]	25.02±0.03[a]	8.05±0.14 [d]
2	40	24	60.66	59.35±0.04[a]	10.44±0.02[a]	70.18±0.04[a]	25.06±0.03[a]	8.02±0.06 [d]
3	25.86	24	56.33	55.54±0.03[d]	8.88±0.01[c]	68.08±0.02[c]	25.25±0.01[b]	7.24±0.03 [d]
4	40	24	59.66	58.88±0.04[b]	9.65±0.01[b]	70.24±0.03[b]	25.12±0.03[a]	8.04±0.04 [d]
5	30	12	60.55	58.66±0.04[b]	9.55±0.01[b]	65.00±0.02[c]	20.44±0.00[c]	12.48±0.10 [b]
6	50	12	63.33	61.12±0.06[a]	10.04±0.03[a]	65.08±0.02[c]	22.10±0.04[a]	13.00±0.02 [a]
7	40	24	60.45	59.22±0.04[a]	9.55±0.02[b]	70.22±0.04[a]	25.04±0.04[a]	8.04±0.04 [d]
8	54.14	24	60.85	58.88±0.04[b]	9.88±0.02[b]	69.08±0.02[b]	26.22±0.04[a]	9.02±0.01
9	40	7.03	58.87	57.77±0.04[c]	9.67±0.03[b]	50.26±0.01[c]	14.02±0.03[a]	14.12[a]±0.03 [c]
10	40	24	59.75	58.45±0.02[b]	10.07±0.03[a]	70.04±0.02[b]	24.88±0.03[a]	8.02±0.03 [d]
11	50	36	61.13	59.85±0.03[a]	10.18±0.03[a]	72.00±0.04[a]	28.24±0.05[a]	10.24±0.04 [c]
12	40	40.97	60.66	59.44±0.02[a]	10.18±0.3[a]	73.84±0.04[a]	28.98±0.04[a]	10.02±0.02 [c]
13	30	36	57.77	56.55±0.01[d]	9.44±0.02[b]	71.02±0.04[a]	27.06±0.02[b]	9.82±0.04 [c]
14	control		60.33	59.44±0.03[a]	10.22±0.03[a]			

Values are means ± standard error of mean. Values on the same column with different superscript are significantly different at P< 0.05.

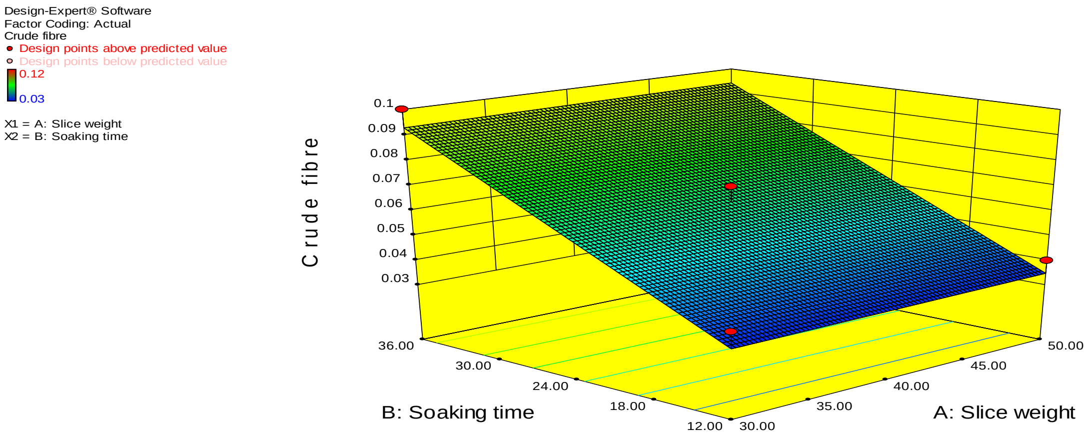

Fig. 1b. 3D Surface Plot of Fibre Content of Cassava Flour.

Table 5. Resistant starch content of cassava flour

Sample	Slice weight (g)	Soaking time (h)	Resistant Starch (%)
1	40	24	1.92±0.02 [ab]
2	40	24	1.94±0.02 [ab]
3	25.86	24	1.90±0.02 [ab]
4	40	24	1.92±0.02 [ab]
5	30	12	1.85±0.02 [b]
6	50	12	1.82±0.02 [b]
7	40	24	1.94±0.02 [ab]
8	54.14	24	1.75±0.01 [c]
9	40	7.03	0.94±0.00 [d]
10	40	24	1.92±0.02 [ab]
11	50	36	2.04±0.03 [a]
12	40	40.97	2.00±0.03 [a]
13	30	36	2.04±0.03 [a]
14	Control		

Values are means ± standard error of mean. Values on the same column with different superscript are significantly different at P< 0.05.

