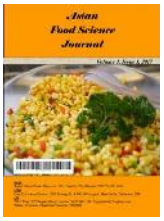

Asian Food Science Journal

6(1): 1-13, 2019; Article no.AFSJ.44825

Determination of Optimum Processing Conditions for the Proximate Composition and Pasting Characteristics of Flour Made from Parboiled Cassava Chips: A Response Surface Analysis

M. Ogbonnaya[1*] and M. O. Iwe[2]

[1]Department of Food Technology, Abia State Polytechnic, Aba, Nigeria.
[2]Department of Food Science and Technology, Michael Okpara University of Agriculture, Umudike, Nigeria.

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AFSJ/2019/44825
Editor(s):
(1) Dr. George Perry, Dean and Professor of Biology, University of Texas at San Antonio, USA.
(2) Dr. Vijaya Khader, Professor, Department of Foods and Nutrition, Post Graduate and Research Centre, Acharya N.G. Ranga Agricultural University, India.
Reviewers:
(1) Idakwoji Precious Adejoh, Kogi State University, Nigeria.
(2) Patrícia Matos Scheuer, Federal University of Santa Catarina, Brazil.
(3) F. A. Bello, University of Uyo, Nigeria.
Complete Peer review History: http://prh.sdiarticle3.com/review-history/27768

Original Research Article

Received 22 September 2018
Accepted 01 December 2018
Published 16 December 2018

ABSTRACT

The effects of processing conditions on the proximate composition and pasting properties were investigated using A Rotatable Central Composite Design (RCCD) for three variables. Processing conditions included parboiling time (10, 12, 13, 14 and 15 min), soaking time (24, 36, 48, 60 and 72h) and drying temperature (40, 45, 50, 55, and 60 ℃). Response data on the pasting properties were analysed in a regression model while the three-dimensional graphs were plotted. Crude protein, fat and fibre contents significantly decreased with increase in soaking time from 24 to 72h. There was also a significant decrease of peak viscosity (from 260.60 – 380.33 to 260.60 RVU) and peak time (from 4.82 to 3.54 min) with an increase in the time of soaking the parboiled cassava chips samples from 24 to 72 h. Increasing the soaking time beyond 48h resulted to increase in breakdown viscosity (175.30 – 221 RVU) of the parboiled cassava flour samples. The breakdown viscosity of the flour samples also decreased significantly with increase in drying temperature from

**Corresponding author: E-mail: madukwex@yahoo.com;*

40℃ to 60℃. There was a decrease in the final viscosity (228.00 to 184.83 RVU) with an increase in the cooking time of cassava parenchyma from 10 to 15min. The optimum processing conditions were found to be parboiling time of 12 min (x_1), a soaking time of 24 h (x_2), and drying temperature of 60℃ (x_3).

Keywords: Parboiled-cassava; pasting characteristics; response surface methodology; TME 419.

1. INTRODUCTION

Cassava, a starchy tuberous root, is of great importance in the nutrition of over eight hundred million people in the tropical countries of the world [1]. Unfortunately, the fresh cassava begins to deteriorate shortly after harvest which limits its contribution to incomes [2] and contains various concentrations of cyanogenic glucosides, linamarin and lotaustralin. Fresh cassava roots can be processed into parboiled flour which can be used as a raw material to produce fufu dough and other added-value products like chin-chin, chips, cookies etc.

Previous studies had reported that parboiling of cassava parenchyma, followed by submerged soaking of the parboiled chips, gave cassava flour with innocuous levels of cyanide contents [3,4,5], due to the fact that free cyanide is both water soluble and heat volatilizable while bound cyanide can be converted by enzyme or heat hydrolysis to give water soluble, and heat volatilizable hydrogen cyanide [6]. However, sun drying method was employed in their studies and thus no drying temperature was specified.

Pasting properties of starch are used in assessing the suitability of its application in food and other industrial products [7]. The problems associated with cassava processing industries include low product quality, inadequate processing technology, raw material availability, and fluctuating prices [8]. Paste or dough made from starchy tubers can be visualised as a gelatinised granules consisting of highly swollen starch but discrete clusters of starch molecules suspended in a starch solution [9]. When manufacturing a starchy rich instant floury product for making doughs, the desired result is achieved by keeping leaching of starch from cell tissue as low as possible to avoid a pasty, gummy or sticky texture of reconstituted product [8].

Parboiling of cassava has been reported to have an effect on the pasting characteristics, by reducing the pasting temperature and hot paste viscosity, as well as by slightly increasing the paste stability [10]. The physicochemical and pasting properties of cassava starch have been found to be affected by drying temperatures in the range of 40℃. to 60ºC [7]. Despite these studies, information on the optimum cooking time, soaking time, and drying temperature for the pasting characteristics of parboiled cassava flour are scanty. The work was thus carried out to determine the optimum processing conditions for the proximate composition and pasting properties of parboiled cassava parenchyma, using response surface methodology.

2. MATERIALS AND METHODS

2.1 Source of Materials

Freshly harvested roots of Cassava Mosaic Disease (CMD) resistant variety (TME 419), a bitter variety, was obtained from the National Roots Crops Research Institute (NRCRI), Umudike, Abia State, Nigeria, at about 11- 12 months old after planting.

