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REGULAR ARTICLE

Characterization of some food formulation functional properties of flour processed from roasted African breadfruit (*Treculia africana*) seeds

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Abstract

This study used Response Surface Methodology was used to roast, identify and characterize the optimum values of functional properties of African breadfruit (*Treculia africana*) seed flour processed for industrial applications. The central Composition Rotable Design of treatment variables at 3 process variables (Roasting temperature RT, Roasting Time RM, and feed quantity FQ) and 5 process levels (-1.682, -1, 0, 1, 1.682) was used to optimize bulk density water and oil absorption capacities, gelation and emulsion capacity of the produced flour. Functional properties of the flour increased above the value of control and relative to process treatment. The effect of roasting temperature was significant ($p < 0.05$) for bulk density, gelation and emulsion capacity. Roasting time and feed quantity significantly ($p<0.05$) influenced water absorption and emulsion capacities of the flour. Optimum values were bulk density 0/79 g/cm3, water absorption capacity 4.00ml/g, oil absorption capacities 2.90m/g, gelation 8.92 w/v. The unified optimum values of the functional properties occurred at process treatment combination of 126.360C, 45.85min and 505.09g, respectively for temperature, time and quantity. Processing African breadfruit seeds into flour at the optimal point will enhance its usefulness in industrial applications were functional properties of flour are of processing important.

Key words: African breadfruits, flour, optimization, functional properties, industrial application

Introduction

The search for substitutes to replace expensive industrial starch in the tropics had to increasing attention on lesser known sources of starch such as African breadfruit seeds. African breadfruit (*Treculia africana*) is a food crop tree of the Moracea family valued for its nutrient contribution to human diet. Though a leguminous crop, there is a growing focus on African breadfruit seed flour in food and pharmaceutical industries because of its cost effectiveness and process suitable functional properties compared with other cereals and legumes. African breadfruit is also affordable and readily available, in most tropical region of the world and has the potential to replace expensive sources of starch from temperate regions of the world.

Functional properties determine product quality and process effectiveness in any given food system (Akobundu et al., 1982). Such properties as bulk density, water and oil absorption capacities, emulsion behavior and foam stability differ greatly for different products and processes. Bulk density influences starch behavior in industrial systems and is important in product formulations where calorie and

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nutrient intakes are of primary consideration (Colona et al., 1989). Water and oil absorptive capacities are important for gels, binding, texturization, thickening etc (Nwabueze et al., 2007). For products requiring reconstitution in water, water and oil absorption capacities are important functional properties, which determine texture, mouth feel and flavour of processed products. Emulsion behavior and gelation characteristics define product stability and bioavailability or delivery of nutrients in processed products. The functional properties of African breadfruit seed are important parameters for its usefulness in food systems (Akobundu et al., 1982). The usefulness of native African breadfruit seed as substitute for industrial starch is limited by its high bulk density, easy breakdown of gels, low water and oil absorption capacities and susceptibility of its functional properties to heat treatments, and inverse relationship between oil absorption capacity and water absorption capacity. However, the functional property limitation of African breadfruit seed flour used for industrial products can be ameliorated by appropriate heat processing using response surface methodology. To determine optimum this functional important for industrial properties Response surface is used to characterize the spectrum of process region. It has successfully achieved premium products (Dziezak, 1990; Chen and Lin, 2002) through the identification of optimum process variable combination. There is a dearth of information in literature on optimum roasting of African breadfruit for flour. Hence this study aimed to characterize and provide an invaluable roast processing template to enhance functional properties and utility of African breadfruits in food and pharmaceutical industries.

Materials and methods

Freshly harvested African breadfruit seeds were purchased from Umuahia Main Market, Ibeku. The seeds were screened for contaminants, washed with portable water and air dried under shade at ambient (32±4^{o}C). The dried seeds were roasted using scientific oven (model 655 f) fishers scientific Co USA. experimentally using the Central Composite Rotable Design (8 factoral, 6 axial and 6 replications at the centre) as described on Tables 1 and 2. The roasted seeds were cooled, dehulled, milled with hand mill (corona model landers and CIA. SA) and sieved into flour using 2.00mm sieve. The flour was stored in cellophane bags at ambient temperatures (+ 28.0^{o}c) and used for determination of functional properties.

