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OPTIMIZATION OF LYE PEELING OF BREADFRUIT (*Artocarpus comminis* Frost) USING RESPONSE SURFACE METHODOLOGY

[1*] H.A.BAKARE, [2] O.F OSUNDAHUNSI [3] J.O. OLUSANYA AND [3] M.O. ADEGUNWA

[1] School of Vocational Education, Michael Otedola College of Primary Education, Noforija, Epe. Lagos, Nigeria
[2] Department of Food Science and Technology, Federal University of Technology, Akure Nigeria.
[3] Department of Home and Hotel Management, Tai Solarin University of Education, Ijagun, Ijebu-Ode Nigeria
***Corresponding author:** adegokebakarehenri@yahoo.com

ABSTRACT

Breadfruit (*Artocarpus communis* Frost) is an important food crop in many tropical developing countries. Conventional peeling, done manually using knives is wasteful and unsuitable for industrial scale operation. Optimum condition for the peeling of breadfruit by immersion in hot lye (NaOH) solution was determined using Response Surface methodology (RSM) for pre-determined three levels of Peeling Efficiency Index (PEI). Some breadfruit was peeled manually and some with hot lye solution. The effects of lye–concentration (0.5-2.0%), immersion temperature (70-90°C) and immersion time (2.5-10min.) on PEI (removal of 6-11% of peel) with subsequent soft and abrasive washing of the peeled crop obtained from 14 experimental points and three replication were analyzed with design expert and statistical analysis system software. Complete lye–peeling (removal of 6% of the fruit) was achieved at 1.6%, 80°C and 5min respectively which were within the critical optimization range (R^2=52%, CV=75.9%) generated by the RSM.

Keyword: Breadfruit, Peeling, RSM

INTRODUCTION

Breadfruit *(Artocarpus comminis* Frost) is a carbohydrate food resource and staple diet many tropical developing countries of the world. The tree fruits primarily between May and August producing 50 to 200 fruit in a year. The mature fruit is round or ovoid, 15-20cm in diameter and weighing 2-10kg on average (Graham *et al.,* 1981). The fruit is produced mainly by Malaysia, the South pacific Island, the Caribbean's and West Africa (Morton, 1987; Loos *et al.*, 1981). Total yearly production in Nigerian is about 10 million metric tones having potential to exceed 100 million metric tones with improved agricultural practice (Adewusi *et al*., 1995) .The economic Utilization of breadfruit has been limited by its poor storage properties (about 3-4 days). However, it has been suggested (Morton, 1987; Thompson *et al*., 1974) that conversion to flour would provide a more stable storage form as well as enhance the versatility of the fruit. Current usage of breadfruit is attaining greater industrial importance particularly in food application such as bakery product, flour confectionaries and related product (Olatunji and Akinrele, 1978) while its starch is of potential value as adhesives in packaging and also in textile and pharmaceutical industries (Whistler *et al*., 1984). The industrial production of breadfruit flour requires new technology to increase production output with minimum processing time to avoid undesirable variation in colour quality arising from undue exposure to sunlight and enzymatic activities. At present, the peeling of breadfruit is done by hand, often by women and children using knives, a process which is tedious, wasteful and time consuming especially for large–scale operation. Hot lye–peeling, a process which combines the effectiveness of both chemical (Talburt and Smith, 1967) has been successfully applied to agricultural produce such as pepper (Floros and Chinnnan,1987), potato (Greig and Manchester, 1958) and cassava (Sreenarayanan *et al*., 1995).

In the present study, the feasibility of peeling breadfruit by immersing in a lye (NaOH) solution was investigated. Response surface methodology (RSM) was to determine to optimum combinations of three processing variables namely; concentration, immersion temperature lye solution and immersion time on peeling efficiency.

MATERIALS AND METHODS

Mature fruit of the seedless variety of breadfruit (*Artocarpus communis* Frost) used for the study were obtained from a local farm at Mamu in Ijebu North local Government area of Ogun State, Nigeria. Twenty–five fruits of various sizes were hand peeled to so that the relationship between the peels and fruit can be established. Some of the fruit were peeled as done normally by women (involving the removal of the pericarp with some of the mesocarp) while others were carefully peeled to remove as much as practicable only the thin pericarp.