2.2 Production of *Fufu* Flours

Cassava *fufu* flours were produced from the Cassava Mosaic Disease resistance variety as shown in Fig. 1. The fresh roots were peeled manually and cut into cylindrical pieces (approx. 6-8cm long). Each batch of the cut cylindrical pieces were submerged in boiling water in a pot. Five different boiling times were studied: 10min, 12min, 13min, 14min and 15min. The cooked pieces were allowed to cool, sliced (3-5cm long, 0.5cm thick), soaked in clean borehole water at ambient temperature (30±3ºC) (one part of cassava to 3 parts of water) for five different times: 24, 36, 48, 60 and 72h with changing water after each 24h. They were oven dried with Electrothermal drying box (model GZX-DH – 30 X 35) at five different temperatures: 40, 45, 50, 55, and 60ºC, and milled to a particle size of 3.0mm using attrition mill (2A premier mill, Hunt and Co., United Kingdom). Sieving was done manually with muslin cloth to obtain fine *fufu* flour. The *fufu* flours obtained were properly packaged and sealed in grip-seal polyethylene bags (GI-model, 2.25” x 2.25”, jiffy bags macro packaging co., United Kingdom). Sieving was done manually with muslin cloth to obtain fine *fufu* flour. The *fufu* flours obtained were properly packaged and stored at room temperature until ready for analysis.

2.3 Proximate Analysis of Flour

The fat, ash, crude protein, moisture, crude fibre and carbohydrate contents were determined according to AOAC [11].

2.4 Pasting Properties

Rheological properties of the *fufu* flours were determined with the aid of a Rapid Visco Analyzer (RVA 3Dr, Network Scientific Unit, SNW 2102, Australia). Parameters that were determined are final viscosity, setback viscosity, pasting time and pasting temperature.

2.5 Experimental Design

A Rotatable Central Composite Design (RCCD) for three variables, as described by Das [12], in a Completely Randomized Design (CRD) was adopted. The model was a second order model (equ. 1).

$$y = ß_0 + ß_1x_1 + ß_2x_2 + ß_3x_3 + ß_{11}x^2_1 + ß_{22}x^2_2 + ß_{33}x^2_3 + ß_{12}x_1x_2 + ß_{13}x_1x_3 + ß_{23}x_2x_3 + ε \quad (1)$$

Where y is the response (dependent) variable or quality parameter, x_1, x_2 and x_3 are the independent variables; x_1 = boiling time (min), x_2 = soaking time (h), and x_3 = drying temperature (^{0}C) as shown in Table 1.

Coded values of x are: -a, -1, 0, +1, and +a. Coded values of +a, 0, and -a represent the maximum, mid, and minimum values levels of independent variables respectively while +1 and -1 represent other two levels. $ß_1$, … $ß_3$ are the coefficients of linear terms (viz., x_1, x_2 and x_3), $ß_{11}$, $ß_{22}$ and $ß_{33}$ are the coefficients of the quadratic terms (viz., x^2_1, $x^2_2$and x^2_3) and $ß_{12}$ $ß_{13}$ and $ß_{23}$ are the coefficients of interaction term (i.e., x_1x_2, x_1x_3 and x_2x_3 respectively) while $ß_0$, $ß_1$, $ß_2$, $ß_{11}$, and $ß_{22}$ are model constants. The total number of experiment, N, required will be, $N = n_f + n_a + n_c$, where n_f = number of experiments necessary for the factorial design at three primary levels = 8, n_a = number of experiments to be carried at +a and -a = 6 and n_c = number experiments to be carried out at ‘center point’= 6. Thus, total number of experiments N was= 20.

2.6 Statistical Analysis

The statistical software package Design-Expert 8.0.7 (Stat Ease Inc., Minneapolis, USA) was used to generate the experimental design matrix, analyze the experimental data and develop the regression model. The goodness of fit of the regression model expressed as the coefficients of determination (R^2), the statistical significance determined by Fisher’s F test, p-value, t-test, (ANOVA) the response surface and the contour plots were studied to estimate the model as well as to determine the optimum levels, as employed by Tijani et al. [13].

3. RESULTS AND DISCUSSION

3.1 Proximate Composition (Table 2)

The results show a general moisture content of parboiled flour samples produced from TME 419. The moisture content ranged from 7.30 to 7.75 (Table 2). These moisture contents fall within the acceptable range for the production of high-quality cassava flour which should have a moisture content of 10% or less for long shelf life [14]. Low moisture content favours long shelf life.

The increase in drying temperature from 40ºC to 60ºC was the main factor that caused a reduction in the moisture content. These variations in the moisture contents, though not significant ($p>0.05$), could be attributed to variations in drying temperatures. Higher temperatures experienced by food result in increased rates of chemical reactions [15]. For example, browning in carbohydrates is favoured as the drying temperature of the carbohydrate food increases. Thus, the *fufu* flour obtained from drying at 60^{0}C had the lowest moisture content and that with the highest moisture content was obtained by drying at 40ºC. Other factors that affect drying of cassava chips, flour and starch are airflows, humidity and tumbling frequency [16].

The flours produced by varying processing conditions had crude protein values (1.59 - 1.69 %,), which fall in the range expected from the variety, TME 419 [17]. There were observed decrease in crude protein content as soaking time increased from 24 to 72h. These reductions had been reported to be due to a combination of leaching into the soaking water and microbial utilisation [18]. As the period of soaking time increased, carbohydrates were converted to organic acids by the activities of microorganisms [19]. This action might have aided the leaching out of the protein into the soaking water. Thus, the processing conditions for the optimum protein content of the flour samples were found to be 13 min x_1, 24 h x_2, and 50ºC x_3.

The fat contents ranged from 0.37 to 0.40%. These reductions, as the time of soaking in water increased from 24 to 72h, might be caused by microbial activities during the submerged soaking processes [17].

The ash contents ranged from 0.45 to 0.48%. Time of soaking was the main factor that caused the decrease in ash contents. These reductions, as the soaking time increased from 24 to 72h, might be caused by the combination of leaching in soaking water and microbial utilisation during fermentation processes [18].

