

Optimisation of pre-treatment conditions for plantain (*Musa parasidiaca*) flour using Box-Behnken design

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RESEARCH ARTICLE

Abstract

The demand for plantain flour has increased in recent years due to its health benefits and industrial applications. Information on the optimum processing conditions to produce plantain flour of good quality is scarce. This study investigated the effects of pre-treatment on some quality attributes of unripe plantain flour. Response surface methodology (RSM) based on Box-Behnken design was used to optimise the pre-treatment conditions: blanching temperature (50-70 °C), blanching time (5-10 min) and potassium metabisulphite concentration (PMC) (1-2%). The functional and pasting properties of the plantain flour were determined using standard laboratory procedures. Data collected were subjected to analysis of variance, while RSM based on Box-Behnken design was used for response surface and regression analysis. Result of functional and proximate composition showed that pre-treatment significantly ($P < 0.05$) affected the parameters. The bulk density, water absorption capacity, swelling power, solubility index and dispersibility values ranged from 0.65-0.71 g/ml, 124.67-160.25%, 32.56-44.32%, 4.32-5.99% and 58-70%, respectively. The moisture content, crude fibre, values ranged from 8.61-11.70% and 2.23-3.59%, respectively. The optimum pre-treatment conditions for unripe plantain flour with a desirability of 0.870 were a blanching temperature of 50 °C, a blanching time of 6.447 min and 1% PMC. The coefficient of determination (R^2) for the quadratic models developed ranged between 0.64 and 0.99 and these high values indicates a good fit between predicted values and the experimental data points.

Keywords: processing conditions, plantain, flour, response surface methodology, Box-Behnken design

1. Introduction

Plantain (*Musa parasidiaca*) is one of the important staple food crops consumed in the tropics after rice, wheat and maize and is obtainable in about 120-130 tropical countries in the world (Kawongolo, 2013). It is an essential food crop in sub-Saharan Africa and serves as source of nutrient and household income for many people in Africa, Asia and South America (Kawongolo, 2013). The aggregated world production of plantain was just over 76 million metric tons (Olumba, 2014), out of which over 12 million metric

tons are harvested yearly in Africa (Fakayode *et al.*, 2011). Nigeria is the fifth largest producer of plantain in the world with about 3,088,938 tonnes produced in 2016 (FAO, 2017). The majority of plantain is produced in the southern part of the country due to the suitability of the weather conditions (Ayanwale *et al.*, 2016). In spite of the large amount of plantain harvested yearly in Nigeria, Odemero (2013) reported that over 40% of the harvested plantain is lost during distribution. Adeniji *et al.* (2010) reported that post-harvest losses of plantain are caused by lack of processing options, rough handling and unavailability of appropriate

storage facilities. Generally, plantain is harvested at a matured but unripe stage and undergoes rapid respiration after harvest, making it a short-lived agricultural product that requires urgent attention immediately after harvest. It is therefore essential to develop techniques to process plantain into more stable agricultural products after harvest.

Matured unripe plantain could be processed into flour. In Nigeria, plantain flour is usually processed into a gruel called *amala* that is often recommended for people with diabetics because of its low glycaemic index (Falade, 2009). The use of plantain flour for production of baked goods has been reported by Arisa *et al.* (2013). However, the end use of plantain flour in food products depends on the attractiveness of its colour. Colour is an important physical parameter in flour quality (Arisa *et al.*, 2013). The colour and other quality parameters of plantain flour can be improved by pre-treating the plantain fruits before drying.

Pre-treatments are unit operations applied to raw materials prior to processing in order to improve the appearance and other properties of the materials. Different pre-treatment methods have been developed and successfully used for pretreating fruit-based agricultural products, such as salt solution, honey dip, lemon juice, ascorbic acid, sulphiting, osmotic pre-treatment, and blanching (Karim, 2005). Sulphiting and blanching are the pre-treatments commonly used for plantain during processing into flour (Arisa *et al.*, 2013). Pre-treatment processes are applied to arrest enzymatic browning, which could affect the colour of plantain fruits during drying. Previous studies on pre-treatment methods to improve the properties of plantain focused on the manipulation of different blanching and sulphiting conditions. There is limited information on the optimum pre-treatment conditions for producing good quality plantain flour.