Lye peeling of breadfruit: Lye–peeling of the fruit was carried out as described by Sreeparayanan, Rubikala and Jayas (1995) with minor modification. A thematically regulated stainless steel water bath was filled with 3-L lye-solution of the required concentration prepared using NaOH pellets, and heated to the desired temperature. The temperature of the lye-solution at any desired level was maintained within ±2°C. The masses of each of the pre-washed fruits to be treated were determined using Acculab electronic digital scale (Model 2001). The fruits were placed in the hot lye solution with the aid of a plastic net and immersed in the solution for the duration of each specified resident/immersion time (measured with a Heure stopwatch) before being removed and washed. Two modes of washing were adopted-soft (hand rinsing) in stream of water and initial weighing, followed by abrasive washing using a brush with plastic thistle and final weighing. The peeling efficiency index (PEI) was calculated for varying levels of treatment as done by Sreeparayanan *et al*., (1995). Three levels/types of efficiency were evaluated; based on the conventional peeling as done by women (PEIA), careful removal of the thin pericarp (PEIB) and on the actual of peels (%peeled) removed from the fruit. Each experiment was replicated three times and the mean response was used for multiple regression analysis to develop an empirical model relating the independent variables to each peeling efficiency and percentage of peels removed.

Experimental procedure

Optimization of lye peeling of breadfruit was carried out using response surface methodology (Montgomery, 2001; Myers and Montgomery, 2002). Based on preliminary experiment, three independent variables considered to be of importance to the peeling process were concentration of lye (NaOH) solution (X1, %w/v, NaOH/ water), temperature of the solution (X2,°C) and immersion time (X3, min). The independent variables (X1, X2 & X3) were selected for optimization on the basis of a three factor and three level face–centered cube (FCD) (Liyana-Pathirana and Shahidi, 2005) consisting of fourteen experimental runs. Peeling efficiency index (PEIA & PEIB) and actual percentage of removed from the fruit wase used as dependent variables for each level of treatment.

Data analysis

The responses surface regression (RSREG) procedure of statistical analysis system (SAS) and design expert (version 6.0.5) software were used to analyze the experimental data as described by Myers and Montgomery, 2003). Experimental data were fitted to a second order polynomial model and regression co-efficient obtained. The generalized second-order polynomial used in response surface analysis was.

$$PEI\ (Y) = ß_o + \Sigma\ \Sigma ßi\ Xi + \Sigma\ ßii\ X^2j + \Sigma\ \Sigma\ ßßiiXi.Xj \quad \ldots\ldots\ldots\ldots(1)$$

Where Bo, Bi, Bij are the regression coefficients for intercept, linear, quadratic and interaction terms, respectively, and Xi and Xj are the independent variables. The design expert software was used to generate response surfaces contour plots while holding a variable constant in the second-order polynomial model. When the results showed a stationery (saddle) point in response surfaces the ridge analysis (canonical analysis) of SAS RSREG procedure was used to compute the estimated ridge of the optimum response.

Verification of Model

Optimal peeling efficiency index (PEI) and actual percentage of peels removed required for the peeling of breadfruit which depended on the independent variables were obtained using predictive equations of RSM. The experimental and predicted values were compared in order to determine the validity of the model.

RESULTS AND DISCUSSION

Results of manual peeling of breadfruit revealed that the thin pericarp of breadfruit is about 6% of breadfruit while the manual removal of the pericarp with part of the mesocarp would involve removing about 11% of the weight of breadfruit. It was necessary to identify the three levels in which the efficiency of the peeling system can be based in order to avoid over or under peeling. Over-peeling leads to wastages and resulted in reduction in unit yield per fruit. Over-peeling by chemical (lye) peeling process could occur as a result of prolonged or over-exposure of unpeeled fruits to unnecessary high concentration of lye-solution. This has implications on processing cost and consumers' health.

The efficiency of lye-peeling process has been reported to be influenced by multiple parameters such as concentration of the lye (NaOH) solution, immersion temperature and time (Floros and Chinnan 1987; Sreeparayanan *et al.*, 1995). The effects of these parameters may either be independent or interactive. Approximate conditions for lye-peeling of breadfruit were determined by varying one factor at a time while keeping the others constant. Index of peeling efficiency was calculated for breadfruit based on the removal of either the pericarp alone or with some of the mesocarp as indicated in Table 1. The actual amounts of peels removed expressed as percentages also determined index of efficiency and effectiveness of the peeling process. The washing condition under which the peels were removed is as stated in Table 1.

In RSM, natural variables are transformed into coded variables which are dimensionless and having a mean zero and the same spread of standard deviation (Meyers and Montgomery, 2002). An appropriate range for each of the three variable factors in Table 1 was used to determine the lower, middle and upper design points for RSM in coded and natural (uncoded values) (Table 2).