The fibre contents varied from 0.54 to 0.61% as the soaking time increased from 24 to 72h. This is attributed to microbial utilisation during submerged soaking. The breaking down of fibre by the microorganisms might have been aided by the parboiling (pre-gelatinization) of the cassava parenchyma before soaking operation. According to FAO [18], gelatinization dramatically increases the availability of starch for digestion by amylolytic enzymes. Fibres in our food speed up the passage of food in the gut, helping prevent constipation.

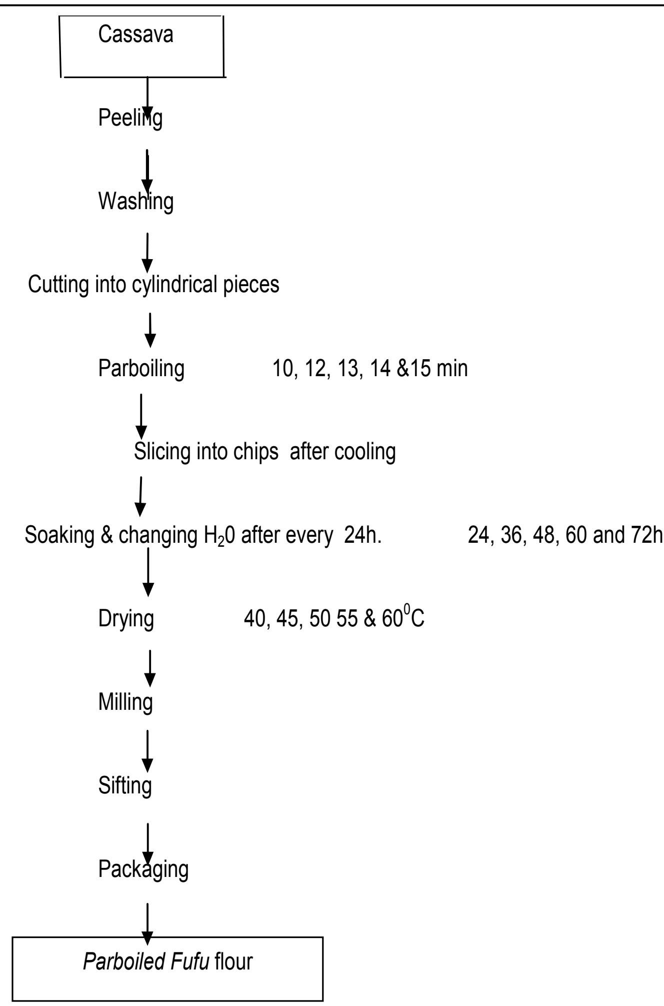

Fig. 1. Flow diagram for processing of parboiled *fufu* flour.

The carbohydrate contents of the parboiled cassava flour samples were influenced only marginally by the process variables. The latter cause in the reduction of the carbohydrate is attributed to the conversion of carbohydrates to organic acids by the activities of microorganisms as the soaking time increased.

3.2 Pasting Properties

The peak viscosities of the flour samples produced ranged from 260.60 – 380.33 RVU (Table 3). Length of soaking and drying temperature were the factors that significantly ($P<0.05$) influenced the change in peak viscosity.

The data on Table 4 showed that soaking time and drying temperature had significant negative ($P<0.05$) linear effects on the peak viscosity of the *fufu* flour produced from parboiled cassava parenchyma. This implies that peak viscosity of parboiled cassava flour decreases with increase in soaking time and drying temperature. This might be due to a reported increase in fermentation rate with increase in soaking time [3].

The decrease in peak viscosity as drying temperature increased is attributed to a reduction in leaching of amylose from the granules as drying temperature increased from 40 to 60ºC [4]. This implies that cassava chips dried at lower temperature easily leaches out amylose to form paste during gelatinisation, than that dried at a higher temperature.

.

The *fufu* flour with the least peak viscosity, thus, was produced at 72h and 60^0C while the *fufu* flour with the highest peak was produced at 24h and 40ºC. Fig. 2 depicts a progressive decrease in the peak viscosity as both soaking time and drying temperature increase.

Flour samples with high viscosities show the water molecules can penetrate their starch granules much easier, and the granules swell enormously leading to weakening of associated forces which in turn makes them susceptible to breakdown [20]. Higher peak viscosity indicates higher granular disruption [21].

Thus, on removal of the non-significant terms, the model is as stated in equation 2.

$$\text{Peak viscosity} = 336.3284 - 26.7081X_2 - 10.7744X_3 \quad (2)$$

The coefficients of determination, R^2: 0.6493 (Table 4) indicate that 65% variations could be accounted for by the model in equation 2.

The values of breakdown viscosity ranged from 175.30 – 221 RVU in the flour samples (Table 3). Both drying temperature and soaking time had significant ($P<0.05$) linear and quadratic effects on the breakdown viscosity of the parboiled flour samples (Table 5) in which the length of soaking had significant ($P<0.05$) linear and quadratic effects on the breakdown viscosity while the drying temperature had only significant ($P<0.05$) quadratic effect. These results depict that the breakdown viscosity decreased continuously with increase in drying temperature, and soaking time caused a quadratic reduction of breakdown viscosity, in the flour samples. The least value of breakdown viscosity, (179.30 RVU) was obtained at soaking time of 48h and drying temperature of 60ºC.