Optimisation process is a tool used for developing optimum synergy of variables that will produce an efficient and economic process in manufacturing setting. The traditional technique of studying one factor at a time can yield a reasonable outcome in some cases, but it is equally important to study the combined effects of many factors and this is what optimisation tend to achieve. Optimisation as used in food processing is a technique used to combine different processing conditions in order to obtain conditions that can produce products of acceptable quality attributes (Sobukola *et al.*, 2008). Response surface methodology (RSM) is a statistical and mathematical technique used for analysing contour plots to obtain the best processing conditions and multiple quadratic regression equation to fit between the factors and the response function. RSM is a useful technology in developing processes and optimising their performance (Raissi, 2009). Optimisation of different biochemical and biotechnological processes related to food processing have been successfully applied using RSM

(Pompeu *et al.*, 2009). The objective of this present study was to optimise the effect of pre-treatment conditions (blanching temperature, blanching time and potassium metabisulphite ($K_2S_2O_5$) concentration) for producing good quality plantain flour.

2. Materials and methods

Materials

Matured unripe plantain fruit was obtained from the plantain plantation of the Federal University of Agriculture (FUNAAB), Abeokuta, Nigeria. Plantain of the same variety and maturity level was carefully selected, while the ripeness stage was determined by matching the peel colour of the plantain fruits against a standardised colour chart. $K_2S_2O_5$ was purchased from Libertas Laboratory (Abeokuta, Nigeria).

Preparation of plantain flour

Matured unripe plantain was processed in the food processing laboratory of Department of Food Science and Technology, FUNAAB, Abeokuta, Nigeria. Plantain fruits were first washed, peeled and sliced using plantain slicer. The plantain slices were pretreated after which they were dried in a cabinet dryer (Serial No 3114; LEEC Limited, Nottingham, UK) for 24 h at 60 °C according to Olaoye *et al.* (2006). The dried chips were then milled into flour using Philips blender (HR2001; Amsterdam, the Netherlands), sieved using a 250 μ m mesh, packed in different zip lock polyethylene bags and stored at room temperature before analysis.

Statistical and experimental design

RSM using the Box-Behnken design was used to develop the experiment and optimisation of pre-treatment conditions for plantain flour. The choice of the three pre-treatment factors was based on earlier studies of plantain flour (Ariola *et al.*, 2016; Oluwalana *et al.*, 2011). These three independent variables were designated as X_1 (blanching temperature), X_2 (blanching time) and X_3 ($K_2S_2O_5$ concentration) and were used to create 17 pre-treatments conditions. The independent variables and their corresponding levels are given in Table 1.

The second order polynomial equation generated as a function of the predicted responses of water absorption capacity, swelling power, solubility index, dispersibility, crude fibre and moisture content is given below:

$$Y_i = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + a_{11}X_1^2 + a_{22}X_2^2 + a_{33}X_3^2 + a_{12}X_1X_2 + a_{13}X_1X_3 + a_{23}X_2X_3 + \epsilon \quad (1)$$

Table 1. Independent variables and their levels in the Box-Behnken design.

Independent variables	Unit	Symbol	Coded levels		
			-1	0	+1
Blanching temperature	°C	X_1	50	60	70
Blanching time	Min	X_2	5	7.5	10
$K_2S_2O_5$ concentration	%	X_3	1	1.5	2

The predicted responses were designated as Y_i associated with each factor level combinations a_2 to $a_{2,3}$ are the regression coefficients: X_1, X_2, X_3 are the factors.

The optimal process parameters for plantain flour were estimated using Design Expert software version 8 (State-Ease, Minneapolis, MN, USA). The coefficients in the second-order polynomial were calculated by multiple regression analysis, based on the experimentally obtained data using Equation (1). The equations were validated using analysis of variance (ANOVA). Response surface plots were drawn to determine the individual and interactive effects of the test variables for water absorption capacity, swelling power, solubility index, dispersibility, crude fibre and moisture content. The optimal values of each factor to optimise the process responses were based on Numerical Optimisation. The order in which the experiments were carried out was randomised to minimise error.

Functional properties of the plantain flour

Determination of bulk density

Bulk density of plantain flour was determined using the method of Mpotokwane *et al.* (2008). An 100 ml measuring cylinder was filled with the sample to mark 100 ml, the cylinder was tapped 50 times and then reweighed. Bulk density was calculated as the ratio of the bulk density and the volume of the container (g/ml) (Akpapunan and Markakis, 1981).

Determination of water absorption capacity

Water absorption capacity of the plantain flour was determined as described by Sathe and Salunkhe (1981). One gram of the sample was mixed with 10 ml distilled water. The mixture was allowed to stand at room temperature for 30 min and then centrifuged at $1.073 \times g$ for 15 min. Water absorption capacity was expressed as percentage increase in weight of sample.

Determination of swelling power and solubility index

Swelling power and solubility index were determined as described by Leach *et al.* (1959). 1% flour solution was prepared and heated in a water bath (Gallenkamp Water bath Model BKS-350-030; Gallenkamp, London, UK), maintained at 90 °C for 30 min with constant stirring and cooling. The suspension was centrifuged at 3000 rpm for 20 min and the supernatant was decanted into a pre-weighed can and dried at 100 °C to constant weight. The dried can were weighed for calculation of solubility, while the weight of wet sediment in centrifuge tube was used to determine swelling power.

