



Received: 07 January 2017
Accepted: 14 March 2017
First Published: 23 November 2017

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Reviewing editor:
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FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Optimization of processing conditions of Ogi produced from maize using response surface methodology (RSM)

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Abstract: Effect of processing conditions involving soaking time (12–36 h) and sedimentation time (6–18 h) on pH, Total titrable acidity (TTA), Viscosity at 60 rpm and sensory evaluation ogi (pap) were evaluated and optimized by response surface modelling. A central composite rotatable experimental design with two factors and five levels (−1.414, −1, 0, 1 and 1.414) was used. The results revealed that the pH, TTA and viscosity at 60 rpm reduced with increase in soaking and sedimentation time. There was no significance difference ($p > 0.05$) in the value obtained for sensory evaluation, however, these ranged from 2.60–3.87 (Aroma), 2.47–3.87 (Taste), 2.60–4.67 (Colour) and 2.60–4.07 (Consistency), respectively. The predicted optimum soaking and sedimentation time were 16 and 8 h, respectively. The desirability value was 0.99. This research suggests ogi production with desired qualities, is achievable at total time of 24 h. Also, varying the soaking and sedimentation time have tendency to affect the quality of ogi.

Subjects: Food Science & Technology; Food Engineering; Processing

Keywords: response surface methodology; Ogi; viscosity; desirability; soaking

ABOUT THE AUTHORS

Olusola T. Bolaji (PhD) is a lecturer and researcher with strong passion for Process and Post Harvest of Agricultural products, food process modelling, and engineering design. My research areas focus on upgrading indigenous technology to a modern application, design process equipment and appropriate modification and adoption, Optimization of food processing conditions and equipment, modelling of engineering properties of food and Food system. Information communication and technology application in food process, food engineering models and food system.

PUBLIC INTEREST STATEMENT

The economy of production time and energy without the betrayal of quality of a product is paramount to commercial production of food product. Soaking and sedimentation are critical in determining the desired qualities of ogi. This is often achieved at room temperature between 48 and 72 and 24h, respectively. The total production time of 120 h (5 days) is often involved as reported. This is a lot of time, but better, if reduced with the quality of the product still intact. It is therefore imperative to establish specific production time considering these two e major processing conditions. and the desired quality is still maintained. This will be greatly relevant to commercial production and encourage time and resource management during ogi production. The result obtained in this study revealed the possibility of producing quality ogi for commercial purposes at reduced soaking time (16h) and sedimentation time (8 h).

1. Introduction

Ogi is a traditional Nigerian food product derived from cereals like maize, sorghum and millet. However, ogi from maize is more popular compared with other cereals. Maize (*Zea mays*) is one of the most important cereals in the world (Adegoke & Adebayo, 1994; Adegunwa, Alamu, Bakare, & Godwin, 2011). A large portion of it, carbohydrates, are stored as starch (Adegoke & Adebayo, 1994). In most African countries, some maize products are fermented foods which constitutes the diets of many infants and adults (Eaton & Nelson, 1991; FAO, 2009; Ijabadeniyi, 2007; Torre, Rodriguez, & Saura-Calixto, 1991). Its production, despite many reported research works is still on a small scale. In this production, domestic equipment are often used (Ijabadeniyi, 2007; Latunde-Dada, 1997).

Soaking and sedimentation have been widely reported as two important fermentation stages involved in the traditional method of processing ogi (Akingbala, Rooney, & Faubion, 1981; Akinrele, 1970; Banigo & Muller, 1972; John & Osita, 2012; Omemu, 2011). Soaking is often carried out at room temperature (Bolaji et al., 2011a, 2011b; John & Osita, 2012). The soaked grains are then washed, wet milled, sieved and allowed to sediment for 24–48 h (Akingbala et al., 1981; Akinrele, 1970; Banigo & Muller, 1972). The ogi slurry may then be processed into varieties of products for infants, children and adult's meal (Onyekwere, Akinrele, & Koleoso, 1989).