4.2 Crude Fibre

The fibre content of the cassava flour samples ranged from 0.03 to 0.12 %with sample 9 having the lowest value (0.03 %) and sample 12 having the highest value (0.12 %). These values are slightly lower than 1.58 % and 1.88 % reported by Iwe et al. [14] and Nwosu et al. [15] respectively. However, slight increase in fibre contents were observed for the different samples with varying soaking time, though the values did not show any definite pattern. Fibre helps in the maintenance of human health and has been known to reduce cholesterol level in the body [15]. It has also been shown that fibre helps to maintain the integrity of the bowel. A low fibre diet has been associated with heart diseases, cancer of the colon and rectum, varicose veins, phlebitis, obesity, appendicitis, diabetes and constipation [16].

$$\text{Fibre} = a + b_1X_1 + b_2X_2$$
$$\text{Fibre} = 0.064 + 5.17X_1 + 0.03X_2 \quad (3)$$

Fibre content was modeled as shown in Eq. 3. Linear model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ had p. value<0.05. Therefore, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are the only terms used in fitting the model. Fig. 1b show the 3D Surface plot of fibre content. From this figure and equation above, the fibre content of the flour is influenced by both slice weight and soaking time, since the coefficients of $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are positive. However, increasing the slice weight showed greater increase in the fibre content than the soaking time since it has higher coefficient value as depicted in Eq. 3 and Fig. 1b.

4.3 Crude Fat

Results obtained for crude fat showed that fat content ranged from 0.18 to 0.52 % for the flour samples with sample 9 having the lowest value (0.18%) and sample 12 being highest (0.52%). This result is consistent with the findings of Ajibola and Olapade. [17] and agrees with the claims of Iwe et al. [16] that cassava tuber is not an oil rich crop.

$$\text{Crude fat} = a + b_2X_2 + b_2X_2^{\,2}$$
$$\text{Crude fat} = 0.43 + 0.11X_2 - 0.048X_2^2 \quad (4)$$

Crude fat content was modeled as shown in Eq. 4. Quadratic model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}^{\mathbf{2}}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ had p. value<0.05. Therefore, $\boldsymbol{X_2}$ and $\mathbf{X_2^2}$ are the only terms used in fitting the model. Fig. 1a show the 3D Surface plot of crude fat content. From this figure and equation above, increasing the slice weight increased the crude fat. However, increasing soaking time slightly decreased the crude fat content.

4.4 Crude Protein

Protein content of the flour samples ranged from 3.02 to 3.30 % with sample 9 having the lowest (3.02 %) and sample 4 highest (3.30 %). This value is considerably low to the reported protein value for wheat flour (11.38 %) by Iwe et al. [14]. The lower protein content recorded in this finding is an indication that cassava flour is not a protein rich diet like wheat flour. This is in agreement with the report of Dhingra and Jood [18] and Akanbi et al. [19]. It has long been established that the bread-making performance of flours depends on the quantity and quality of their proteins [14]. Proteins are major constituents of most structural and cellular components in any living organism as they compose of amino acids and hence help in cellular growth.

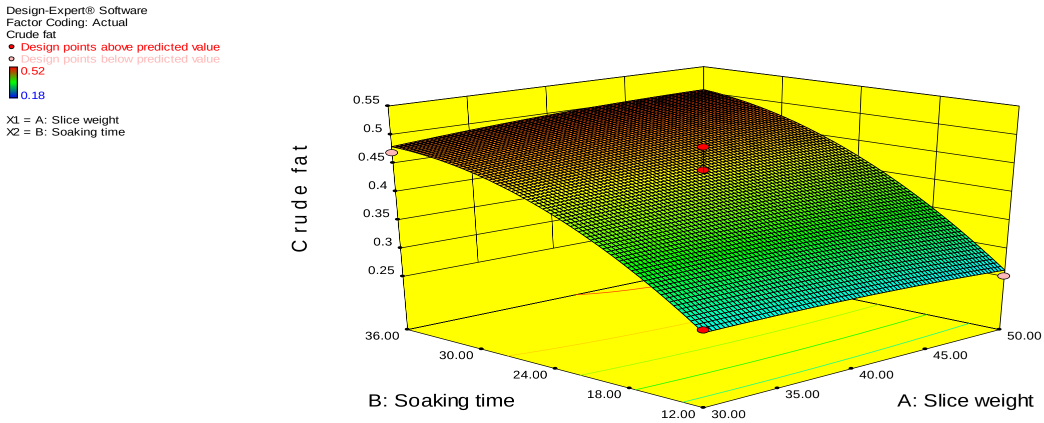

Fig. 1c. 3D Surface Plot of Crude Fat Content of Cassava Flour.