Determination of bulk density

Bulk density was determined using the methods (Okakaand Porter, 1979). 50 g of each sample was poured into a 100ml volumetric cylinder. The cylinder was tapped several times on a laboratory bench to a constant weight. The bulk density (g/cm^3) was calculated as weight of sample (g) divided by flour volume (cm^3).

Determination of gelation capacity

Determination of gelation capacity employed the method (Okakaand Porter, 1979). 2 – 20) % (weight/volume) of each sample of African breadfruit seed flour was mixed with distilled water to form a suspension, heated in 5ml boiling test tubes for 1 h using boiling water bath. Cooled under running tap water and further cooled in a refrigerator for 2 h. The test tubes were inverted to examine if their contents would slip off. The least Gelation concentration is the lowest concentration (% suspension) at which the flour paste in the test tube failed to slip off.

Table 1. Range and level of experimental variables.

Variables	Code	a	b	c	d	e
		-.1682	-1	0	+1	+1.682
Roasting temperature (%) RT	X_1	126.36	140	160	180	193.64
Roasting time (min) RM	X_2	31.59	35	40	45	48.41
Feed quantity (g) FQ	X_3	331,80	400	500	600	668.20

Table 2. Experimental layout.

Variables			Combinations	Replication	Experimental
X_1 RT	X_2 RM	X_3 FQ			
±1	±1	±1	8	1	8
±1.682	0	0	2	1	2
0	±1.6282	0	2	1	2
0	0	±1.682	2	1	2
0	0	0	1	6	6

Determination of water and oil absorption capacities

Water and oil absorption capacities were determined using the method (Narayana and Narasinga-Rao, 1982). 1 g of African breadfruit seed flour was mixed with distilled water (10ml) or oil (10ml) for water and oil absorption capacities respectively. The respective mixtures were allowed to stand for 30min at room temperature, then centrifuged for 30min at 600rpm using calibrated centrifuge tubes. The volume of formed supernatant after centrifuge was read off as absorbed water or oil.

Absorption capacity (water) = Total water in original sample minus free water (after absorption) x density of water.

Absorption capacity (oil) = Total oil in original sample minus free oil (after absorption) x density of oil.

Determination of emulsion capacity

Determination of emulsion capacity was determined according to the method [Onwuka, G. I. (2005.

Two grams of African breadfruit flour was blended with 25ml distilled water for 30 seconds at room temperature. Measured 25ml portion of vegetable oil was introduced into the mixture and further blended for 30 seconds. At the end of blending the mixture was transferred into calibrated centrifuge tubes and centrifuged for 5 minutes at 1600rpm. The volume of supernatural oil after centrifuge was read from the tube. Emulsification capacity is the amount of oil held as emulsion per gram of sample.

$$\text{Emulsion capacity (\%)} = \frac{\text{Height of emulsified layer}}{\text{Height of whole mixture in centrifuge tube}} \times \frac{100}{1}$$

Statistical assay

Data generated from experimental runs was analyzed using second order polynomial regression. The study was based on the hypothesis that response (Y) is functionally related to variables of roasting temperature X_1, roasting time X_2 and feed quality X_3 by the equation,

$$Y = \beta o + \Sigma\beta_1 xi + \Sigma\beta_{11} x_{12} + \Sigma\beta j_1 x_i x_j \varepsilon \ldots\ldots (1)$$

Where

Y = response; β_o = intercept, Xiji = independent variables,

Minitab statistical software version 15 of Minitab Inc, Pennsylvania USA was used for complete statistical and optimization assays.

Table 3. Functional properties of roasted African breadfruit seed flour.