Determination of dispersibility

Dispersibility of the plantain flour was determined using the method described by Kulkarni and Ingle (1991). 10 g of flour sample was suspended in an 100 ml measuring cylinder and distilled water was added to reach a volume of 100 ml. The mixture was stirred vigorously and allowed to settle for 3 h. The volume of settled particles was recorded and subtracted from 100 and the difference was reported as percentage dispersibility.

Proximate analysis

Moisture

Moisture content of the plantain flour was determined using air-oven method as described by AOAC (2000). A Gallenkamp hot air oven CHF097 model) was used to dry all samples to constant weight. The percentage moisture content was determined using the formula:

$$\text{Percentage moisture content} = \frac{W_1 - W_2}{W} \times 100 \quad (2)$$

where:

W_1 = weight of sample in dish before drying;

W_2 = weight of dried sample + dish after drying;

W = weight of sample.

Crude protein content

Total nitrogen in the plantain flour was determined using the micro-Kjedhal method as described by AOAC (2000). A conversion factor of 6.25 was used for the determination of crude protein present in the samples.

Fat content

Fat content was determined using Soxhlet method as described by AOAC (2000). Petroleum ether was used for the extraction and the percentage of fat present was determined using Equation 3:

$$\text{Percentage fat content} = \frac{x - y}{z} \times 100 \quad (3)$$

where:

x = weight of fat + flask;

y = weight of flask;

z = weight of sample (in grams).

Crude fibre and ash content

Crude fibre content of the plantain flour was determined using the method described by AOAC (2000). Also, the ash content of the plantain flour was determined using the method described by AOAC (2000)

Total carbohydrate content

The total carbohydrate content of the plantain flour was calculated by difference method using Equation 4:

$$\% \text{Carbohydrate} = 100 -$$

$$(\text{Protein} + \text{Moisture} + \text{Fat} + \text{Fibre} + \text{Ash}) \quad (4)$$

3. Results and discussion

Functional properties of pre-treated plantain flour

Bulk density

The bulk density of the plantain flours varied from 0.65 to 0.71 g/ml. The minimum bulk density (0.65 g/ml) was obtained from treatment 13 (60 °C blanching temperature, 10 min blanching time and 2% $K_2S_2O_5$ concentration), whereas maximum bulk density was observed for treatments 1, 8 and 10 (60 °C, 7.5 min, 1.5%; 50 °C, 7.5 min, 1.0%; 50 °C, 7.5 min, 2.0%) as shown in Table 2. The quadratic effect of blanching time had a significantly negative effect ($P < 0.05$) on the bulk density of the flours (Table 3). As the $K_2S_2O_5$ concentration increased, the bulk density of the plantain flour increased (Figure 1A), whereas with an increase in blanching temperature the bulk density of the plantain flours decreased (Figure 1B). Similar findings have been reported by Oluwalana *et al.* (2011) for plantain flour. However, this is contrary to the findings of Fagbemi (1999) who reported that blanching increased the bulk density of plantain flour. The significant decrease in bulk density as blanching temperature increased may be due to the changes in the porosity of the starch present in the plantain and which subsequently decrease the bulk density.

Table 2. Effect of pre-treatment on the functional properties of pre-treated plantain flour.¹

Treatment	BT (°C)	Bt (min)	$K_2S_2O_5$ (%)	Y_1 (g/ml)	Y_2 (%)	Y_3 (%)	Y_4 (%)	Y_5 (%)
1	60	7.5	1.5	0.70	134.70	38.54	67.0	4.80
2	70	7.5	1.0	0.67	129.04	36.85	68.0	4.52
3	50	5.0	1.5	0.67	153.12	42.81	68.0	5.61
4	60	5.0	2.0	0.69	138.16	37.48	69.5	4.42
5	60	7.5	1.5	0.71	134.84	38.78	69.5	4.82
6	60	7.5	1.5	0.71	133.04	38.62	68.0	4.81
7	70	10.0	1.5	0.67	127.34	34.80	66.0	4.50
8	50	7.5	1.0	0.71	158.72	44.18	70.0	5.89
9	60	7.5	1.5	0.71	135.94	38.03	67.0	5.66
10	50	7.5	2.0	0.71	152.56	43.89	68.0	5.66
11	70	5.0	1.5	0.67	124.67	32.56	58.0	4.49
12	60	10.0	1.0	0.67	138.84	37.99	70.0	4.59
13	60	10.0	2.0	0.65	136.16	37.98	68.5	4.62
14	50	10.0	1.5	0.68	160.25	44.32	64.5	5.99
15	60	7.5	1.5	0.71	135.05	38.52	69.5	4.76
16	60	5.0	1.0	0.67	137.38	37.62	69.0	4.70
17	70	7.5	2.0	0.69	126.88	33.57	66.0	4.32

¹ BT = blanching temperature; Bt = blanching time, $K_2S_2O_5$ = potassium metabisulphite, Y_1 = bulk density, Y_2 = water absorption capacity, Y_3 = swelling power, Y_4 = dispersibility, Y_5 = solubility index.