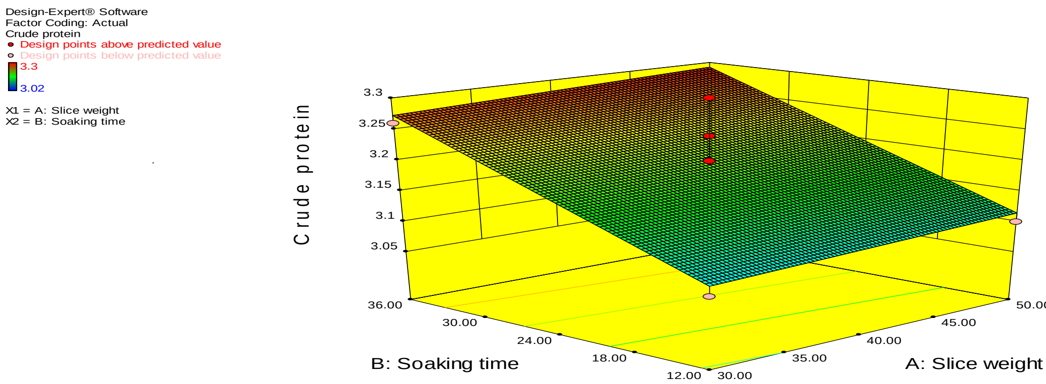

Fig. 1d. 3D surface plot of crude protein content of cassava flour

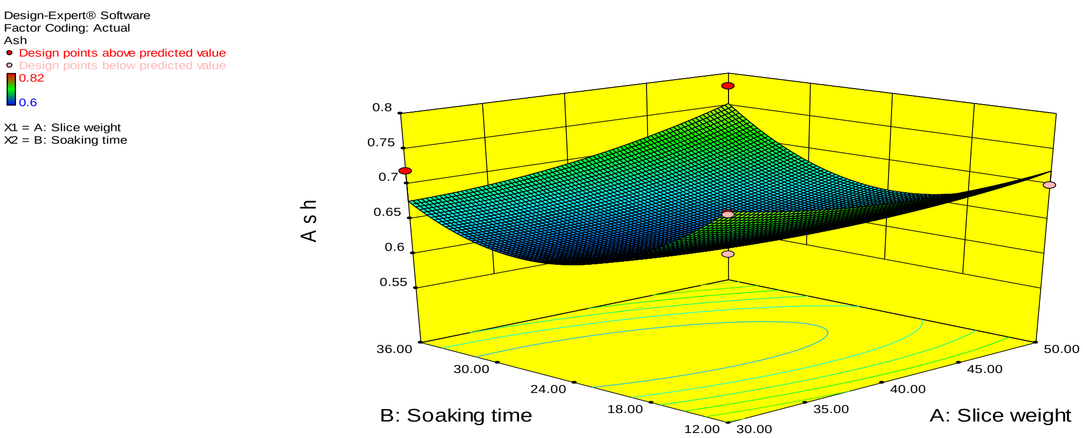

Fig. 1e. 3D Surface Plot of Ash Content of Cassava Flour

Crude Protein $= a + b_1X_1 + b_2X_2$
Crude Protein $= 3.19 + 9.57X_1 + 0.08X_2$ (5)

Crude protein was modeled as shown in Eq. 4. Linear model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ had p. value<0.05. Therefore, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are the only terms used in fitting the model. Fig. 4.4a show the 3D Surface plot of crude protein of the flour. From this figure and equation above, the crude protein content of the flour is influenced by both slice weight and soaking time, since the coefficients of $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are positive. However, increasing the slice weight showed greater increase in the crude protein content than the soaking time since it has higher coefficient value as depicted in Eq. 5 and Fig. 1d.

The lower protein content recorded in this finding is an indication that cassava flour is not a protein rich diet like wheat flour. This is in agreement with the report of Dhingra and Jood [18] and Akanbi et al. [19]. It has long been established that the bread-making performance of flours depends on the quantity and quality of their proteins. Proteins are major constituents of most structural and cellular components in any living organism as they compose of amino acids and hence help in cellular growth.

4.5 Ash Content

The ash content of the flour samples significantly ranged from 0.60 to 0.82 % with sample 7 having the lowest ash content value (0.60 %) while sample 9 had the highest (0.82 %). This result is in agreement with the findings of Sanni et al. [20] and Ajibola and Olapade [17] but slightly higher to the report of Iwe et al. [14]. Ash content is a reflection of the mineral matter in a food sample.