The production of this product on a large scale requires the optimisation of the processing conditions without compromising the quality of the product. In order to make use of the generated data from important independent variables, and employ statistical techniques to develop empirical models useful in predicting optimal conditions for operations, response surface modelling is often used (Box & Draper, 2007; Nakai, Li-Chan, & Dou, 2006). The important conditions in the production of ogi are soaking and sedimentation period. The soaking period is expected to reduce the hardness of the maize grain while the sedimentation period gives the required tartness often desired by some consumers (Bolaji, 2014). In the optimization of ogi processing conditions (soaking and steeping period), some important variables useful in determining the quality of ogi slurry and its secondary products were employed. These variables include viscosity, pH, total titratable acid (TTA) and pasting properties (Akingbala et al., 1981; Akinrele, 1970; Banigo & Muller, 1972; Bolaji et al., 2011a; Bolaji, Oyewo, & Adepoju, 2014; Omemu, 2011). This will suggest great relevance to commercial application and encourage time and resource management during ogi production compared with about one hundred and twenty hours reported in literature for soaking and sedimentation operations.

The economy of production time and energy without the betrayal of quality of a product is paramount to commercial production of any food product. Ogi, a fermented cereal gruel, is often processed by soaking grains in water at ambient temperature ($25 \pm 2^\circ\text{C}$) or with boiled water for 48–72 h (Akingbala et al., 1981; Banigo & Muller, 1972; Bolaji et al., 2011a; Bolaji et al., 2014; Omemu, 2011). This is followed by decantation, washing of grains, wet milling and sieving and allow the filtrate to sediment for another 24–48 h. About 72–120 h may be committed to the processing of this important weaning and adult breakfast food product. This time is enormous, putting into consideration the suggested/proposed commercial production of the ogi and gelatinised products. It is therefore imperative to establish specific time to the major processing conditions (soaking and sedimentation time) and match this with the desired qualities of these products. The fact that the desired product qualities can be obtained and predicted at a reduced processing time should be of economic importance for commercialisation process.

2. Materials and method

Maize variety of ART 98/SW6-OB white was obtained from the Institute of Agricultural Research and Training (IAR&T) Ibadan, Nigeria for the production of ogi. Attrition Mill (Atlas Exclusive Alzico Limited Type YL 112M-4) was used in milling and potable water was used in cleaning and soaking. About thirteen kilograms of maize were obtained. A kilogram was used for each samples as suggested by Response Surface Modelling (RSM) comprising of central composite design with two factors and level was used as shown in Table 1 in the production of ogi. The two independent variable factors used were soaking and sedimentation time and the dependent variable responses were pH, viscosity, TTA,

Table 1. Coded values of the independent variables

	$-\alpha$	-1	0	$+1$	$+\alpha$
X_1 (Hours)	15.51	12	24	36	32.49
X_2 (Hours)	7.76	6	12	18	16.24

Notes: $\alpha = 1.4142$; X_1 = Soaking time; X_2 = Sedimentation time.

Table 2. Treatment schedule

	Trial	Soaking time (hr)	Sedimentation time (hr)
1	Block	15.51	7.76
2	Block	32.49	7.76
3	Block	15.51	16.24
4	Block	32.49	16.24
5	Block	12.00	12.00
6	Block	36.00	12.00
7	Block	24.00	6.00
8	Block	24.00	18.00
9	Block	24.00	12.00
10	Block	24.00	12.00
11	Block	24.00	12.00
12	Block	24.00	12.00
13	Block	24.00	12.00

aroma, taste, colour, consistency, overall acceptability and pasting properties. The design is as shown in Table 2. The soaked maize grains samples were washed with clean water, sieved with 212 μm sieve and sedimented according to the designed.

2.1. Model development

A second order polynomial equation was fitted to determine the relationship between dependent and independent variables. The model proposed for the response (Y_i) was:

$$Y_i = b_0 + b_1X_1 + b_2X_2 + b_{11}X_1^2 + b_{22}X_2^2 + b_{12}X_1X_2$$

where X_1 and X_2 are soaking time (hr) and sedimentation time (hr), respectively, b_0 is the value of the fitted response at the centre point of the design. Regression coefficient b_1 - b_2 and b_{11} - b_{22} are for linear, quadratic and interaction (i.e. cross product terms), respectively. $Y(i = 8)$ is the predicted response for pH, viscosity, total titratable acidity, aroma, taste, colour, consistency and overall acceptability. Analysis of Variance (ANOVA) was performed to check the fitted models' adequacy and accuracy. The significance of regression coefficients was accessed by p -value at 0.1 significance levels (Nakai et al., 2006).