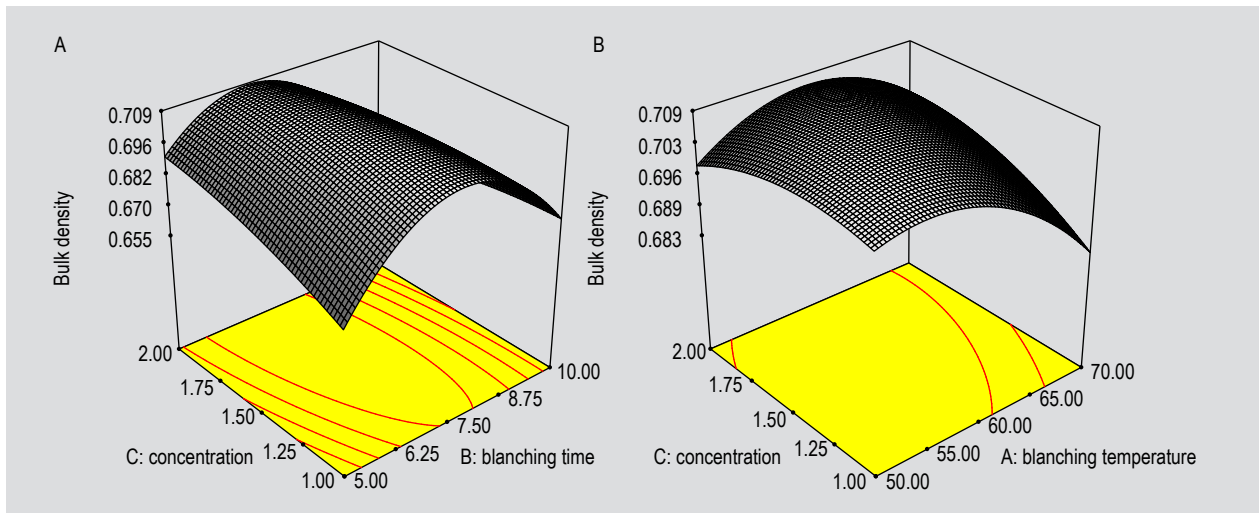


Figure 1. Response surface plot for bulk density (g/ml) as a function of potassium metabisulphite concentration and (A) blanching time or (B) blanching temperature.

Water absorption capacity

Water absorption, which measures the capacity of flour to absorb water and swell for enhanced consistency, is desirable in food systems as it helps to improve yield and consistency (Adepeju *et al.*, 2011). The water absorption of the plantain flour varied from 126.88 to 160.26%. The minimum water absorption capacity was obtained for treatment 17 (70 °C blanching temperature, blanching time 7.5 min and $K_2S_2O_5$ concentration of 2.0%), whereas the maximum value (160.25%) was observed for treatment 14 (50 °C, 10 min and 1.5%) (Table 2). From Table 3, the main effect of blanching temperature had negative significant effect ($P < 0.05$) on the water absorption capacity whereas, quadratic effect of blanching temperature had positive significant effect on the water absorption capacity. The

water absorption capacity of the plantain flour decreased as the blanching temperature increased (Figure 2B), whereas the water absorption capacity increased as the blanching time increased. $K_2S_2O_5$ concentration however had no significant effect on the water absorption capacity (Figure 2A). Similar results have been reported by Oluwalana *et al.* (2011) for plantain flour.

Dispersibility

Dispersibility is a measure of the reconstitution ability of flour in water. The higher the dispersibility the better the flour reconstitutes in water (Kulkarni and Ingle, 1991). The dispersibility of plantain flour varied between 58 and 70%. The treatments 8 and 12 (50 °C, 7.5 min, 1.0% and 60 °C, 10 min, 1.0%) had the maximum values while treatment 11