Ash$= a + b_2X_2 + b_2X_2^2$
Ash$= 0.63 + 0.02X_2 + 0.08X_2^2$ (6)

Ash content was modeled as shown in Eq. 6. Quadratic model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_2}$ and $\boldsymbol{X_2}^2$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ had p. value<0.05. Therefore, $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ are the only terms used in fitting the model. Fig. 1e show the 3D Surface plot of ash content. From this figure and equation above, increasing both the slice weight and soaking time increased the ash content of the flour. However, increasing the soaking time slightly showed greater increase in the ash content than the slice weight since it has higher coefficient value as depicted in Eq. 6.

4.6 Carbohydrate

Cassava flour samples recorded high carbohydrate content which ranged from 79.18to 90.02 %.Sample 12 had the lowest carbohydrate content (79.18%) while sample 9 had the highest (90.02 %). This value is considerably higher to the reported value for wheat flour (74.31 %) as documented by Iwe et al. [14]. This is an indication that cassava tubers are good sources of carbohydrate compared to wheat and hence could supply most of the body's energy requirement.

Carbohydrate $= a + b_1X_1 + b_2X_2$
Carbohydrate$= 82.64 - 0.27X_1 - 3.08X_2$ (7)

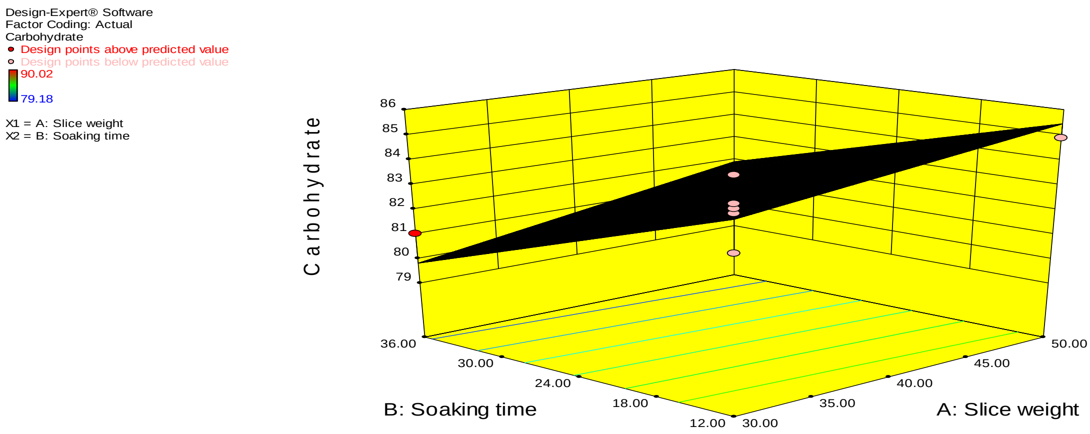

Fig. 1f. 3D Surface Plot of Carbohydrate Content of Cassava Flour.

Carbohydrate was modeled as shown in Eq. 7. Linear model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, X_1 and X_2 are slice weight and soaking time respectively. From the ANOVA, only X_1 and X_2 had p. value <0.05. Therefore, X_1 and X_2 are the only terms used in fitting the model. Fig. 1.1f show the 3D Surface plot of carbohydrate of the flour. From this figure and equation above, the carbohydrate content of the flour is affected by both slice weight and soaking time. Increasing both the slice weight and soaking time decreased the carbohydrate content since both coefficients are negative. However, increasing soaking time showed greater decrease in the carbohydrate content than the slice weight as depicted in Eq. 7 and Fig. 1.1f.