2.1.1. Chemical analysis determination

The pH and Total Titratable Acidity (TTA) were determined according to the official method of Association of official Analytical Chemist (AOAC, 1995).

2.2. Viscosity determination

The procedure described by Akharaiyi and Omoya (2008) was used to determine the viscosity of the samples. About 40 g of the ogi produced from maize was placed inside a measuring cylinder and

500 ml of clean water was added and stirred till it dissolved completely in water. It was then placed on a heating mantle and stirred consistently till the solution gelatinized (ogi). The viscosities of gelatinized samples were then measured with aid of RV85 viscometer. The pap was poured into the beaker, above the immersion groove on the spindle shaft. All the measurement was taken immediately the gelatinized ogi was produced. The readings were taken after 1 min rotation speed.

2.2.1. Sensory evaluation of the samples

The method reported by Bolaji et al. (2011a) was employed. About 100 g of ogi slurry was measured from each sample and about 50 ml of cold water was added and stirred in a bowl and gelatinised with boiled water (100°C), in this case, the same amount of water (400 ml) was used for all the samples. It was stirred until a porridge (ogi) was obtained and sensory evaluation was carried out. The sensory attributes of the “ogi” samples were evaluated using hedonic scale. This was done using a 20 member panellist familiar with the ogi. Each panellist was asked to score each attribute on a nine-point hedonic scale where one and nine represent liked extremely and disliked extremely, respectively. The attribute evaluated were colour, aroma, taste, consistency and overall acceptability. Data obtained were subjected to appropriate statistical analysis using ANOVA to detect the differences in the mean scores.

3. Results and discussion

Matrix designs of combination of variables conducted by central composite analysis as shown in Tables 1 and 2 describes the results of two level factorial experimental designs with five replications of the central point. The results of the experimental design for Y_i ($i = 8$), that is, the responses and $X_1 - X_2$ (the conditions) were shown in Table 3. The responses ranged from 6.69–6.90% (pH), 0.13–0.47% (TTA), 103.9–104.2map/s (Viscosity) 2.60–3.87 (Aroma), 2.47–3.87 (Taste), 2.60–4.67 (Colour), 2.60–4.07 (Consistency) and 2.53–4.20 (Overall Acceptability).

3.1. Analysis of variance of quadratic model

ANOVA and regression coefficients are listed in Tables 4 and 5. The ANOVA for the data obtained is as presented in Table 4. The coefficients for the actual functional relations for predicting Y_i ($i = 1-8$) were presented in Table 5. The table also showed interactions upon responses, regression coefficient (R^2) and F -value. The responses, for the model had lower values of regression coefficient ($R^2 < 0.89$) as it ranged from 0.00–0.89 and F -value ranged from 0.18–10.72.

Table 3. Responses of variables and processing conditions

Std	Soaking time (hr)	Sedimentation time (hr)	pH	Viscosity at 60 rpm (mpa/s)	Aroma	Taste	Colour	Consistency	Overall acceptability	TTA (%)
1	15.51	7.76	6.81	104.1	2.93	3.07	3.00	3.33	3.20	0.32
2	32.49	7.76	6.82	103.9	3.07	3.47	3.07	4.07	3.40	0.35
3	15.51	16.24	6.70	104.0	2.60	2.80	2.93	2.60	2.67	0.38
4	32.49	16.24	6.80	104.1	2.67	2.73	2.80	2.80	2.53	0.37
5	12.00	12.00	6.69	104.0	3.87	4.53	4.07	3.87	4.00	0.34
6	36.00	12.00	6.86	104.0	3.13	2.73	2.60	2.87	2.73	0.47
7	24.00	6.00	6.88	104.0	3.53	3.87	3.73	3.40	3.60	0.24
8	24.00	18.00	6.73	104.0	3.87	3.87	3.60	3.60	4.00	0.21
9	24.00	12.00	6.88	104.1	3.07	2.47	2.93	3.40	3.07	0.31
10	24.00	12.00	6.85	104.2	2.67	3.20	2.73	3.13	2.87	0.31
11	24.00	12.00	6.90	104.1	3.40	3.53	4.47	3.80	3.40	0.13
12	24.00	12.00	6.83	104.1	3.53	4.00	4.67	3.67	4.20	0.28
13	24.00	12.00	6.84	104.0	3.20	3.40	3.60	3.60	3.60	0.13