S/No Expt. Runs	Roasting temp.RT (°C) (X_1)	Roasting time RM (min) (X_2)	Feed Quantity FQ (g) (X_3)	Bulk density (g/cm$_3$)	Water absorption capacity (ml/g)	Oil absorption capacity (ml/g)	Gelation (w/v)	Emulsion capacity (%)	Foaming stability (ml)
1	140	35	400	0.70	3.90	1.69	8.02	68.00	6.70
2	140	35	600	0.70	3.99	1.70	8.00	68.00	6.74
3	140	45	400	0.78	3.80	1.99	7.88	68.00	6.61
4	140	45	600	0.70	3.90	1.99	7.88	68.10	6.65
5	180	35	400	0.78	3.90	1.51	7.30	62.05	5.61
6	180	35	600	0.74	4.00	1.51	8.00	62.10	5.53
7	180	45	400	0.79	4.01	1.60	8.55	62.20	5.47
8	180	45	600	0.60	3.66	1.59	7.80	60.00	5.50
9	126.36	40	500	0.73	4.06	1.77	8.90	68.00	5.66
10	193.64	40	500	0.73	5.06	1.50	8.90	60.10	5.60
11	160	31.59	500	0.69	3.50	1.69	7.01	65.00	6.71
12	160	48.41	500	0.60	4.30	1.41	8.88	63.10	5.59
13	160	40	331.80	0.67	3.06	1.57	7.50	65.00	5.55
14	160	40	668.20	0.67	3.10	1.66	7.54	65.20	5.89
15	160	40	500	0.72	3.01	1.59	7.50	71.00	5.45
16	160	40	500	0.64	4.70	1.68	7.60	71.00	5.50
17	160	40	500	0.63	4.40	1.66	7.50	71.00	5.49
18	160	40	500	0.64	4.21	1.64	7.45	71.00	5.49
19	160	40	500	0.61	4.16	1.61	7.50	71.00	5.0
20	160	40	500	0.60	4.04	1.61	7.60	72.10	5.50
Control (Raw)				4.00	2.88	2.52	64.80	13.10	9.16

Table 4. Analysis of variance (ANOVA) regression models of functional properties.

Properties	Df	Seq. SS	Adj. SS	Adj. MS	P
Bulk density	9	0.057850	0.51850	0.065761	0.066
Gelation capacity	9	4.58730	4.55730	0.50637	0.015^{xx}
Water absorption capacity	9	2.69735	2.69735	0.29971	0.335
Oil absorption capacity	9	0.232053	0.232053	0.025784	0.231
Emulsion capacity	9	295.557	295.557	32.8397	0.000^{xx}

xx = Significant superscript

Table 5. Predicted optimum and experimental peak of functional.

Parameters	Optimum	Peak
Bulk density g/cm^3	0.79	0.78
Gelation w/v	8.90	8.90
Water absorption capacity ml/g	2.40	5.06
Oil absorption capacity ml/g	2.00	1.08
Emulsion capacity	66.15	71.00

Results and discussion

The results of the functional properties of the dehulled seed flour sample are shown on Table 3, and the analysis of variance regression models of functional properties are reported on Table 4. The optimization profiler (Fig. 1) describe the optimum value of functional properties at desirability range of 0.5-1.0 at global setting of process variable The predicted optimum and experimental peak values were similar (Table 5) are relevant to aim of study.