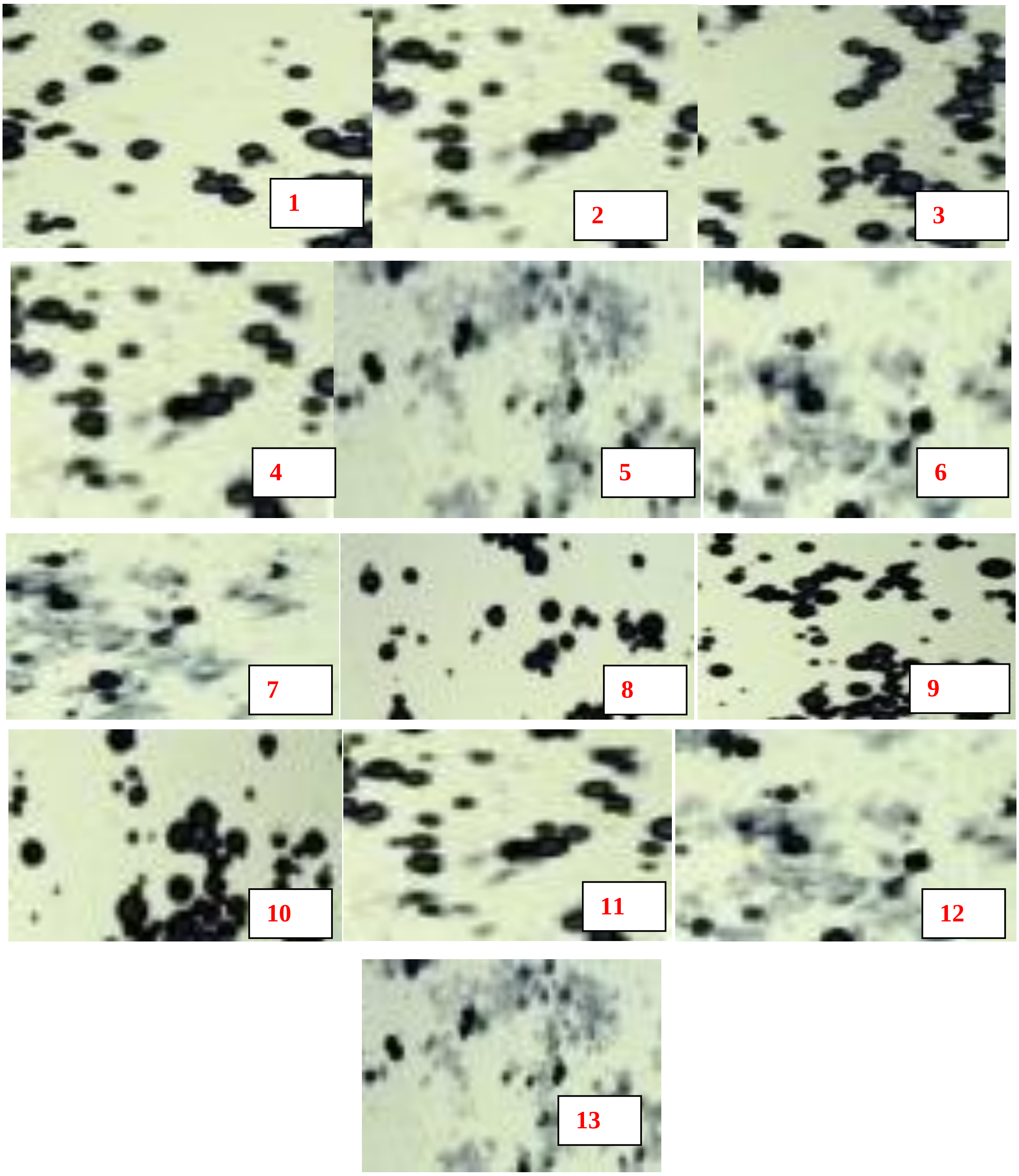

Fig. 1g. Microstructure of Cassava flour

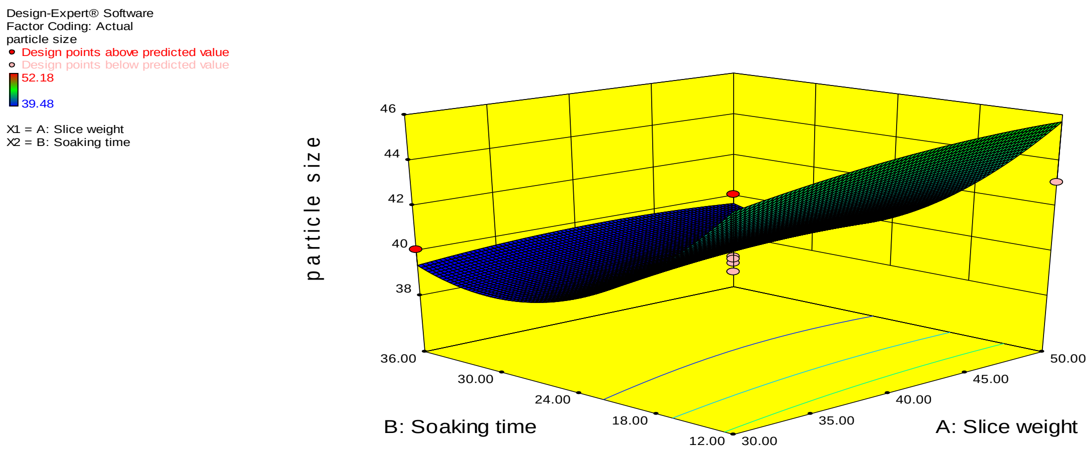

Fig. 1h. 3D surface plot of particle size of cassava flour

Microstructures of the cassava flour suggest that there is a structural difference among the flours prepared under different soaking time and slicing weight.