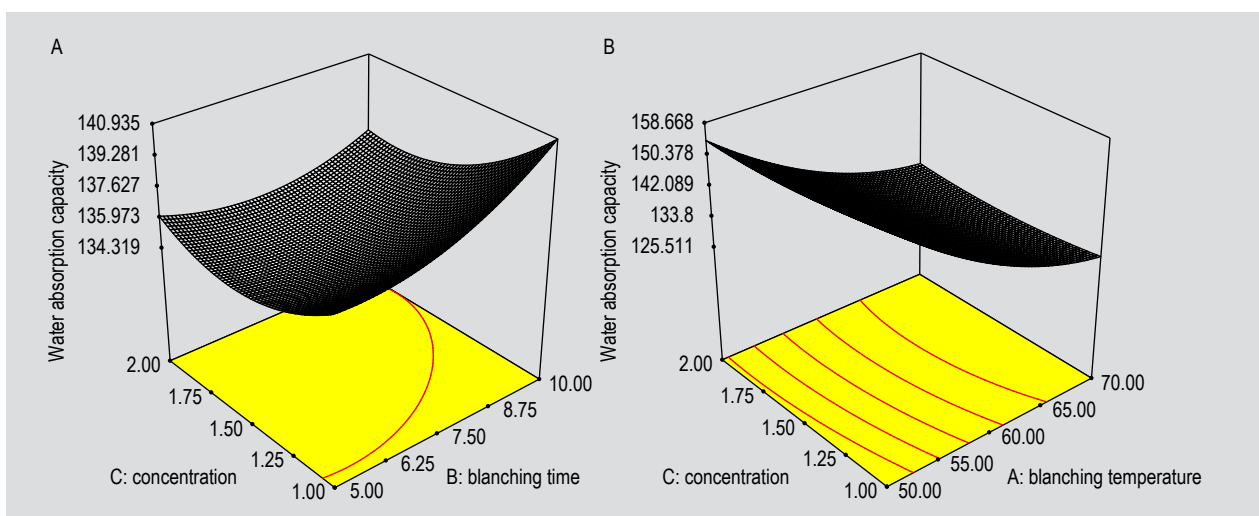


Figure 2. Response surface plot for water absorption capacity (%) as a function of potassium metabisulphite concentration and (A) blanching time or (B) blanching temperature.

(70 °C, 5.0 mins, 1.5%) had the minimum value (Table 2). The main effect of blanching temperature and quadratic effect of $K_2S_2O_5$ concentration had positive significant effect on the dispersibility of the plantain flours while the quadratic effect of blanching temperature and interactive effect of blanching temperature and blanching time had negative significant effect on the plantain flour (Table 3). There was significant decrease in dispersibility as the blanching temperature and time increased (Figure 3B) whereas the dispersibility initially decreased with increase in $K_2S_2O_5$ concentration, but it later increased with increase in concentration (Figure 3A). The decrease in dispersibility as blanching temperature increased may be attributed to

partial gelatinisation of the starch in the plantain which caused a reduction in the hydrophilic ability leading to reduction in hydration capacity of the flour thereby causing a reduction in dispersibility.

Proximate composition of pre-treated plantain flour

Moisture content

Moisture content of plantain flour ranged from 8.61 to 11.70%. The treatment 1 (60 °C blanching temperature, 7.5 min blanching time and 1.5% $K_2S_2O_5$) recorded maximum moisture content (11.70%), whereas treatment

Table 3. Regression analysis of responses for functional properties and physicochemical composition.^{1,2}

Coefficient	Y ₁	Y ₂	Y ₃	Y ₄	Y ₅	Y ₆	Y ₇	Y ₈	Y ₉	Y ₁₀	Y ₁₁
R ²	0.874	0.985	0.982	0.906	0.879	0.777	0.974	0.974	0.969	0.982	0.860
A	-0.005	-14.59*	-4.68*	1.56*	-0.67*	0.76*	-0.47*	-0.30*	-0.52*	-0.35*	-0.58*
B	-0.0075	1.16	0.58	-0.56	0.06	-0.12	-0.11*	0.014	-0.11*	0.012	0.25
C	0.0025	-1.28	-0.47	0.62	-0.085	1.20	0.00	0.027	-0.040	0.00	0.051
A ²	-0.009	5.40*	0.99*	-2.66*	0.35*	-0.64*	0.095	-0.086*	0.24*	-0.028	-0.89*
B ²	-0.034*	1.23	-0.87*	-1.41	-0.17	-0.31*	-0.11*	-0.00012	-0.098	0.036	-0.72*
C ²	-0.004	1.69	0.13	2.46*	-0.22	-0.25*	0.037	-0.0026	-0.022	-0.076*	-0.83*
AB	0.005	-1.11	0.18	-2.87*	-0.093	-0.30	0.0087	-0.048	0.14*	0.0075	-0.45
AC	0.005	1.00	-0.75	0.000	0.0075	0.061	-0.15*	-0.005	0.014	-0.043	-0.31
BC	-0.001	-0.87	0.032	-0.50	0.078	0.33	-0.039	0.0037	-0.046	0.041	-0.15
F-value	5.42	53.52	43.49	7.50	5.66	17.60	29.70	29.20	24.57	44.21	4.78
P-value	0.0182	0.0001	0.0001	0.0073	0.879	0.0005	0.0001	0.0001	0.0002	0.0001	0.0257

¹ A = blanching temperature; B = blanching time; C = potassium metabisulphite concentration; Y₁ = bulk density; Y₂ = water absorption capacity; Y₃ = swelling power; Y₄ = dispersibility; Y₅ = solubility index; Y₆ = carbohydrate; Y₇ = protein; Y₈ = fat; Y₉ = crude fibre; Y₁₀ = ash; Y₁₁ = moisture; R² = coefficient of determination.