Table 4. Analysis of variance and model fitting for response parameters of ogi

Sequential model sum of squares	Df	pH	Viscosity at 60 rpm (mpa/s)	Aroma	Taste	Colour	Consistency	Overall accept.	TTA (%)
<i>Regression</i>									
Linear	2	0.03*	0.00*	0.01*	0.38	0.47	0.55**	0.00*	0.03*
Quadratic	2	0.02	0.02*	0.16	0.43	0.59	0.12	0.07	0.07
Interaction	1	0.00*	0.02	0.00*	0.00*	0.04*	0.13	0.04	0.00*
Residual error	4	0.00	0.02	1.60	1.97	1.22	0.93	1.57	0.04
<i>Lack of fit</i>									
Linear	6	0.02	0.05	0.57	2.00**	3.84**	0.85**	1.97	0.07
Quadratic	3	0.00*	0.00*	0.41	1.56	3.21	0.60	1.86	0.00*
Interaction	5	0.02*	0.03	0.57	1.99	3.80	0.72	1.93**	0.07
Pure error	4	0.00	0.02	1.60	1.97	1.	0.93	1.57	0.04

Note: Df—Degree of freedom.

*Significantly different at $p < 0.05$.

**Not significantly different at $p > 0.05$.

Table 5. Coefficient of regression for sensory parameters

Coefficient	pH	Viscosity at 60 rpm (mpa/s)	Aroma	Taste	Colour	Consistency	Overall acceptability	TTA (%)
Model	6.45	104.0	3.19	3.36	3.40	3.39	3.33	0.89
<i>Linear</i>								
X_1 (soaking time)	0.03	0.00*	-	-	-	-	-	0.06
X_2 (Sedimentation time)	0.01	0.01						0.00*
<i>Quadratic</i>								
X_{11}	0.00*	0.00	-	-	-	-	-	0.00
X_{22}	0.00	0.00*	-	-	-	-	-	0.00*
<i>Interaction effect</i>								
X_1X_2	0.00	0.00	-	-	-	-	-	0.00
R^2	0.89	0.67	0.00	0.00	0.00	0.00	0.00	0.62
F - Value	10.72	2.86	0.18	0.60	1.77	0.75	0.63	2.27

*Significantly different at $p < 0.05$.

3.2. Effect of soaking and sedimentation time on pH of ogi

The quadratic model with $R^2 = 0.89$ described the changes in pH of ogi as shown in Table 5. Soaking and sedimentation time were observed to be functions of pH of ogi. This was in accordance with the report by Nwokoro and Chukwu (2012) on Akamu which had a pH range of 6.6 at the initial stage of production and later decreased with increase in fermentation time. Also, the pH value obtained by Adelekan and Oyewole (2010) followed the same trend. Increase in soaking and sedimentation time affected the pH values as shown in Figure 1. There was a decrease in pH values with increase in soaking and sedimentation time. The report by Akinleye et al. (2014) for total titrable acidity also followed the trend reported in this work while Adelekan and Oyewole (2010) reported a contrary trend. Figure 2 showed an increase in total titratable acidity with increase in soaking and sedimentation time.

Figure 1. Response surface and contour plot showing the effect of soaking and sedimentation time on pH of ogi.