Multiple regression equation was generated to relate response variable to coded levels of independent variable using least squares technique (Myers and Montgomery, 2002) to predict quadratic polynomial models for the respective peeling efficiency index (PEI). Analysis of variance (ANOVA) was used to access the extent to which the selected quadratic models adequately represented the data obtained for the peeling efficiency (Liyama-Pathirana and Shahidi, 2005). The result of ANOVA for the respective peeling efficiencies (responses) with their corresponding regression coefficients of multiple determinations (R^2) for the fruit generated by the software is shown in Table 3. Equation (1) was fitted to each of the dependent variables. The adequacy and goodness of fit were evaluated using the regression coefficient (R^2) and the sum square of lack of fit respectively. R^2 is the percent of variance in the dependent variables (PEIA, PEIB and actual % peeled) that is explained collectively by all the independent variables (concentration of lye, immersion temperature and time). The closer the value of R^2 is to 100%, the better the empirical model. Results obtained in Table 3 revealed that R^2 gave a good ($50<R^2>75$) explanation of the variance for the three peeling efficiency responses for the lye-peeling of breadfruit. Inability of the model to give a very good ($R^2<75\%$) explanation of the variance in the response suggest that it might be necessary to give consideration to other factors that are relevant to lye-peeling of breadfruit besides the three independent variables (lye-concentration, immersion temperature and time) used for the experiment. These factors may include; variation in agronomic characteristics within and among cultivars, the effect of the latex exudates on the attachment of pericarp of breadfruit to its mesocarp). R^2 values in Table 3 also indicated that calculation of peeling efficiency index of breadfruit is best explained when it is based on the conventional way of peeling by women (11% mass of peels)

Coefficient of variation (C.V.) is a measure expressing standard deviation as a percentage of the mean (Thomas and Nelson, 1996). It described the extent to which the data were dispersed as indicated in Table 3. ANOVA of the regression parameters of the predicted response surface models for peeling efficiency of the fruit indicated the linear, quadratic and interaction ((cross product) did not produce a significant effect in each case ($p>0.01$ or $p>0.05$). Thus, none of the three effects of independent variables was primarily responsible for determining the term that may cause significant effects in the response (PEI). The models indicated that lye-concentration and temperature made more contribution to the response in term of linear effects; this suggests that efficiency of peeling increases as lye-concentration and temperature increase.

The relation between independent and dependent variables was viewed through a three dimensional representation of the responses surface concreted by the models for the entire peeling efficiencies. The analysis of the contour surface responses revealed that the stationary points for Peeling Efficiency indices were at maximum (Table 5). Ridge analysis was performed to determine the critical levels of the design variables that produce the maximum response. The critical values in term of coded and uncoded variables for the peeling efficiencies (responses) are given in Table 4. Predicted critical values for lye-peeling of breadfruit suggest the desirability of using lower concentration of lye (0.06%), temperature (58.6%) but higher immersion time (9.14 min) to achieve the peeling of the fruit on the basis of 11% mass of peels (PEIA) than to use the other peeling efficiency responses.

Verification experiment

Result of R^2 (Table 3) had indicated the desirability of basing the peeling efficiency index (PEI) of breadfruit on 11% mass of peel (PEIA) or % peeled. Result of ridge analysis (Table 4) had also indicated that maximum efficiency responses at these choices of peeling efficiency (PEIA and % peeled) for breadfruit were 0.1 to 1.7% lye concentration, 58.6^{o}C immersion temperature and 6.8 to 9.1 min immersion time.

Verification experiments were performed as these predicted conditions that were derived from ridge analysis or RSM to verify whether actual peeling could be achieved at the predicted range (i.e., to confirm the relationship between statistical prediction and actual experimental results). It was observed that actual peeling of breadfruit was achieved within the predicted range (1.6%, 80°C and 5 min) irrespective of the washing conditions that was employed; thus confirming the validity of the models. However, the use of abrasive washing made it possible to achieve lye-peeling of breadfruit 1.0%, 80°C and 5min of lye-concentration, immersion temperature and time respective

