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Use of Response Surface Methodology in Predicting the Apparent Viscosity of 'Achi' *Brachystegia spp.* Flour

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Abstract: Response Surface Methodology (RSM) was used to obtain the predicted values of the apparent viscosity of 'achi' flours from different toasting time. The processing variables were processing time (pt), salt concentration (sc), palm oil concentration (poc). The data generated from the experiment was analyzed by regression analysis. Linear and quadratic effects of processing time and palm oil concentration were significant ($p<0.05$). Salt concentration had no linear or quadratic effect ($p>0.05$) on apparent viscosity of 'achi' flour. The Coefficient of determinations (R^2) for the fit was 0.816 (82%). This high R^2 value showed that the model developed for the response variables appeared adequate for predictive purposes. The experimental and predictive values were closely related showing that the model correctly predicted the response variables.

Key words: Response surface methodology, predicting, 'achi' flour, apparent viscosity

INTRODUCTION

Food crops including cereals and legumes, roots and tubers are processed for different reasons. For example cocoyam can be processed as soup thickeners or as chips for preservation of the product. Ndjouenkeu *et al.* (1996) reported that many polysaccharides currently available as industrial gums were first used in an empirical way in domestic cookery. Obvious examples include pectin as the setting-agent in jam, carrageenan in milk desserts and starch as thickener in soups and sauces. There are many others, however, that are not yet exploited commercially, but are used extensively in traditional local recipes, particularly in the less industrialized regions of the world. These materials usually come from plants that grow wild or are cultivated only on a very limited scale and their functional properties as food hydrocolloids remain largely unexplored.

In Africa, the main culinary use of indigenous hydrocolloids is in thickening soups and stews and the plants used include okra *(Hibiscus esculentus)*, 'ogbono' dika nut *(Irvingia gabonensis)*, mbol (*Belschmiedia zenkeri*), Kelekelin *(Triumfetta Cordifolia)*, 'akparata' *(Afzelia africana)* and 'achi' *(Brachystegia spp)* (Ndjouenken *et al.*, 1996; Anonymous, 2005). The first two of these are the most common in domestic cooking in the Central and Western parts of Africa.

Okra gum, cocoyam flour, has received some scientific attention, unlike *Brachystegia spp* 'achi' which is popular in the Eastern part of Nigeria. The tree is a woody plant found mostly in the rain forest zone and the seed is seasonal but its use in soup making is not seasonal. The seeds can be processed in large quantity and preserved to eliminate the inconveniences encountered by the home-maker in getting food ready for the table and also to improve their storage potential (Keay *et al.*, 1974; Okaka, 2005).

Food crops may be processed as intermediate products or processed for immediate consumption. When processed as base material for other food manufacture, they should have satisfactory intrinsic properties such as nutritional values and acceptable flavor, color and texture, as well as possessing additional critical functional properties that make them compatible with and if possible, enhance the food to which they are added (Wang and Kinsella, 1976). For example, adding protein prevents fat or water from separating during heating of a meat product and also forms stable emulsions or foams (Iwe, 2003). Herh *et al.* (2000) reported that in food products, small changes in the amount of additives can have a dramatic effect on the final product.

Viscosity is an important functional property of foods such as beverages and batters and design of processing lines (Iwe, 2003). Lewis (1987) and Steffe (1996) reported that viscosity is often very important for quality control, particularly on products that are expected to be of a particular consistency in relation to appearance or mouth feel, for instance cream, yogurt, tomato paste and custards.

The functional properties of food additives, condiments and thickeners are factors to consider before their choice. These properties are often affected by the conditions under which the ingredient is applied, such as medium (fat and water), the presence of any other ingredients, acidity, ion strength and temperature and processing time in particular (Iwe, 2003).

Because of the many processing variables involved in the investigation and their corresponding interactions,

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response surface methodology was employed to obtain regression equation models for predicting the response variables of apparent viscosity.

Response surface methodology (RSM) is a statistical technique for investigating multiple parameters alone or in combination, on response variables. It was developed by Box and Wilson (1951) to study the relationship between a response and several related factors. Its applications in different processing area were reviewed by Hill and Hunter (1966). Myers *et al.* (1989) reviewed the evolution of RSM from 1966 to 1988, including progress in experimental design, data analysis and applications. RSM has been successfully applied for predictions and optimizing of conditions in food research (Sefa-Dedeh and Stanley, 1979; Iwe, 2000).

Prediction of apparent viscosity of 'achi' based on such processing variables as processing time, salt conc. and palm oil conc., has not been widely reported. The objective of this study is to apply response surface methodology to develop a model equation for predicting apparent viscosity of 'achi' flour.

MATERIALS AND METHODS

Sources of samples: Samples of *Brachystegia spp* 'achi' were purchased from Eke-Aba, market in Abakaliki, Ebonyi State, Nigeria.

Preparations of samples: Achi' (*Brachystegia Spp*) seeds were sorted and cleaned. The dry seeds were toasted in a hot sand bath for 6, 9, 12 and 15 minutes respectively using kerosene stove and dehulled while hot with stone. The dehulled seeds were milled four times in a traditionally corn mill (Corona corn mills) to produce 'achi' powder. The milled powders were then sieved with American standard sieve number 40, with aperture of 435µm. The different flours obtained were packaged, labeled and stored in airtight polyethylene before analysis.