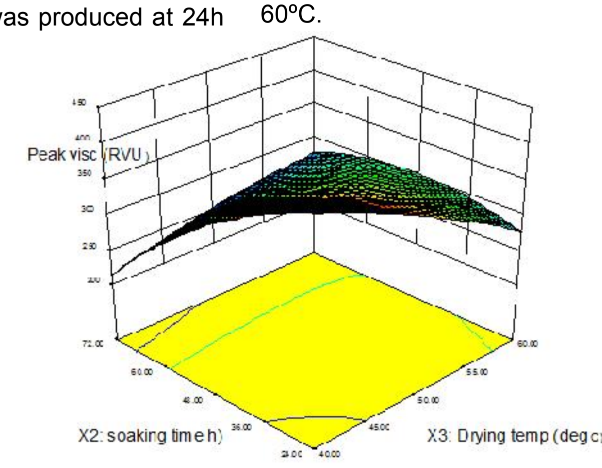

Fig. 2: Effect of processing conditions on the peak viscosity of flour samples

Also, increasing soaking time beyond 48h significantly (P<.01) increased the breakdown viscosity. The increase in breakdown viscosity as soaking time exceeded 48h might be attributed to absorption of water molecules for longer period of time. The breakdown is responsible for the long cohesive nature of the cassava paste. The response surface plots of breakdown viscosity as shown in Fig. 3 generally showed an increase in breakdown viscosity as soaking time exceeded 48h and a decrease in breakdown viscosity as drying temperature increased from 40ºC to 60ºC. Thus, the optimum processing condition for minimal breakdown viscosity was 48h and 60ºC.

Taking only the significant (p=.05) terms from Table 5, the regression model therefore is as stated in equation 3:

Breakdown viscosity = 192.1177 - 2.7600X3 + 6.8940X22 - 2.0973X32 (3)

The R^2 was 0.7901 (Table 5) showing that the 79% variation could be accounted for by the model for the flour samples.

The final viscosities of fufu flours ranged from 184.83 to 228.00 RVU (Table 3). Soaking time had highly significant (P<.01) linear effect, while time of parboiling had a highly significant quadratic effect (P<.01), on the final viscosity (Table 6). This suggests that increasing both the time of soaking and cooking time led to a decrease in the final viscosity.

From Table 6, the decrease in the final viscosity of parboiled flour samples with an increase in drying temperature from 40ºC to 60ºC was not significant (P>0.05). Lower viscosity with an increase in soaking time might be attributed to reduced bulk density on longer soaking time.

The higher viscosity of pastes from cassava parenchyma cooked for less than 12 min might be attributed to more starch granules in them which retain their rounded shape with slight or no swelling than those parboiled for more than 12min [8]. During heating, at the time of water absorption, materials are leached out from the starch granules. Final viscosity is the most commonly used parameter to determine a particular starch-based sample quality. It is used to indicate the ability of starch to form various paste or gel after cooling. Higher final viscosities in starch paste indicate lesser stability after cooling; hence retrogradation will take place faster [22]. Thus, flour samples cooked from 12 to 15 min and soaked in water for 72h had improved stability.

Fig. 4 indicates a progressive reduction in the final viscosity of the fufu flour samples with increase in time of soaking from 24 to 72h. Increasing the time of parboiling up to 12min and above decreased the final viscosity as well.

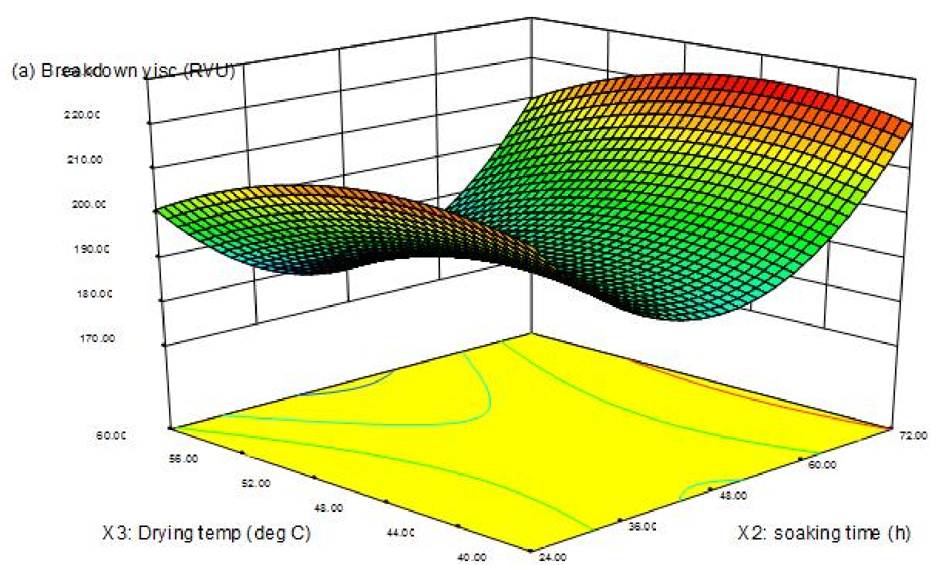

Fig. 3. Effect of processing conditions on the breakdown viscosity

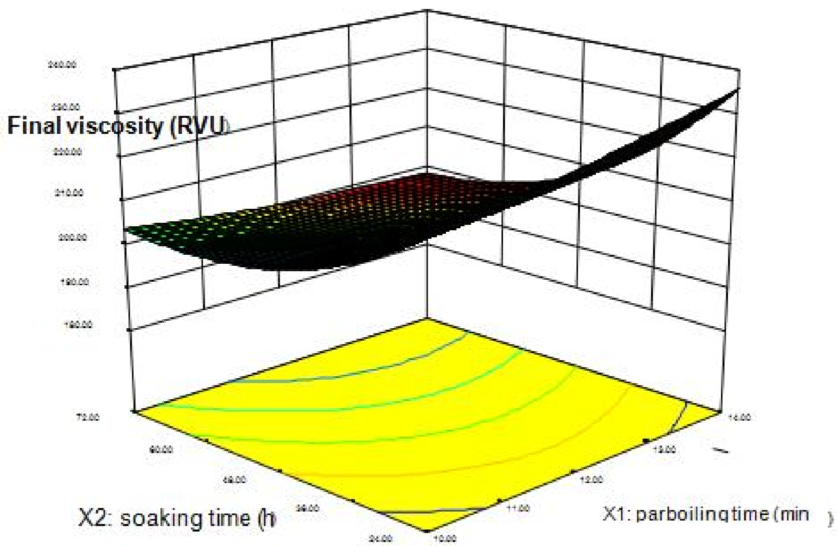

Fig. 4. Effect of processing conditions on the final viscosity

After removing the non-significant terms, the estimated coefficients for the quadratic model, using the data in Table 6, is as stated in equation 4:

Final viscosity = 203.7530 – 10.9281X2 + 2.2881X12 (4.)