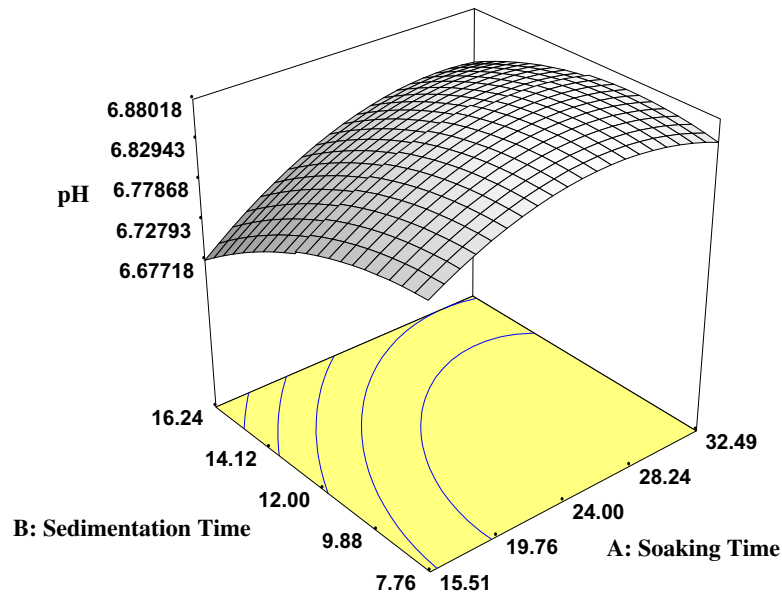
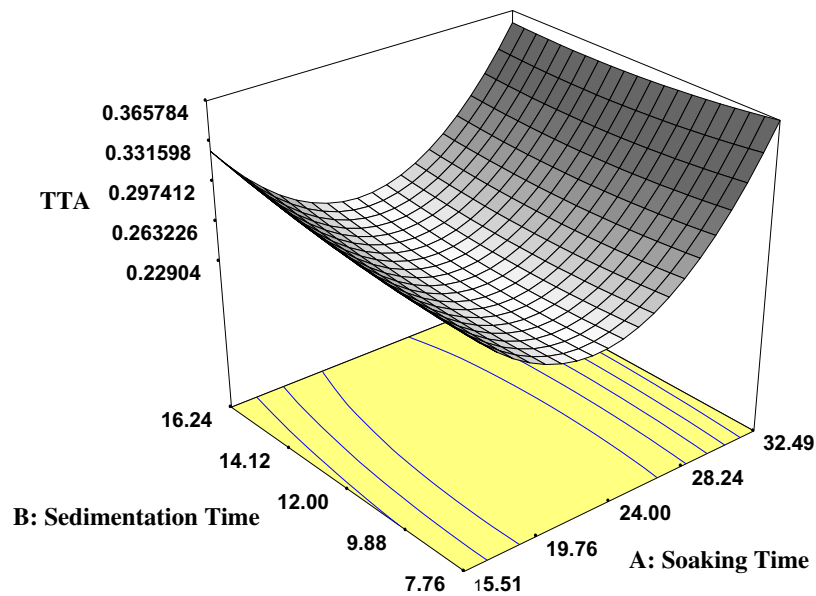


Figure 2. Response surface and contour plot showing the effect of soaking and sedimentation time on TTA of ogi.



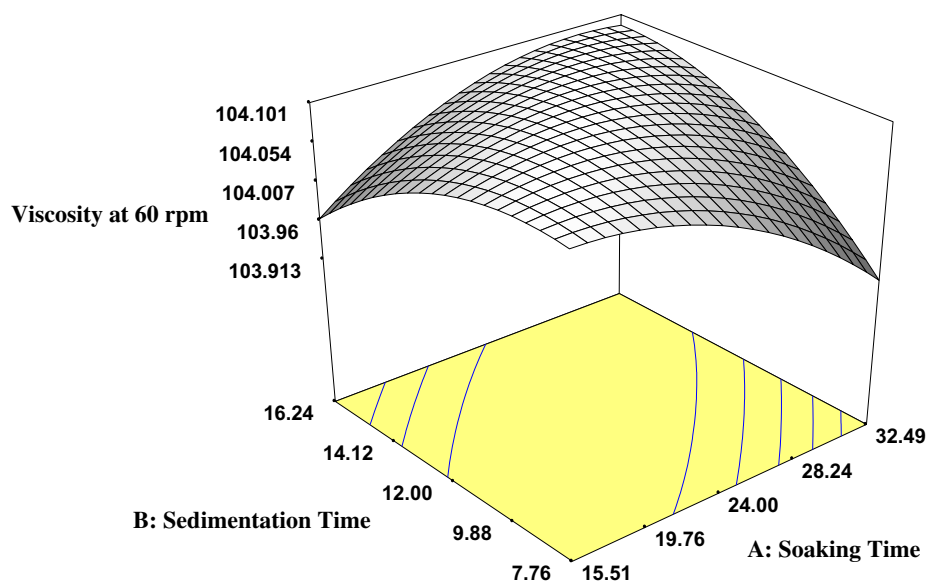
3.3. Effect of soaking and sedimentation time on viscosity of pap from ogi