² Significant values at 5% level are indicated with an asterisk.

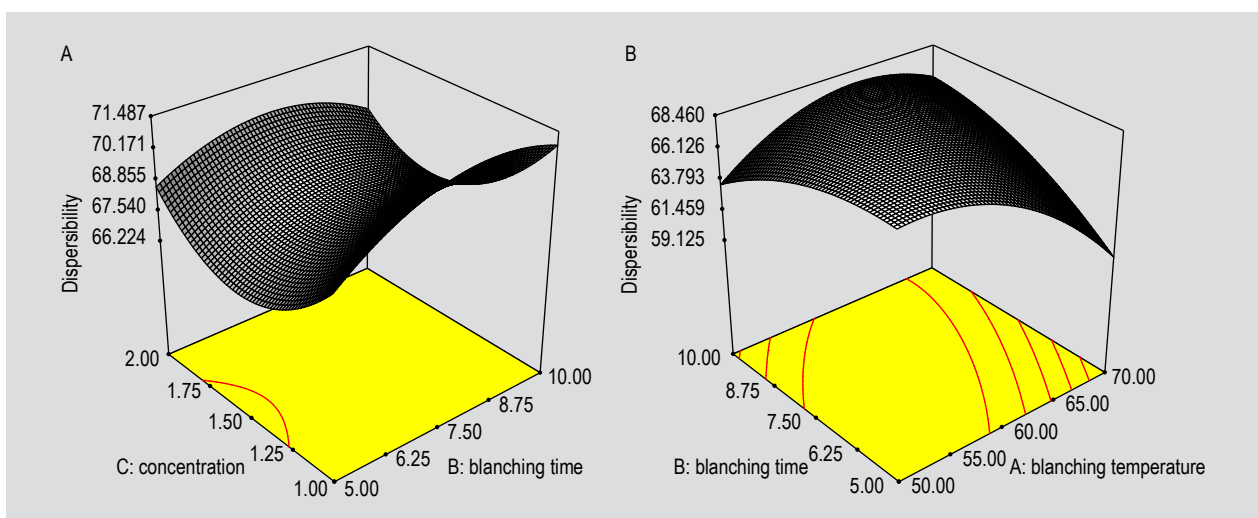


Figure 3. Response surface plot for dispersibility (%) as a function of blanching time and (A) potassium metabisulphite concentration or (B) blanching temperature.

7 (70 °C, 10 min, 1.5%) had the minimum moisture content (8.61%). The average value of moisture content for all treatments is given in Table 4. The main effect of blanching temperature, quadratic effect of blanching temperature and time and potassium metabisulphite concentration had negative significant ($P < 0.05$) effect on the moisture content of the plantain flours (Table 3). The quadratic model developed for moisture content had a coefficient of determination (R^2) of 0.90 (Table 3). There was a significant increase in moisture content with increasing blanching

time and $K_2S_2O_5$ concentration (Figure 4A), whereas the moisture content initially increased with an increase in blanching temperature but later decreased (Figure 4B). The moisture content of all pre-treated plantain flour obtained in this work were lower than the permissible level for moisture content of food flour according to Ayers and Westcot (1992) which makes the flour shelf stable.

Table 4. Effect of pre-treatment on the physicochemical properties of pre-treated plantain flour.¹