Viscosity measurements: The method of Sathe and Salunkhe (1981) was adopted in determining the viscosity of the flour samples. Sample dispersion 2.0 % (w/v) was prepared with distilled water at room temperature (28±2°C) under continuous stirring (British magnetic stirrer). The viscosity of the hydrated dispersion was measured at 28°C±2 using the NDJ-8S digital viscometer. Measurements were made on 2% (w/v) dispersion of each flour sample at constant time intervals of 2 hours with a shear-rate (30/m).

Effect of palm oil concentration on apparent viscosity: Dispersion 2% (w/v) of each flour was prepared with palm oil in concentrations between 0-2.5% (w/w). The dispersions were hydrated for 2 hours with continuous stirring. Apparent viscosity of each dispersion was measured at 25±1°C using the NDJ-8S digital display viscometer.

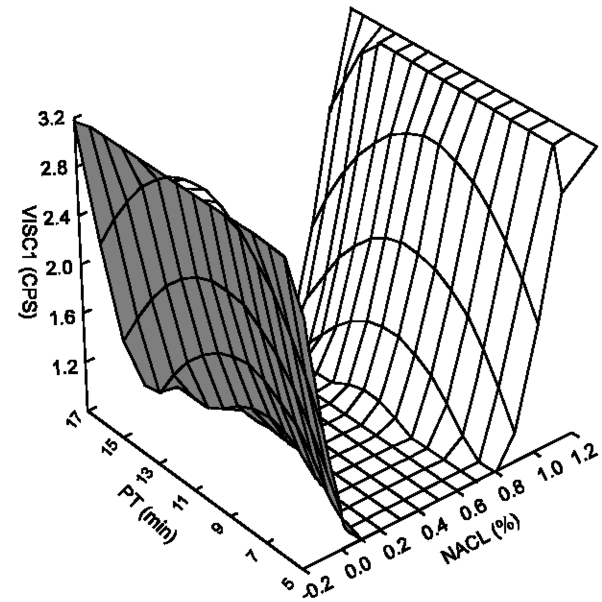

Fig. 1: Effect of processing time and NaCl concentration on the apparent viscosity of 'achi' flour.

Effect of sodium chloride (NaCl) concentration on apparent viscosity: Dispersion 2% (w/v) of each flour was prepared with sodium chloride solution in concentration between 0.0M and 1.0M according to the method of McWalters and Homes (1979). The dispersions were hydrated for 2 hours with continuous stirring. Apparent viscosity of each dispersion was measured at 25±1°C using the NDJ-8S digital display viscometer.

Experimental design: A three factor central composite design CCD (King, 1993; Cochran and Cox, 1957) was used. The independent variables were processing time (pt), palm oil concentration (PoC) and Salt concentration (Sc).

Statistical analysis: Experimental data was analyzed using response surface methodology. The second-order polynomial fitted was

$\beta_0 + \beta_1 pt + \beta_2 PoC + \beta_3 Sc + \beta_{11} pt^2 + \beta_{22} PoC^2 + \beta_{33} Sc^2 + \beta_{12} ptPoC + \beta_{13} ptSc + \beta 23PoCSc + \beta_{123} ptpoCSc + e$

Where,

Y is the response variable as previously described to be predicted, β_0 is the intercept, β_1, β_2, $\beta_{3....}$ β123 are the estimated coefficients and pt, poil and Sc are the independent variables.

The regression was fitted using Statistic Program.

RESULTS AND DISCUSSION

The response of dependent variables to the processing conditions is shown in Table 1 and the linear and quadratic effects of the variables, P. oil concentrations

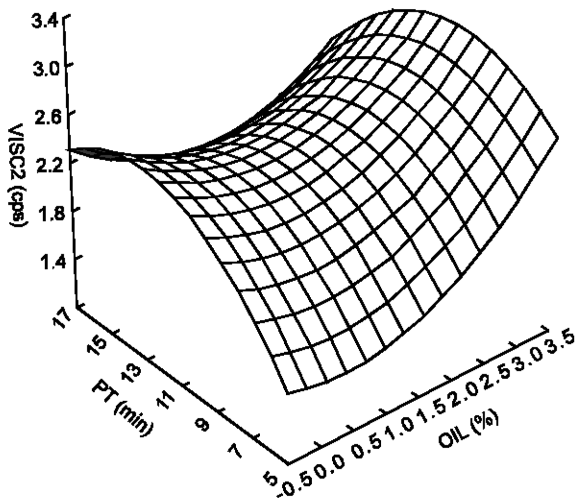

Fig. 2: Effect of processing time and oil concentration on the apparent viscosity of 'achi' flour.