In this research work, the coefficient of regression ($R^2 = 0.67$) was poor fit and there were no significance difference at ($p > 0.05$) among the samples. The viscosity of gelintintised ogi from ogi ranged from 103.9–104.2 mpa/s at 60 rpm and was contrary to the value obtained by Oyarekua (2011) on co-fermented cereals/cowpea ogi. Some researchers reported that viscosity may not be affected by fermentation (Oyarekua, 2011). Soaking and sedimentation time affected the viscosity of ogi as observed in Figure 3. There were increase in viscosity as soaking and sedimentation time increases.

3.4. The effect of soaking time and sedimentation time on sensory attributes of pap from ogi

There was no significance difference ($p > 0.05$) among the samples on the sensory parameter. Some researchers have also reported similar trend for some product (Adegunwa et al., 2011; Adelekan & Oyewole, 2010; Ladunni, Aworh, Oyeyinka, & Oyeyinka, 2013).

Figure 3. Response surface and contour plot showing the effect of soaking and sedimentation time on viscosity of ogi.



3.5. Effect of soaking time and sedimentation time on pasting properties of ogi

The results of the pasting responses ranged from 280–3483cp (Peak viscosity), 235–1869cp (Trough viscosity), 45.8–1614cp (Breakdown viscosity), 754–3976cp (Final viscosity), 519–1960cp (Setback viscosity), 5.63–5.87 min (Peak time) and 73.45–87.3°C (Pasting temperature). The coefficient of soaking time and sedimentation time on pasting properties (Peak, Trough, Breakdown, Final, setback viscosities, Peak time and Pasting temperature) were reported in Table 6. The seven responses under different combination as defined in the design (Table 1) were analysed using the Analysis of Variance (ANOVA) at $p < 0.05$ significant level. The coefficients for the actual functional relations for predicting ($Y_i = 1-7$) were presented in Table 6. The responses for the model had lower values of regression coefficient ($R^2 < 0.79$) and F -value ranges from 1.91–10.36 as shown in Table 6, the peak time decreased with increase in soaking and sedimentation time. Similarly, the pasting temperature decreased with increase in soaking and sedimentation time.

Table 6. Coefficient of regression for pasting properties

Coefficient	Peak (cp)	Trough (cp)	Breakdown (cp)	Final (cp)	Setback (cp)	Peak time (min)	Pasting temp. (°C)
Model	10,029.06	5,321.51	8,771.67	1,419.09	1,481.54	-1.37	44.56
<i>Linear</i>							
X_1 (soaking time)	-334.76	-175.69	-83.28	19.74	-	0.28	1.45
X_2 (sedimentation time)	-600.99	-292.03	-1,051.53	265.00	-	0.49	3.24
<i>Quadratic</i>							
X_{11}	-	-	-1.56	-4.72	-	-	-
X_{22}	-	-	27.04	-23.49	-	-	-
<i>Interaction effect</i>							
X_1X_2	24.70	13.31	11.36	15.61	-	-0.02	-0.12
R^2	0.75	0.64	0.79	0.58	0.00	0.78	0.55
F - value	8.88	5.36	5.19	1.91	10.23	10.36	3.62

3.6. Prediction for desirability

The desirability functions of response surface modelling were used to determine the optimum soaking and sedimentation time of ogi production. The advantage of using desirability functions was described by Singh, Panesar, Nanda, and Kennedy (2010). The author stated that different scaling are compared while qualitative and quantitative responses used. In some cases, transformation of different responses to measurement may be employed (Singh et al., 2010). Optimization was based on the desirability function, $D = (d_1 \times d_2 \times d_3 \times \dots \times d_n) / n$ where d_i are the desirability indices for each response. In most desirable, $d_i = 1$, where $d_i = 0$, means least desirable and n is the number of response used (Derringer & Suich, 1980). The responses may be used as the control parameters to determine the optimum quality characteristics with respect to soaking and sedimentation time.