The coefficient of determination (R2), 0.8335 (Table 6) of the models explain 83% variations of the total variations in the flour samples.

The values of setback viscosity ranged from 54.33 to 100.47 RVU (table 3). Soaking time was the highly significant factor ($p<0.01$) affecting the setback viscosity of the flour samples (Table 7). This indicates that setback viscosity increased with increase in soaking time of the parboiled cassava flour. Thus, an optimum value of 24h was obtained for the least setback viscosity while the highest setback viscosity was obtained at 72h. This might be attributed to an increase in water absorption on longer submerged soaking time. During fermentation, proteolytic activity takes place which causes an increase in the number of polar groups that increase water absorption of the flour [20]. A study by Sanni and Ajakaye [21] showed that the initial moisture content of fufu before drying affect the setback viscosity of fufu paste; fufu with the least initial moisture content before drying had the least setback viscosity.

Setback value is a measure of the stability of the paste after cooking [21]. Low set back of fufu paste indicates that the flour will exhibit a low tendency to undergo retrogradation during freeze/thaw cycles [23]. Fig. 5 depicts an insignificant increase in setback viscosity with an increase in soaking time from 24 to 48h and significant increase as soaking time exceeded 48h.

Therefore, the linear models are as stated in equation 5, after removing the non-significant terms:

Setback viscosity = 52.7587 + 8.1519X2 (5)

Having the coefficient of determination (R^2) as 0.3102 (Table 7), this model, therefore, account for only 31% of the total variation for the setback viscosity of the flour samples.

Peak time ranged from 3.54 to 4.82min in the fufu flour samples (Table 3). Length of soaking significantly ($P<0.01$) affected the peak time (Table 8).

These results indicate that the least peak time was obtained at a soaking time of 48 to 72h. This might be attributed to a decrease in viscosity as time of soaking of the pre-gelatinized cassava parenchyma increased [7]. Figure 6 indicates a significant linear decrease in the peak time with an increase in soaking time of the parboiled flour samples up to 48h and above. The regression model is therefore stated in equation 6 as:

Peak time = 3.6838 - 0.2131X2 + 0.1105X22 (6)

The coefficient of determination (R^2) was 0.5417, revealing that 54% variations in the peak viscosity could be accounted for by the model in equation 6.

Pasting temperatures ranged from 71.79 to 71.25ºC and 71.07 to 71.97ºC for flour samples produced from parboiled cassava parenchyma. However, these changes in pasting temperatures were not significantly different (P>0.05). Parboiling of cassava has been reported to marginally change the pasting characteristics by reducing the pasting temperatures and hot paste viscosity and by slightly increasing the paste stability [6].

Pasting temperature is the temperature at which starch granules begin to swell rapidly. Pasting temperature has been reported to relate to water binding capacity; a higher pasting temperature implies higher water binding capacity, higher gelatinization and lower swelling property of starch due to high degree of association between starch granules [22].

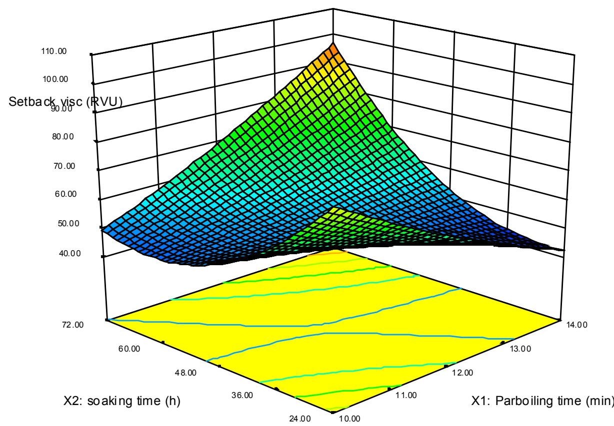

Fig. 5: Effect of processing conditions on the setback viscosity of the *fufu* flour samples