4.7 Particle Size

Particle size $a = b_2X_2 + b_2X_2^2$
Particle size = $40.05 - 0.33X_2 + 2.55X_2^2$ (8)

Particle size of the flour ranged from 39.48 to 52.18µm with sample 4 having highest particle size (52.48 µm) and sample 9 having highest (52.18 µm). Particle size was modeled as shown in eq. 7. Quadratic model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ had p. value <0.05. Therefore, $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ are the only terms used in fitting the model. Fig. 1h show the 3D Surface plot of particle size. From this figure and equation above, increasing soaking time increased the particle size of the flour while an increase in the slice weight showed a reduction in the particle size since its coefficient is negative as depicted in Eq. 8 and Fig. 1h.

4.8 Amylose

The amylose content of the flour samples significantly ranged from 14.02 to 28.98 % with sample 9 having the lowest amylose content value (14.02%) while sample 12 had the highest (28.98%). Ajibola and Olapade [17] reported similar value for amylose content of cassava flour. Amylose is composed of unbranched α-1,4 linked glucose units, while amylopectin has chains of α -1,4 and also-1,6 branching links [21].High amylose starches are useful in the confectionery industry where candy pieces require a stabilizer to supply individual piece shape and integrity. According to Akanbi et al. [19], starch is used to impart viscosity to food. It is probable that the apparent increase in amylose content in the cassava flour is as a result of enzyme/acid hydrolysis of amylopectin at the amorphous regions of the starch granule.

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Amylose= $a + b_1X_1 + b_2X_2$
Amylose= $25.02 + 0.53X_1 + 4.24X_2$ (9)

Amylose was modeled as shown in eq. 9. Linear model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ had p. value <0.05. Therefore, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are the only terms used in fitting the model. Figure show the 3D Surface plot of amylase of the flour. From this figure and equation above, the amylase content of the flour is influenced by both slice weight and soaking time. Increasing both the slice weight and soaking time increased the amylase content of the flour since both coefficients are positive. Meanwhile, increasing soaking time showed greater increase in the amylase content than the slice weight as depicted in Eq. 9 and Fig. 1i.

Amylopectin = $a + b_1X_1 + b_2X_2$
Amylopectin = $25.02 + 0.53X_1 + 4.24X_2$ (10)

Amylopectin was modeled as shown in Eq. 10. Linear model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ had p. value <0.05. Therefore, $\boldsymbol{X_1}$ and $\boldsymbol{X_2}$ are the only terms used in fitting the model. Fig. 1j show the 3D Surface plot of amylopectin of the flour. From this figure and equation above, the amylopectin content of the flour is influenced by both slice weight and soaking time. Increasing both the slice weight and soaking time increased the amylopectin content of the flour since both coefficients are positive. However, increasing soaking time showed greater increase in the amylopectin content than the slice weight as depicted in Eq. 10 and Fig. 1j.

Cyanogenic glycosides (HCN) of the flour ranged between 7.24±0.03 to 14.12±0.03 mg/kg (Table 5). These values are within the reported safe ranges for human consumption [22, 14]. As depicted in the equation; **y=** $\boldsymbol{a+b_1X_1 + b_2X_2^2}$ (Eq. 11) as suggested by regression (modeling), **y=** $\boldsymbol{8.03-1.40X_2+2.34X_2^2}$**;** the hydrogen cyanide content of the flour is decreased with increasing soaking time but slightly increase with increasing slice weight (Eq. 11 and Fig. 2).