Treatment	BT (°C)	Bt (min)	$K_2S_2O_5$ (%)	Y_6	Y_7	Y_8	Y_9	Y_{10}	Y_{11}
1	60	7.50	1.5	77.17	3.86	2.35	2.73	2.63	11.26
2	70	7.50	1.0	80.24	3.52	1.95	2.42	2.22	9.65
3	50	5.00	1.5	76.39	4.29	2.51	3.59	2.98	10.24
4	60	5.00	2.0	79.02	3.83	2.32	2.66	2.58	9.58
5	60	7.50	1.5	77.24	3.69	2.33	2.66	2.61	11.46
6	60	7.50	1.5	76.96	3.80	2.31	2.62	2.69	11.61
7	70	10.00	1.5	81.63	3.25	1.86	2.28	2.38	8.61
8	50	7.50	1.0	77.70	4.19	2.44	3.54	2.85	9.28
9	60	7.50	1.5	77.19	3.78	2.29	2.64	2.71	11.39
10	50	7.50	2.0	76.11	4.59	2.52	3.29	2.98	10.51
11	70	5.00	1.5	81.04	3.36	1.92	2.33	2.28	9.07
12	60	10.00	1.0	78.40	3.65	2.30	2.50	2.58	10.56
13	60	10.00	2.0	79.22	3.46	2.35	2.47	2.62	9.88
14	50	10.00	1.5	75.63	4.14	2.64	2.97	3.05	11.57
15	60	7.50	1.5	76.96	3.75	2.30	2.63	2.66	11.70
16	60	5.00	1.0	78.95	3.86	2.29	2.51	2.70	9.69
17	70	7.50	2.0	80.63	3.33	2.01	2.23	2.18	9.62

¹ BT = blanching temperature; Bt = blanching time; $K_2S_2O_5$ = potassium metabisulphite; Y_6 = carbohydrate; Y_7 = protein; Y_8 = fat; Y_9 = crude fibre; Y_{10} = ash; Y_{11} = moisture.

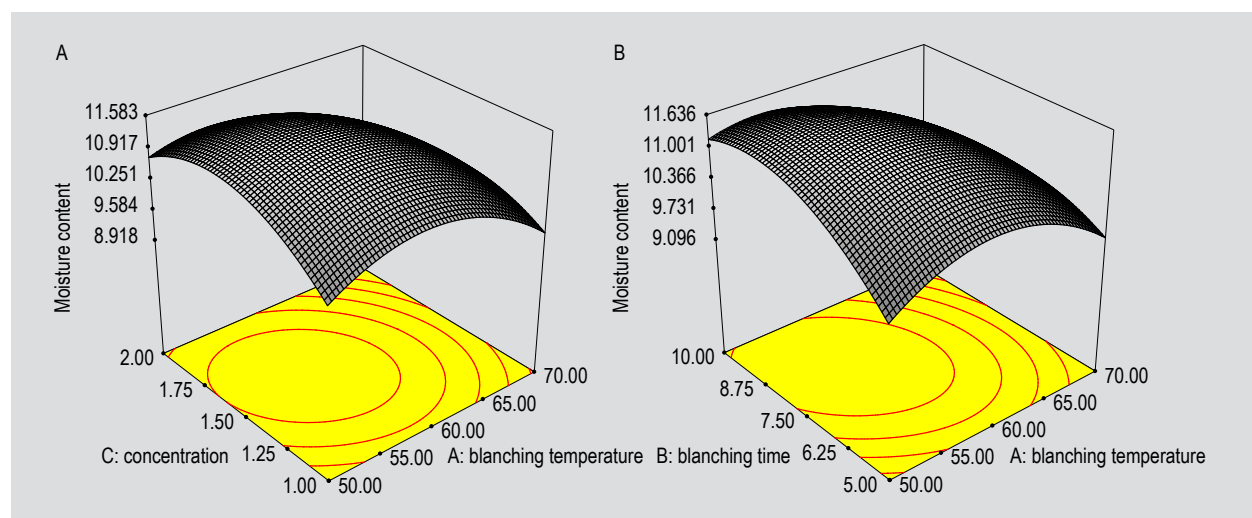


Figure 4. Response surface plot for moisture content (%) as a function of blanching temperature, and (A) potassium metabisulphite concentration or (B) blanching time.

Crude fibre

Consumption of diets high in dietary fibre is emphatically identified with various physiological and metabolic impacts because it contributes lower calories and helps in flushing cholesterol, carcinogens and unwanted chemicals from the body (Susan, 2003). Table 4 shows that crude fibre content of plantain flour varied from 1.27 to 4.58%. The treatment 17 (70 °C blanching temperature, 7.5 min blanching time and 2% $K_2S_2O_5$) had minimum crude fibre, whereas treatment 3 (50 °C, 5 min, 1.5%) had maximum value. The main effects of blanching temperature and time had a significantly negative ($P<0.05$) effect on crude fibre, whereas the quadratic effect of blanching temperature and interactive effect of blanching temperature and time had a significantly positive ($P<0.05$) effect on the crude fibre (Table 3). The quadratic model developed for crude fibre content had a coefficient of determination (R^2) of 0.96 (Table 3). The significant reduction in crude fibre of the plantain flour as the blanching temperature increased may be due to leaching of low-molecular weight components, such as minerals and sugars from the plantain into the

blanching water (Wenberg *et al.*, 2006). As the blanching temperature increased, the crude fibre content of the plantain flour decreased (Figure 5A) and similar trend was observed for blanching time (Figure 5B).