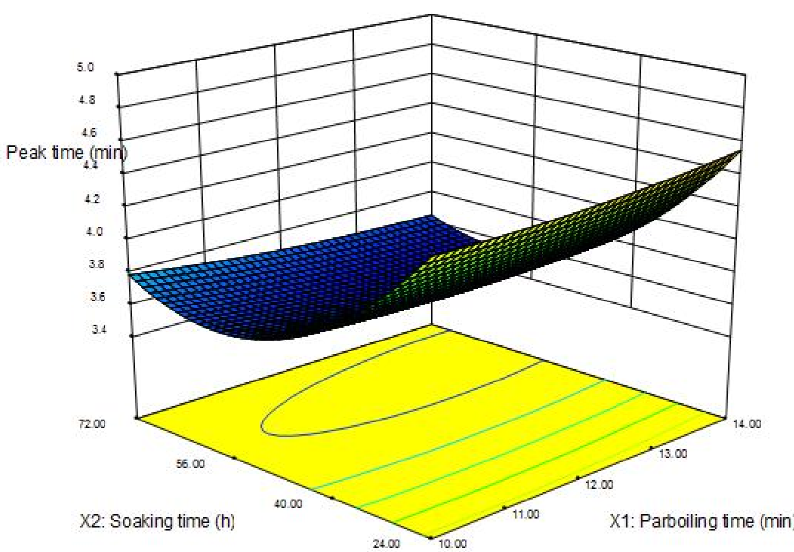

Fig. 6. Effect of processing conditions on the peak time of the flour samples

Table 1. Rotatable central composite design (RCCD) for 3 variables

Expt. No.	Parboiling time x_1(min)	Soaking time x_2 (h)	Drying temperature x_3 (^{o}C)
1	-1(12)	-1(36)	-1(45)
2	+1(14)	1(36)	1(45)
3	-1(12)	+1(60)	-1(45)
4	+(14)	+1(60)	-1(45)
5	-1(12)	-1(36)	+1(60)
6	+1(14)	-1(36)	+1(60)
7	1(12)	+1(60)	+1(60)
8	+1(14)	+1(60)	+1(60)
9	-1.682(10)	0 (48)	0 (50)
10	+1.682(15)	0 (48)	0 (50)
11	0 (13)	1.682(24)	0 (50)
12	0 (13)	+1.682(72)	0 (50)
13	0 (13)	0 (48)	-1.682(40)
14	0 (13)	0 (48)	+1.682(60)
15	0 (13)	0 (48)	0 (50)
16	0 (13)	0 (48)	0 (50)
17	0 (13)	0 (48)	0 (50)
18	0 (13)	0 (48)	0 (50)
19	0 (13)	0 (48)	0 (50)
20	0 (13)	0 (48)	0 (50)

Table 2. Proximate composition of parboiled *Fufu* flour

Run	Moisture content (%)	Crude Protein (%)	Fat (%)	Ash (%)	Fibre (%)	CHO(%)
1	7.32±0.03	1.66^{a} ±0.04	0.40^{b}±0.02	0.44^{a}±0.02	0.59^{b}±0.01	89.59±0.03
2	7.34±0.04	1.63^{a} ±0.03	0.40^{b}±0.02	0.45^{a}±0.02	0.60^{b}±0.01	89.56±0.04
3	7.33±0.04	1.61^{b} ±0.04	0.38^{a}±0.01	0.45^{a}±0.01	0.57^{a}±0.01	89.66±0.03
4	7.34±0.04	1.61^{b} ±0.03	0.39^{a}±0.01	0.45^{a}±0.01	0.57^{a}±0.01	89.64±0.03
5	7.35±0.03	1.65^{a} ±0.03	0.39^{a}±0.01	0.45^{a}±0.02	0.60^{b}±0.01	89.59±0.02
6	7.34±0.04	1.66^{a} ±0.04	0.40^{b}±0.02	0.46^{a}±0.02	0.59^{b}±0.01	89.55±0.03
7	7.33±0.03	1.61^{a} ±0.03	0.40^{b}±0.02	0.45^{a}±0.01	0.57^{a}±0.01	89.64±0.03
8	7.33±0.04	1.62^{a} ±0.03	0.37^{a}±0.01	0.45^{a}±0.01	0.57^{a}±0.01	89.66±0.02
9	7.34±0.02	1.63^{a} ±0.02	0.39^{a}±0.01	0.46^{a}±0.02	0.60^{b}±0.01	89.58±0.03
10	7.32±0.03	1.63^{a} ±0.03	0.40^{b}±0.02	0.46^{a}±0.01	0.60^{b}±0.01	89.59±0.03
11	7.30±0.02	1.69^{a} ±0.02	0.40^{b}±0.02	0.48^{b}±0.02	0.61^{b}±0.01	89.52±0.03
12	7.34±0.04	1.59^{b} ±0.02	0.37^{a}±0.01	0.45^{a}±0.01	0.54^{a}±0.01	89.69±0.03
13	7.30±0.03	1.63^{a} ±0.03	0.40^{b}±0.01	0.45^{a}±0.02	0.59^{b}±0.01	89.63±0.03
14	7.75±0.05	1.64^{a} ±0.03	0.39^{a}±0.01	0.46^{a}±0.01	0.58^{b}±0.01	89.16±0.02
15	7.33±0.03	1.62^{b} ±0.02	0.39^{a}±0.01	0.46^{a}±0.01	0.59^{b}±0.01	89.58±0.03
16	7.32±0.04	1.62^{b} ±0.02	0.39^{a}±0.02	0.48^{b}±0.02	0.58^{a}±0.01	89.60±0.03
17	7.34±0.05	1.62^{b} ±0.02	0.40^{b}±0.02	0.46^{a}±0.01	0.59^{b}±0.01	89.59±0.03
18	7.33±0.03	1.63^{a} ±0.02	0.39^{a}±0.02	0.48^{b}±0.01	0.59^{b}±0.01	89.58±0.03
19	7.33±0.05	1.63^{a} ±0.02	0.39^{a}±0.01	0.47^{a}±0.01	0.59^{b}±0.01	89.59±0.03
20	7.32±0.03	1.63^{a} ±0.01	0.39^{a}±0.02	0.47^{a}±0.01	0.59^{b}±0.01	89.60±0.03

Any two means followed by the same superscript for the same attribute in the same column are not significantly different at 5% level. All determinations were done in triplicates.
M.C = Moisture content.