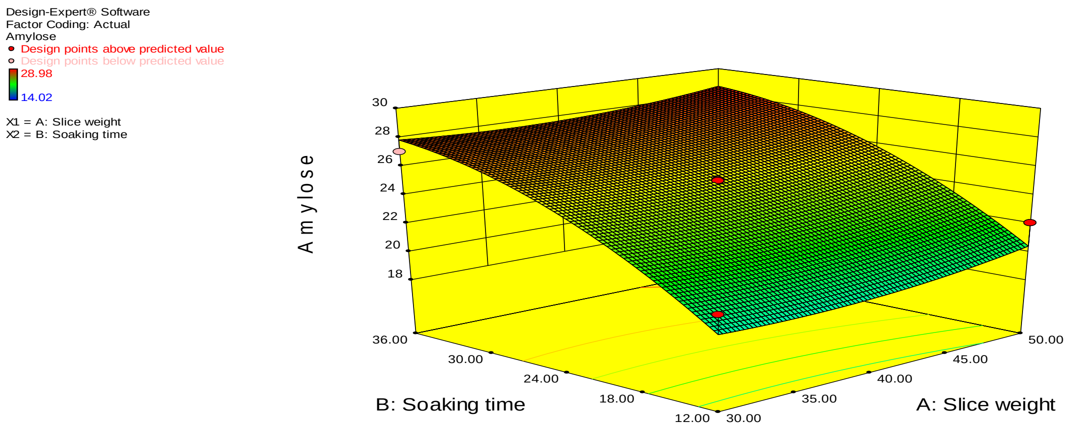

Fig. 1i. 3D surface plot of amylose content of cassava flour

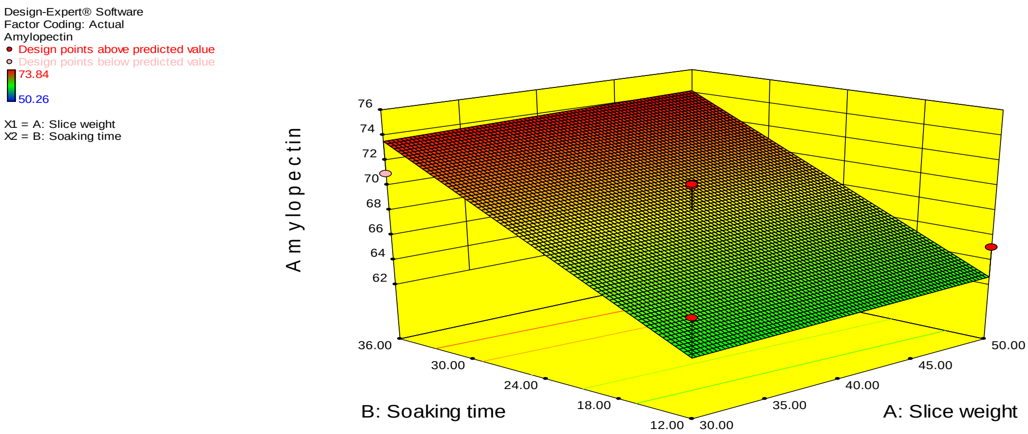

Fig. 1j. 3D surface plot of amylopectin content of cassava flour

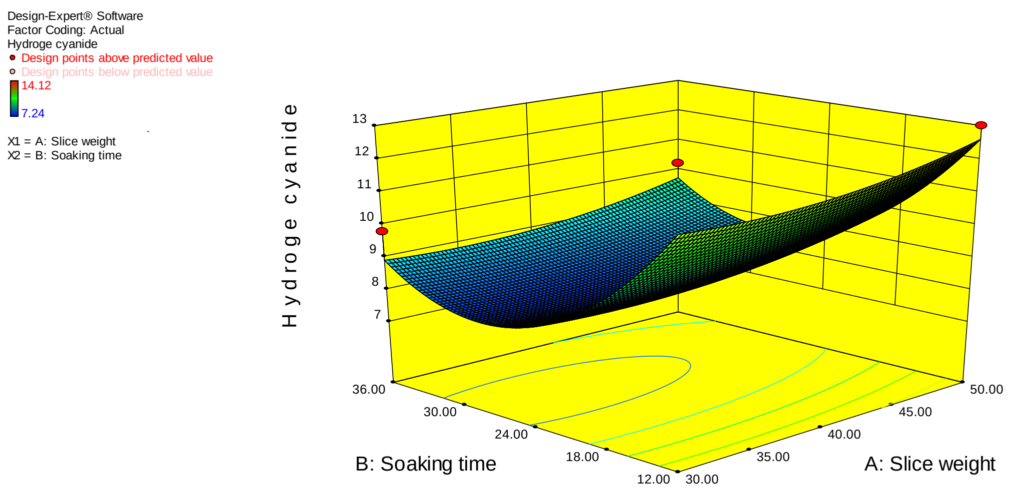

Fig. 1k. 3D surface plot of hydrogen cyanide content of cassava flour

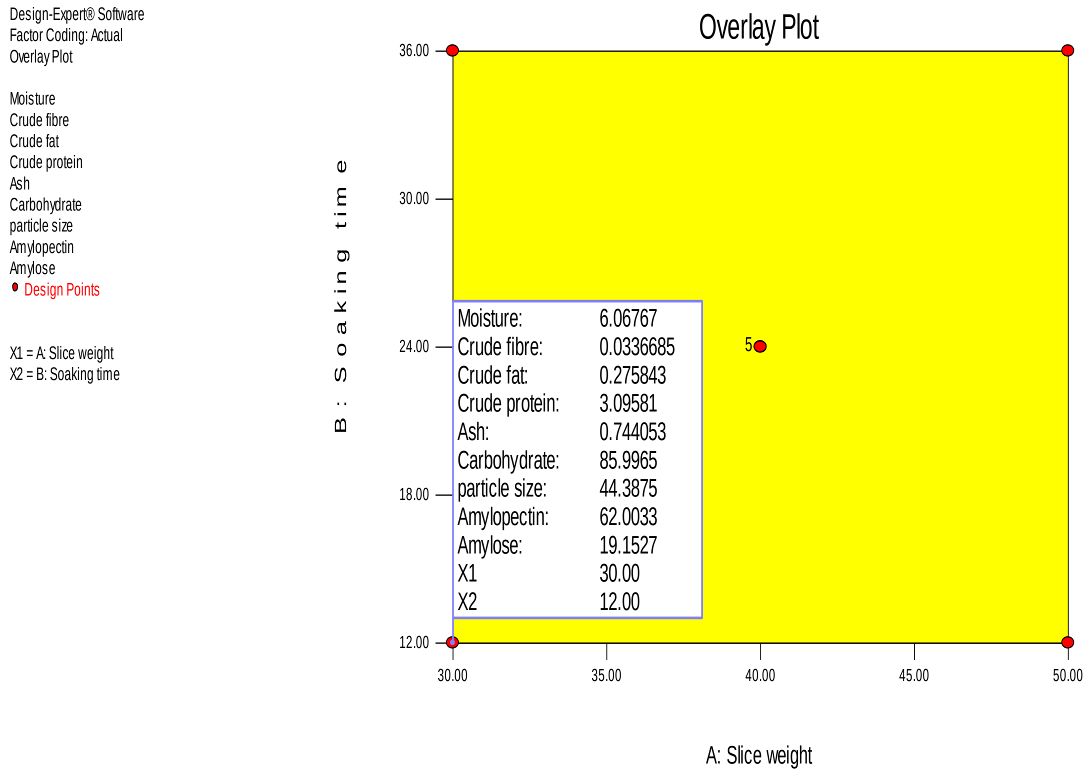

Fig. 2. Optimization Graph for the physicochemical properties of cassava flour

4.9 Hydrogen Cyanide

Cyanogenic glycosides (HCN) of the flour ranged between 7.24 to 14.12mg/kg with sample 3 having lowest HCN content (7.24 mg/kg) and sample 9 having highest content (14.12 mg/kg) (Table 5). These values are within the reported safe ranges for human consumption [22, 14].

Hydrogen cyanide (HCN) is the predominant anti-nutrient in cassava tubers and cassava products. The knowledge of cyanogenic glycoside content of food is vital because cyanide being an effective cytochrome oxidase inhibitor interferes with aerobic respiratory system [15].

$$HCN= a + b_2X_2 + b_2X_2^2$$
$$HCN= 8.03 – 1.40X_2 + 2.34X_2^2 \quad (12)$$

HCN was modeled as shown in Eq. 12. Quadratic model was suggested by RCCD software. $\boldsymbol{a}$ is the intercept, $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ are slice weight and soaking time respectively. From the ANOVA, only $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ had p. value <0.05. Therefore, $\boldsymbol{X_2}$ and $\boldsymbol{X_2^2}$ are the only terms used in fitting the model. Fig. 1k shows the 3D Surface plot of HCN of the flour. From