Table 1: Experimental Data on Lye-peeling of Breadfruit

Lye conc. (%) X_1	Temperature ^{0}C X_2	Time (min) X_3	PEIA*	PEIB	Actual peels removed (%)	Washing conditions AW	SW
0.5	70	5	0.35	0.62	5.56	Up	Up
0.5	90	5	0.34	0.60	5.41	Up	Up
0.5	90	10	0.57	0.96	8.60	Up	Up
1.0	80	5	0.21	0.36	3.27	P	Up
1.0	90	5	0.86	1.50	1.5	P	Up
1.0	90	10	0.80	1.40	12.6	Op	Up
1.0	85	10	0.89	1.32	14.0	Op	Up
1.5	80	5	1.83	3.19	28.8	Op	P
1.5	80	2.5	0.47	0.82	7.41	P	Up
1.5	90	2.5	0.49	0.85	7.74	P	Up
2.0	70	5	0.34	0.59	5.29	P	Up
2.0	80	5	0.88	1.54	13.8	P	P
2.0	80	5	0.96	1.68	15.1	P	P
2.0	90	2.5	1.27	1.39	8.30	P	p

*PEIA= Peeling efficiency based on 11% mass of peels (i.e. removal of pericarp with some mesocarp)
PEIB= Peeling efficiency based on 6% mass of peels (i.e. removal of pericarp alone)
(%) = Peeling efficiency based on actual mass of peels removed from fruit expressed as percentages
AW = Abrasive washing Soft washing P = Peeled
OP = Over peeled UP = under peeled

Table 2: Independent Variables and their Coded and Uncoded Values used for Optimization

Independent variables	Units	Symbol	Breadfruit		
Lye- concentration	%	X_1	- 1	0	+1
Immersion	^{O}C	X_2	05	1.25	2.0
Immersion time	Min	X_3	70	80	90
			2.5	6.25	10

Table 3: Regression coefficients of the predicted quadratic polynomial models for peeling efficiency of breadfruit

Coefficients	Breadfruit [a]PEI A	[b]PEI	% PEELED[c]
β_O (intercept)	1.166	2.010.	9.015
LINEAR			
β_1	0.175	0.327	2.878
β_2	0.270	0.532	3.693
β_3	0.233	0.188	3.358
QUADRATIC			
β_{11}	-0.335	-0.651	-6.167
β_{22}	-0.062	-0.135	-2.105
β_{33}	-0.789	-1.406	-11.089
CROSS PRODUCT			
β_{12}	0.346	0.480	3.281
β_{13}	-0.644	-0.833	-5.408
β_{23}	0.017	0.380	2.038
R^{2d}	0.56	0.52	0.51
C.V[e]	71.3	73.97	76.59

a….Peeling efficiency index (PEL A) based on 11% mass of peels

b….Peeling efficiency index (PEI B) based on 6% mass of peel for breadfruit

c…..Peeling efficiency based on actual mass of peels removed.

d…. Coefficient of multiple determinations e…. coefficient of variance

Table 4: Analysis of variance of the factors and the critical values obtained from ridge analysis of the response surface for peeling efficiency index

	Analy-sis	Of	Variance		bCritical Values	Critical Val-ues
Source	DF[a]	Sum of squares	Mean Squares	F-Values	Coded	Uncoded
PEIA						
NaOH conc.(%)	4	0.8518	0.2129	0.78	-584	0.062
Temperature (°C)	4	0.5640	0.1410	0.52	-2138	58.62
Time (min)	4	0.5703	0.1426	0.52	0.771	9.14
PEIB						
NaOH conc.(%)	4	1.8825	0.4706	0.60	2.7579	3.31851
Temperature (°C)	4	1.0163	0.2541	0.32	7.1863	151.80
Time (min)	4	1.7164	0.4291	0.54	0.2211	7.0791
% Peeled4						
NaOH 4conc.(%)	4	115.06	28.7670	0.43	0.5313	1.648
Temperature (°C)	4	58.993	14.7484	0.22	1.3627	93.627
Time (min)	4	137.99	34.4975	0.52	0.1471	6.8016

a…… Degree of freedom

b…… Critical value obtained from ridge analysis *…… not significant at 5%*

Table 5: Comparison of predicted and experimental values for response variables of breadfruit

Efficiency index	Eigen values	Stationary point	Predicted values[a]	Observed[b]
PEIA	0.0489, -0.273,-0.9654	Maximum	0.8286	0.923
PEIB	-004013,-0.5121-1.6399	Maximum	4.3927	1.1681
% peeled	-1.5247, -5.3045 -12.53	Maximum	22.5428	12.624

[a].. Predicted value using ridge analysis of response surface quadratic model
[b]…Mean standard deviation of triplicate determinations from different experiments

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