Table 3. Pasting properties of parboiled *fufu* flour samples

Run	Peak Viscosity (RVU)	Breakdown Viscosity (RVU)	Final Viscosity (RVU)	Set back Viscosity (RVU)	Peak time (min)	Pasting temp (^{0}C)
1	377.22[a]	192.83[c]	219.92[a]	40.48[e]	3.78[b]	71.79
2	372.97[a]	194.81[d]	228.00[a]	48.96[c]	3.83[b]	71.62
3	204.50[c]	205.08[b]	191.50[d]	42.08[e]	3.60[b]	71.45
4	298.50[c]	203.65[b]	196.67[c]	66.25[b]	3.58[b]	71.45
5	307.23[a]	189.81[d]	212.83[c]	57.08[c]	3.79[b]	71.79
6	303.58[a]	191.92[d]	223.58[a]	48.17[d]	3.83[b]	71.66
7	285.50[c]	202.33[b]	189.25[d]	41.83[e]	3.60[b]	71.46
8	284.08[b]	200.08[b]	191.50[d]	61.08[b]	3.60[b]	71.46
9	345.08[b]	191.16[c]	219.92[a]	57.00[c]	3.78[b]	71.66
10	342.92[b]	190.84[c]	212.83[b]	54.75[c]	3.83[b]	71.62
11	380.33[a]	221.92[a]	223.58[b]	43.53[e]	4.86[a]	71.62
12	260.60[d]	216.24[a]	184.83[d]	100.47[a]	3.58[b]	71.45
13	338.58[b]	190.84[c]	204.68[c]	54.33[c]	3.66[b]	71.26
14	337.08[b]	175.39[c]	200.08[c]	54.92[c]	3.78[b]	71.42
15	338.58[b]	190.33[c]	204.58[c]	54.33[c]	3.79[b]	71.42
16	342.65[b]	192.59[c]	204.55[c]	55.14[c]	3.66[b]	71.42
17	340.08[b]	192.58[c]	202.42[c]	55.01[c]	3.66[b]	71.25
18	340.65[b]	190.58[c]	204.34[c]	54.25[c]	3.79[b]	71.42
19	342.79[b]	192.38[c]	204.58[c]	54.17[c]	3.79[b]	71.25
20	340.92[b]	192.83[c]	202.42[c]	54.33[c]	3.66[b]	71.25

Any two means followed by the same superscript letter for the same attribute in the same column are not significantly different at 5% level.

Table 4. Estimated regression coefficient for peak viscosity

Factor	Coefficient Estimate	Df	Standard Error	p-value Prob > F
Intercept	336.3284	1	7.3284	
X_1-Parboiling time	-1.3960	1	4.6170	0.7686
X_2-Soaking time	-26.7081	1	4.7516	0.0002
X_3-Drying temp	-10.8681	1	4.7516	0.0452
$X_1.X_2$	0.0988	1	6.7198	0.9886
$X_1.X_3$	0.6888	1	6.7198	0.9204
$X_2.X_3$	13.2863	1	6.7198	0.0762
X_1^2	-0.0660	1	2.4202	0.9788
X_2^2	-6.6362	1	3.8083	0.1120
X_3^2	-2.2637	1	3.8083	0.5654
R^2 = 0.6493				

Table 5. Estimated regression coefficient for breakdown viscosity

Factor	Coefficient Estimate	Df	Standard Error	p-value Prob > F
Intercept	192.1177	1	1.7985	
X_1-Parboiling time	-0.0099	1	1.1331	0.9932
X_2-Soaking time	1.9888	1	1.1661	0.1189
X_3-Drying temp	-2.7600	1	1.1661	0.0395
$X_1.X_2$	-0.9625	1	1.6491	0.5724
$X_1.X_3$	0.0175	1	1.6491	0.9917
$X_2.X_3$	0.1250	1	1.6491	0.9411
X_1^2	-0.0929	1	0.5939	0.8788
X_2^2	6.8940	1	0.9346	0.0000
X_3^2	-2.0973	1	0.9346	0.0487
R^2 = 0.7901				

Table 6. Estimated regression coefficient for Final viscosity

Factor	Coefficient estimate	Df	Standard error	p-value Prob > F
Intercept	203.7530	1	1.4491	
X_1-Parboiling time	1.8751	1	0.9130	0.0671
X_2-Soaking time	-12.0569	1	0.9396	0.0000
X_3-Drying temp	-1.7581	1	0.9396	0.0908
$X_1.X_2$	-1.4263	1	1.3288	0.3083
$X_1.X_3$	-0.0312	1	1.3288	0.9817
$X_2.X_3$	0.5113	1	1.3288	0.7085
X_1^2	2.2881	1	0.4786	0.0007
X_2^2	0.2539	1	0.7530	0.7430
X_3^2	-0.2024	1	0.7530	0.7936
R^2 = 0.8335				

Table 7. Estimated regression coefficient for setback viscosity

Factor	Coefficient estimate	Df	Standard error	p-value Prob > F
Intercept	51.6382	1	4.0292	
X_1-Parboiling time	2.1595	1	2.5384	0.4148
X_2-Soaking time	8.1519	1	2.6125	0.0109
X_3-Drying temp	0.7231	1	2.6125	0.7876
$X_1.X_2$	5.4813	1	3.6946	0.1687
$X_1.X_3$	-2.7888	1	3.6946	0.4678
$X_2.X_3$	-2.6538	1	3.6946	0.4890
X_1^2	0.6432	1	1.3306	0.6392
X_2^2	3.8609	1	2.0938	0.0950
X_3^2	-0.4828	1	2.0938	0.8223
R^2 = 0.3102				

Table 8. Estimated regression coefficient for peak time

Factor	Coefficient estimate	Df	Standard error	p-value Prob > F
Intercept	3.6838	1	0.0711	
X_1-Parboiling time	0.0122	1	0.0448	0.7917
X_2-Soaking time	-0.2131	1	0.0461	0.0009
X_3-Drying temp	0.0231	1	0.0461	0.6270
$X_1.X_2$	-0.0137	1	0.0652	0.8373
$X_1.X_3$	0.0013	1	0.0652	0.9851
$X_2.X_3$	0.0013	1	0.0652	0.9851
X_1^2	0.0096	1	0.0235	0.6929
X_2^2	0.1105	1	0.0370	0.0136
X_3^2	-0.0083	1	0.0370	0.8271
R^2 = 0.5417				