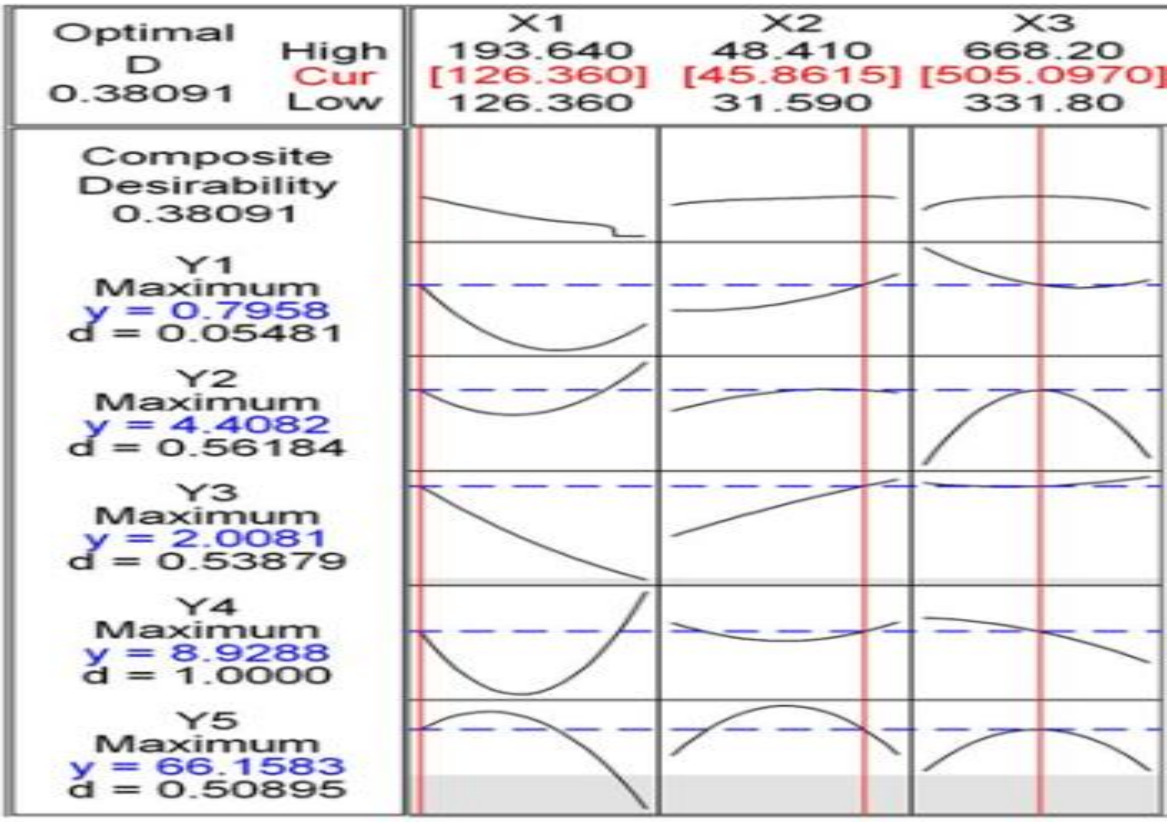

Fig. 1. Optimization plot for functional properties of roasted African breadfruit seeds flour.
Key: X_1 = Roasting Temperature (RT), X_2 = Roasting Time (RM), X_3 = feed quantity (FQ), Y_1 = Bulk Density, Y_2 = Water Absorption Capacity, Y_3 = Oil Absorption Capacity, Y_4 = Gelation, Y_5 = Emulsion Capacity

Bulk density

The bulk densities ranged from 0.60g/cm^3 to 0.78g/cm^3. The differences in bulk density of the samples could be due to the operating variable combinations. Bulk density being a measure of the heaviness of sample reflects the amount of starch present in the flour. Heat treatment as consistent with roasting has significant ($p<0.05$) effects on rupture of starch cells and compaction of starch granules (Nwabueze et al., 2007). Starch aggregation influences bulk density. The R^2 for bulk density is 71.14%. The model adequately analyzed the response characteristics as function of process variables. Except for roasting temperature, the effects of the independent variables in linear, quadratic and interactive terms were not significant ($p<0.05$). Roasting temperature showed significant ($p<0.05$) quadratic effects on bulk density. The resulting polynomial equation after removing the non-significant terms becomes

$BDA = 0.963735 + 0.000100RT^2 \quad R^2 = 71.14\%$ .... (2)

The bulk density of 0.79g/cm^3 was observed at 126.36° C (roasting temperature) 45.86min. (roasting time) and 505.09kg (feed quantity).