this figure and equation above, the HCN content of the flour is affected by both slice weight and soaking time. Increasing the slice weight cause an increase in the HCN content of the flour. However, increasing the soaking time slightly decreased the HCN (Fig. 1k).

To carry out the optimization of the physicochemical properties, the response optimizer of the design expert was used. The responses were set as follows: Moisture (maximized), Crude fibre (maximized), Crude fat (maximized), Crude protein (minimized), Ash (minimized), Carbohydrate (minimized), Particle size (minimized), Amylopectin (minimized) and Amylose (minimized). The setup generated one solution for numerical optimization at maximum desirability. $\boldsymbol{X_1}$ (30.00 mm) and $\boldsymbol{X_2}$ (12.00 h) as Moisture = 6.06767, Crude fibre =0.0336685, Crude fat = 0.275843, Crude protein = 3.09581, Ash = 0.744053, Carbohydrate = 85.9965, Particle size = 44.3875, Amylopectin = 62.0033 and Amylose = 19.1527.

5. CONCLUSION

This study has established that there are variations in the properties of cassava flour based on the differences in slice weight and soaking time which have shown significant variations on their proximate and physicochemical properties. The findings showed that slice weight and soaking time of 25.86 g and 24 h respectively produced cassava flour that exhibited the most desirable proximate and physicochemical properties intended for use in bakery products.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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