4. CONCLUSION

The results from the research work show that the soaking time of the cassava parboiled parenchyma was the major factor affecting the nutrient composition and pasting properties of the reconstituted fufu flour samples. Increasing the soaking time from 24 to 72 h of parboiled chips samples had significant changes in the protein, fat and fibre contents, peak viscosity, breakdown viscosity, final viscosity, setback viscosity and peak time. Increasing the parboiling time of cassava parenchyma from 10 to 12 min decreased the final viscosity. As the drying temperature increased from 40^0C to 60^0C, the breakdown viscosity of the fufu flour samples also decreased significantly but the flour was unattractive when dried at 60^0C. The optimum processing conditions for the production of parboiled cassava flour were found to be parboiling time of 12 min (x_1), soaking time of 24 h (x_2), and drying temperature of 60ºC (x_3).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Omodamiro RM, Iwe MO, Ukpabi UJ. Pasting and functional properties of lafun and starch processed from improved cassava genotype in Nigerian Food Journal. 2007;25(2):122-129.
2. Amoah RS, Sam-Amoah LK, Adu Boahen C, Duah F. Estimation of the material losses and garri recovery rate during the processing of varieties and ages of cassava into garri. Asian Journal of Agric research. Knowledgia Review, Malaysia. 2009;1-8.
3. Chukwuemeka OC. Effect of process modification on the physico-chemical and sensory quality of fufu-flour and dough. Afr. J. of Biotech. 2007;6(19):1949-1953.
4. Njoku BA, Banigo EOI. Physico-chemical properties of precooked cassava (*Manihot esculenta* Crantz) flour prepared by adaptation of a traditional process. Nigerian Food Journal. 2006;24(1):98-106.
5. Uzoka FA, Ojiako EO. Effects of methods of processing on the quality of cassava flour in Nigeria in the new Millenium. 32nd Annual Conference of Nutrition Society of Nigeria. Ambrose Alli Univ. Ekpoma. 28-30th, 2001.
6. Ogbonnaya M, Odom TC, Nwakodo CS, David-Chukwu NP. Influence of soaking time and drying temperature on some physico-chemical and proximate composition of flour produced from parboiled cassava. Research Journal of Food Science and Quality Control. 2018;4(1).
7. Aviara NA, Igbeka JC, Nwokocha LM. Effect of drying temperature on physicochemical properties of cassava starch. Intl. Agrophys. 2010;24:219-225.
8. Rodriguez-Sandoval RE, Quintero FA, Sandoval AA, Cuvelier G. Effect of processing conditions on the texture of reconstituted cassava dough. Brazilian Journal of Chemical Engineering. 2008;25(4):713-722.
9. Ihekoronye AI, Ngoddy PO. Integrated food science and technology for the tropics. Macmillan Publishers London. 1985;3(152):271-273.
10. Abraham TE, Raja KCM, Manoharan EP, Mathew AG. Effect of heat-moisture treatment on textural characteristics of cassava flour. American Asso. of Cereal, Inc Minnesota USA. 1982;60(1):7-8.
11. AOAC. Official methods of analysis. Association of Official Chemists. Washington D.C USA; 1995.
12. Das H. Food Processing Operations Analysis. Asian Books Private Limited, New Delhi. 2005;357-367.
13. Tijani IDR, Jamal P, Alam MZ, Mirghani MES. Optimization of cassava peel medium to an enriched animal feed by the white rot fungi Panus tigrinus M609RQY. International Food Research Journal. 2012;19:427-432.
14. Dziedzoave NT, Abass AB, Amoa-Awua WKA, Sabiah M. Quality management manual for production of high quality cassava flour. IITA Ibadan. 2006;6-7.
15. Ayo JA, Tehinse JF. Food Dehydration (Principles and Practice). Amana Printing and Advertising Ltd., Kaduna, Nigeria. 2006;309.
16. IITA: Fufu flour. Integrated Cassava Project (ICP) of the International Institute of Tropical Agriculture (IITA) Ibadan, to encourage, promote and expand agribusiness development in the cassava subsector in Nigeria. (iita-icp@cgiar.org). 2005
17. Ituen EUU, Ituen IS. Selecting cassava varieties for composite bread. World Journal of Applied Science and Technology (WOJAST). 2011;3:81-88.
18. FAO. Effects of food processing on dietary carbohydrates: Carbohydrates in human nutrition. Report of a Joint FAO/WHO Expert Consultation, Rome. (FAO Food and Nutrition Paper – 66)l 1998
19. Oyewole OB, Ogundele SI. Effect of length of fermentation on the functional characteristics of fermented cassava fufu. Journal of Food Technology in Africa. 2001;6(2):38-40.
20. Etudaiye HA, Nwabueze TU, Sanni LO. Quality of fufu processed from cassava mosaic disease (CMD) resistant varieties. African Journal of Food Sci. 2009;3:61-67.
21. Sanni LO, Ajakaye FI. Influence of the initial moisture contents on the functional and sensory qualities of dried fufu.

Proceedings of the 13th ISTRC Symposium. 2007;460-465.
22. Adebayo-Oyetoro AO, Olatidoye OP, Ogundipe OO, Balogun IO, Apara TO. Effect of local cassava fermentation methods on functional pasting and sensory properties of lafun. Continental J. Agric. Sci. 2012;6:1-8.
23. Maziya-Dixon B, Adebowale AA, Onabanjo OO, Dixon AGO. Effect of variety and drying methods on physic-chemical properties of high quality cassava flour from yellow cassava roots. African Crop Science Conference Proceedings. 2005;7: 635-641.

Peer-review history:
The peer review history for this paper can be accessed here:
http://prh.sdiarticle3.com/review-history/27768