Thus roasting temperature primarily influenced the bulk density of samples. The bulk density values of these results are comparable with values in literature for parboiled seeds flow of African breadfruit (Nwabueze et al., 2007; Akubor, 1997). Contrary to the expectations the interactive effects of the process variables on bulk density of samples were not significant. Results implied that high temperature short time treatment could impair the bulk density of African breadfruit seeds except in infant food formulations, where low bulk density is preferred (Enwere, 1998).

Gelation

The gelation values of treated samples were higher than the gelation values of native seeds of African breadfruits. The mean values ranged from 5.6 w/v to8.90 w/v. A relationship between the gelation values of samples and the roasting temperature and roasting time was observed within the process variable spectrum. Gelation values of the samples were indicative of the degree of heat treatment including temperature and durations of treatment.

The estimated regression Co-efficient of gelation of samples was 79.83%, which implied that 79.83% of the total variation in data was due to process treatment. Roasting temperature had significant ($p<0.05$) linear and quadratic effects on gelation properties of African breadfruit seeds. It is the key determinant of gelation profile of African breadfruit seed flour.

The polynomial equation after removing the non-significant terms becomes

$GL_A = 41.6573 + 0.0011RT^2$..$R^2 = 79.83\%$(3)

The optimum gelation value was 8.92w/v at 126.36°C (roasting temperature) 45.86mm (roasting time) and 505.09 (feed quantity).

The gelling capacity of food is an important functional attribute for food processing. Large numbers of important food are gels and gelation is the basic processing step in the manufacture of various foods. The gelling capacity is the standard that is usually employed to evaluate food ingredients. The quality properties of many foods, especially, textural properties and juiciness are influenced by gelling. A higher gelation value as shown by these results implies a higher degree of cook which reduces, subsequent cooking time for instant gruels (Colona et al., 1989), or other food products that require reheating before consumption.

From results it is apparent that roasted seed flour has gelation superiority over control for the formulation of instant cereal gruels and weaning diets. The raw seed flours suffer easy breakdown and retrogradation of gel. Hence find limited use in industrial formulations. The deficiency of native seed flours can be improved by appropriate parboiling (Nwabueze and Atuonwu, 2006), or roasting as observed by this study.

Water absorption capacity (WAC)

The water absorption (2.88 – 5.06 g/g) showed variations giving an optimum of 4.40g/g The differences are attributable to heat treatment applied in the study. The Estimated regression co-efficient for WAC was 63.08%. Analysis showed that the only feed quantity had significant ($p<0.05$) quadratic effects on WAC. Other process variables lack significant effects on WAC. No interactive effect of the independent variables on WAC was observed. The primary determinant of WAC is the native starch contents of foods, which is influenced by seed variety (Nwabueze, 2012). Starch particle aggregation is influenced by seed variety. It implied that mixing of varieties of African breadfruit seeds would result in inconsistent water absorption capacity of materials used for industrial formulations.

After removing the non-significant terms the polynomial equations becomes

$WC_A = -2.53656 - 0.00003FQ^2$………………………………………………………… $R^2 = 64.08\%$ (4)

Results revealed that though roasting temperature and roasting time may have direct relationship on WAC of the samples, but more important is the critical mass of African breadfruit seeds as that factor influenced the quantum of rupture of starch cells. WAC increased with increase in roasting temperature and roasting time. Report in literature indicated that changes in WAC could be attributed to starch gelatinization during roasting brought about by starch – water interactions in the presence of heat and moisture (Nwabueze et al., 2007). WAC is related to the texture of a product and is influenced by product porosity. WAC explains the ability of flour or product to rehydrate (Lin et al., 1974) or absorb water during processing. Good WAC implies improvement in texture, processing properties and usefulness in food systems especially for baked products and confectionaries. The ability for slow imbibition of water during product formulations has been identified as an important function property (Nwabueze et al., 2007), which underscores the usefulness of African breadfruit seed flour in food system requiring moisture and water activity control in final products.