Optimisation of pre-treatment parameters

Numerical optimisation technique was used to establish the optimum pre-treatment conditions that would produce plantain flour of desired parameters having maximum bulk density, water absorption capacity, swelling power, solubility index, crude fibre and minimum moisture content. The selection of responses for the optimisation process was carefully done to ensure that the parameters that have great influence on the end use of the product (plantain flour) were selected. In addition to that, parameters which regression analysis reported to be significant ($P<0.05$) were selected. The optimum pre-treatment variables that would produce plantain flour of desired parameters having maximum bulk density (0.71 g/ml), water absorption capacity (160.25%), swelling power (44.32%), solubility index (5.99%), crude fibre (3.59%) and minimum moisture content (8.60%)

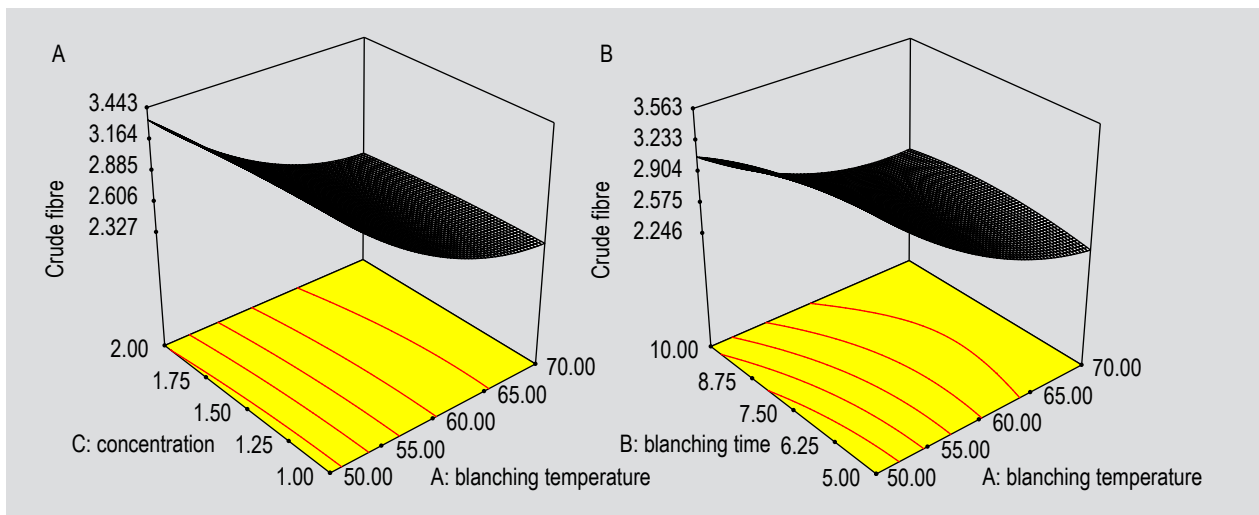


Figure 5. Response surface plot for crude fibre content (%) as a function of blanching temperature and (A) potassium metabisulphite concentration or (B) blanching time.

Table 5. Solutions to the optimisation of pre-treatment process variables.^{1,2}

BT	Bt	$K_2S_2O_5$	BD	WAC	SP	Disp.	SI	CF	MC	Desirability
50.00	6.447	1.00	0.697	157.56	43.71	70.70	5.68	3.51	9.49	0.870
50.00	6.431	1.00	0.697	157.55	43.71	70.70	5.68	3.51	9.48	0.870
50.00	6.479	1.00	0.698	157.59	43.73	70.69	5.68	3.51	9.51	0.870
50.00	6.387	1.00	0.697	157.51	43.68	70.71	5.67	3.51	9.45	0.870

¹ BT = blanching temperature; Bt = blanching time; $K_2S_2O_5$ = potassium metabisulphite; BD = bulk density; WAC = water absorption capacity; SP = swelling power; Disp = dispersibility; SI = solubility index; CF = crude fibre; MC = moisture content. ² Bold values show the selected optimum pre-treatment.

with desirability of 0.0870 was found to be a blanching temperature 50 °C, blanching time of 6.447 min and 1% $K_2S_2O_5$ solution (Table 5).

4. Conclusions

This study revealed that blanching temperature, blanching time and $K_2S_2O_5$ concentration could be used to pretreat plantain fruits to produce good quality plantain flour. The optimised pre-treatment conditions was found to be 50°C blanching temperature, blanching time 6.447 minutes and 1% $K_2S_2O_5$ concentration. The desirability for all the responses was found to be 0.870 and all the derived mathematical models for the various responses were found to be significantly fit to predict the data. This work has shown that the appearance of plantain flour could be improved with the use of appropriate pre-treatment conditions.

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