The optimum pH, total titrable acidity and viscosity at 60 rpm were 6.69–6.9%, 0.2–0.3% and 103.9–104.2mpa/s, respectively. When soaking time and sedimentation time was set at target 8 h, the desirability obtained was 0.99, most desirable and the corresponding pH, total titrable acidity and viscosity at 60 rpm were 6.81, 0.29% and 104.09mpa/s, at optimum condition for soaking and sedimentation time (Figure 4).

When soaking and sedimentation time were set at target 16 and 8 h, respectively, the desirability obtained was 1.00, and the corresponding pasting properties (peak, trough, breakdown, final, set-back viscosities, peak time and pasting temperature) were 1896.96, 1434.54, 420.2, 3467.7, 1481.54cp, 5.72 min and 84.11°C, respectively and this point was taken as the optimum condition for soaking and sedimentation time. The responses were used as the control parameters to determine the optimum quality characteristics with respect to soaking and sedimentation time as shown in Table 7.

Figure 4. Optimization plot for ogi at varying soaking and sedimentation time.

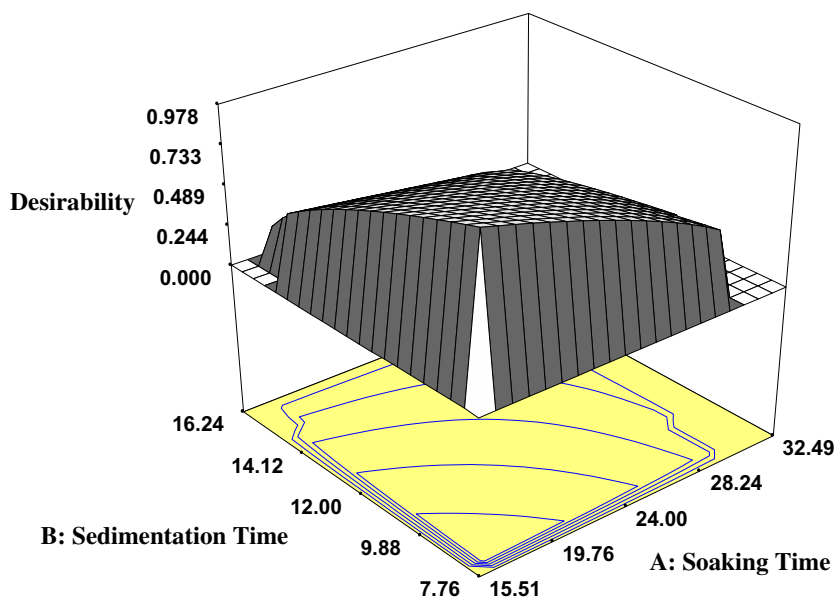


Table 7. Selected point for optimization of responses

Response	Goal	Lower limit	Upper limit	Weight
pH	Is in range	6.69	6.9	1
Total titrable acidity	Is in range	0.2	0.3	1
Viscosity at 60 rpm	Is in range	103.9	104.2	1

4. Conclusion

This study showed that soaking and sedimentation time of ogi have strong tendency to affect the quality of ogi which subsequently will affect the gelatinze products. The result obtained from this study revealed the possibility of producing quality ogi for commercial purposes at reduced soaking time (16 h) and sedimentation time (8 h) as predicted. Predicted soaking and sedimentation time of 16 and 8 h, respectively will produce pH 6.81%, total titrable acidity of 0.29% and viscosity at 60 rpm 104.09mpa/s. Soaking time and sedimentation time of ogi if set at 16 and 8 h, respectively will give the pasting properties of the predicted values and total considerable reduction in the production time, contrary to widely reported long production time in the literature.

Funding

The authors received no direct funding for this research.

Competing Interests

The authors declare no competing interest.

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Citation information

Cite this article as: Optimization of processing conditions of Ogi produced from maize using response surface methodology (RSM), Olusola T. Bolaji, Lateefat Adenuga-Ogunji & Titilope A. Abegunde, *Cogent Food & Agriculture* (2017), 3: 1407279.

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