Optimum water absorption capacity (4.40g/g was achieved at 126.36%, 45.86min and 505.09g variable condition of roasting temperature, roasting time and feed quantity respectively.

Oil absorption capacity (OAC)

Results showed decreases in oil absorption capacity values of the samples. The values ranged from 2.52 ml/g for native seeds to 1.41 ml/g treated sample. The difference in OAC values could be due to influence of heat on fat cells (Nwokocha and Ugbomoiko, 2008). In agreement with literature (Nwokocha and Ugbomoiko, 2008) there is an inverse relationship between fat content and OAC of products or flour as reported on Table 3. The inverse differences between the two absorption capacities ranged from 50 to 70.35%. The estimated regression co-efficient R^2 was 69.10%. There were no significant differences ($p<0.05$) in OAC due to linear, quadratic and interactive effects of the process variables. The ability of food to absorb oil contributes to its usefulness in achieving acceptable sensory properties as OAC aids flavor retention and month feel of foods (Nwabueze et al., 2007). In agreement with literature, these results implied that roasting had effects on oil contents of African breadfruit seeds. While it increased oil content and it reduces the ability of the flour to absorb oil (Nwabueze et al., 2007). Roasted breadfruit seed flour could have good potential for use in food systems that require fat related emulsion. The optimum OAC was 2.00 ml/g at optimum variables combinations of 126.36°C (roasting temperature, 45.86min (Roasting time) and 505.09g (feed quantity).

Emulsion capacity

The results of the emulsion capacity of the samples showed the mean values of emulsion capacity ranged from 64.80% to 72.10%. The model's co-efficient of determination R^2 was 97.68%. All operating variables had significant ($p<0.05$) linear and squared of effects on emulsion capacity as indicated by the model. No significant interactive effect of process variables on emulsion capacity was observed. The polynomial equation without the non-significant terms becomes

$EC_A = 290.955 + 1.909RT + 8.123RM + 0.0241FM - 0.094RM^2 - 0.000FQ^2$ ………………… $R^2 = 97.68\%$ (5)

The highest emulsion capacity under optimum condition was 66.158%. at 126.360C (Roasting temperature, 45.86min) (Roasting time) and 505.09g/g (feed quantity).

The difference in emulsion capacity between the heat processed and raw unprocessed African breadfruit seeds is not significant. The optimization provides an opportunity for formulators of emulsion based products to determine and apply the range of process variables to achieve the desired emulsion behavior of products.

Conclusion

The response surface model satisfactorily determined the optimum values. The optimum values for bulk density, water absorption capacity, oil absorption capacity, gelation and emulsion capacity were 0.7958 g/cm³, 4.4082 ml/g, 2.0081 ml/g, 8.9288 w/v and 66.1583%

respectively (at desirability (d) range of 0.05 – 1.0). at optimum process, variable setting of 126.36°C Roasting temperature, 45.86min) (Roasting time) and 505.09g/g (feed quantity).

The optimum range for roasting of African bread fruit seed lies between -1.682 and +1.0 of the process spectrum (X_1 =a, X_2 =d, X_3 =c). Roast processing (roasting) improves the functional properties of African breadfruit seed flour, which enhances its usefulness in food and pharmaceutical systems. When properly processed African breadfruit seed flour is a potentially convenient, cost effective alternative for expensive imported industrial starch of temperate grains. used in food and pharmaceutical industries. The cost and nutritional benefits will ultimately ensure the good health and wellbeing of population of tropical regions.

Author contributions

A. C. Umezuruike and T. U Nwabueze jointly designed and sourced the materials for study. A. C Umezuruike conducted the experiments, while T. U. Nwabueze conducted the statistical assays. Both authors jointly participated in the writing the manuscript.

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