Table 1: Regression coefficient

Parameters	Coefficient	Std Error	p-value
Constant	4.010	1.593	0.025
Pt	0.728	0.257	0.013
PoC.	1.940	0.338	0.000
Sc.	2.693	1.409	0.077
Pt^2	-3.111	0.012	0.020
PoC^2	-0.605	0.095	0.000
Sc^2	-1.195	0.987	0.246
PtPoC.	5.946	0.043	0.193
Pt.Sc.	-9.892	0.093	0.304
PoC Sc.	-1.975	0.022	0.389
R^2	0.806		

Table 2: Analysis of variance (ANOVA) for regression model of apparent viscosity obtained from the surface experiments

Regression	df	Sum of squares	Mean square	F-value	R^2
Regression	1	4.780	0.956	11.620	0.81
Residual	14	1.152	0.082		
Total	19	5.931			

and Pt were significant. Oil concentration had significant ($p<0.05$) linear and quadratic effect on viscosity, while salt concentration showed no significant ($p<0.05$) effect linear and quadratic.

In this study the effect of processing variables on viscosity of "achi" flours presented in Table 1, showed that the coefficient of determination R^2, for the model equation was calculated to be 0.806, which was considered high enough for prediction purposes, this showed that the regression model was very suitable for describing viscosity under varying conditions of processing time, palm oil concentration and salt concentration within the limits of the experimental design. The result demonstrated that the response surface had a maximum point at the code level 10.5 (Pt), 2.475 (PoC) and 2.8708 (Sc).

As can be seen from the response surface plot (Fig. 1, 2 and 3), the apparent viscosity increased when the concentration of salt was decreased and both the processing time and palm oil concentration increased. Fig. 1, shows the interaction between the processing time and salt concentration, with resultant increase in viscosity as salt concentration was decreased, while Figs. 2 and 3 shows the interaction of processing time and palm oil concentration and the interaction of the

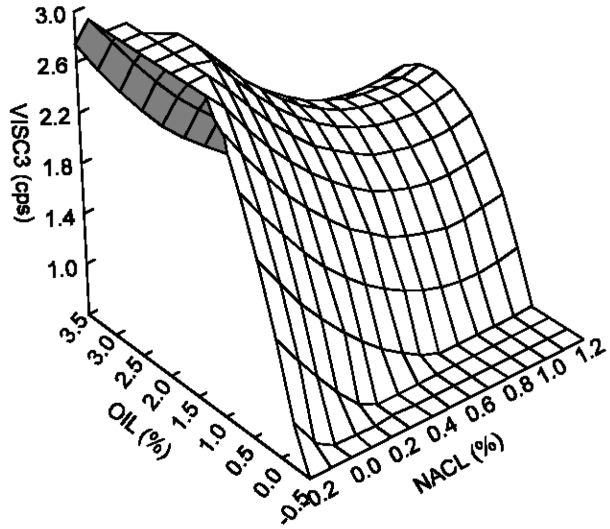

Fig. 3: Effect of oil concentration and salt concentration on the Apparent Viscosity of at different processing level, oil and salt concentrations of 'achi' Flour.

Table 3: Experimental and predicted values of apparent viscosity of 'achi' flour

S/N. Processing Time (mins).	Palm oil Con (%)	Salt Con (M)	Exptal. value (cps)	Predicted value (cps)
	0.0	0.0	0.917	0.920
	1.0	0.4	2.639	2.640
6.0	1.5	0.6	2.067	2.070
	2.0	0.8	2.017	2.020
	2.5	1.0	1.983	1.980
	0.0	0.0	0.883	0.880
	1.0	0.4	2.783	2.780
9.000	1.5	0.6	2.017	2.020
	2.0	0.8	1.967	1.970
	2.5	1.0	1.550	1.550
	0.0	0.0	0.967	0.970
	1.0	0.4	2.250	2.250
12.000	1.5	0.6	2.050	2.050
	2.0	0.8	1.983	1.980
	2.5	1.0	1.950	1.950
	0.0	0.0	0.900	0.900
	1.0	0.4	1.983	1.980
15.000	1.5	0.6	1.917	1.920
	2.0	0.8	1.617	1.620
	2.5	1.0	1.117	1.120

three processing variables respectively. There was an increase in apparent viscosity with (Figs. 2 and 3) increase in processing time and palm oil concentration. This increase was probably affected by the conditions under which the ingredients were applied, such as concentration and processing time (Iwe, 2003).

This model was tested for adequacy by the analysis of variance (Table 2). The regression model for apparent viscosity was highly significant ($p<0.001$). Table 2, also suggests that viscosity was primarily determined by the linear term and quadratic terms of the processing time and palm oil concentration. The results also showed that the response surface had a maximum point based on the response surface plot and the response model. The maximum response predicted by the model was 3.10cps.

The experimental and predicted values of the response variable, shown in Table 3 are closely related. This shows that the model correctly predicted the viscosity of "achi" flour. The model equation therefore could be applied in predicting the apparent viscosity of food systems or other legumes with similar processing conditions.

Conclusion: The Response Surface Methodology was effective in predicting the apparent viscosity of 'achi' flours. Results indicated that the variables Pt and PoC were significant on apparent viscosity. The effect of processes variables on apparent viscosity result could be ranked in the following order PoC (x3) > Pt (x1) > Sc (x3). Response variables predicted with model equation under processing conditions were in general agreement with experimental data.

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