ISSN:
Print - 2277 - 0593
Online - 2315 - 7461

Journal of Natural Sciences, Engineering and Technology

OPTIMISATION OF LYE-PEELING OF CASSAVA (*Manihot esculenta* Crantz) USING RESPONSE SURFACE METHODOLOGY

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ABSTRACT

Cassava (Manihot esculenta Crantz) is an important root 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 cassava 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 cassava was peeled manually and some with hot lye solution. The effects of lye–concentration (4-12%), immersion temperature (75-100°C) and immersion time (2.5-10min.) on PEI (removal of 11-15% of root) obtained from 23 experimental points and three replication were analyzed with design expert and statistical analysis system software. Complete lye–peeling (removal of 11% of the root) was achieved at 9.7%, 86°C and 5min respectively which were within the critical optimization range (R^2=43%, CV=44% and root mean square error 0.3935) generated by the RSM.

Keyword: Cassava, Peeling, RSM ,Optimisation

INTRODUCTION

Cassava (*Manihot esculenta* Cranz) is one of the world's most important staple food crop in the tropic and a major source of energy for million of people in these regions. (Asiedu, Ng, Vuylsteke & Hahn 1992; Adeniji, Sanni, Barimalaa & Hart 2007) It is a major contributor to food security, employment and income of household producing the crop in Nigeria. (Ugwu, and Ukpabi 2002; Omodamiro *et al.,* 2007). Nigeria has been a major producer of the crop since 1989 (FAO, 1991; FAO STAT 2002; IITA 2005). It currently produces 34 million tons representing 42.5% and 21.3% of Africa and Worlds Production respectively (FAO 1994). The domestic and industrial utilization potentials of cassava have been further enhanced because it is a relatively cheap and readily available source of carbohydrate (Nwachukwu 2005; Nwozu, 2005). Virtually every aspects of cassava processing has been mechanized except peeling, which is still been manually done by and using knives

(Sreenapayanan, Rubikala & Jayas 1995). Manual peeling is wasteful, cumbersome, and inefficient. Effort is still being made to develop efficient peeling machine that is suitable for roots of all cultivars and size (The Bulletin 2005). Manual peeling, in spite of its inefficiency, cumbersomeness and wastefulness remain the only option available to processor. Hot lye-peeling, a process which combine the effectiveness of both chemical attack and thermal shock in loosening and softening the surface skin of plant materials (Talbert and Smith,1967, Sreeperayanan e*t al*., 1995) has been successfully applied to the peeling of some fruits.

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

MATERIALS AND METHODS

Cassava (*Manihot esculenta* Crantz) used for the study were obtained from the college farm of Michael Otedola College of Primary Education (MOCPED), Noforija, Epe. The variety used was the low cyanide clone. Twenty five roots of various sizes were hand peeled to so that the relationship between the peels and fruit can be established. Some of the root were peeled as done normally by women (involving the removal of the periderm with some of the cortex) while others were carefully peeled to remove as much as practicable only the thin periderm.

Experimental design

Lye peeling of cassava: Lye–peeling of cassava was carried out as described by Sreeparayanan, Rubikala and Jayas (1995) with minor modification. A themostatically 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 root to be treated were determined using Acculab electronic digital scale Model 2001. The fruit 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 . The peeling efficiency index (PEI) was calculated for varying level of treatments as done by Sreeparayanan, Rubikala and Jayas (1995).

$$PEI = \frac{Mu - Mp}{Mu - Mk}$$

Mu = Mass of root before peeling

Mp = Mass of peeled root

Mk = Mass of hand peeled root if only the thin corky periderm were removed.

Where MK = 0.89Mu for cassava root

Three levels/types of efficiency were evaluated: The first(PEIA) was based on the conventional peeling as done by women involving the removal of the corky periderm and the inner cortex, the second(PEIB) involved the removal of the thin periderm while in the third, process efficiency of the actual amount of peel removed (%peeled) removed from the root was determined . 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.

Optimisation using RSM

Optimization of lye peeling of cassava 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 twenty three experimental runs. Peeling efficiency index (PEIA & PEIB) and actual percentage of removed from the root was 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 was 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 coefficient obtained. The generalized second-order polynomial used in response surface analysis was.

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

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 cassava which depended on the independent variables were obtained using predictive equations of RSM. The experimental and predicted values were correlated to determine the extent of relationship while the adequacy of the model was evaluated using Root Mean Square Error (RMSE), R-square and Coefficient of variation.

RESULTS AND DISCUSSION

Results of manual peeling of cassava revealed that the thin periderm of cassava is about 11% of the root while the manual removal of the pericarp with part of the mesocarp would involve removing about 15% of the weight of cassava. It was necessary to identify the three levels in which the efficiency of the peeling system can be based in order to prevent over or under peeling. Over -peeling leads to wastages and resulted in reduction in unit yield per root. Over-peeling by chemical (lye) peeling process could occur as a result of prolonged or over-exposure of unpeeled roots to excessive high concentration of lye-solution. This has implications on processing cost, product quality 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, Rubikala and Jayas 1995). The effects of these parameters may either be independent or interactive. Approximate conditions for lye-peeling of cassava were determined by varying one factor at a time while keeping the others constant. Index of peeling efficiency was calculated for cassava based on the removal of either the periderm alone or with some of the cortex 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 (Table 1) was used to determine the lower, middle and upper design points for RSM in coded and natural (uncoded values) as provided in 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) was applied. The result of Analysis of variance (ANOVA) for the respective peeling efficiencies (responses) with their corresponding regression coefficients of multiple determinations (R^2) for the root generated by the software is shown in Table 3. Equation (1) was fitted to each of the dependent variable. 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 of R^2 (43.96 to 52.43) obtained for the models in Tables 3 gave a good ($25 < R^2 < 50\%$) explanation of the variance for the three peeling efficiency responses for the lye-peeling of cassava (Berry and Feldman, 1985). 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 cassava besides the three independent variables (lye-concentration, immersion temperature and time) used for the experiment.

Table 1: Experiment data on lye-peeling of Cassava

S/N	Lye conc. (%)	Temperature 0C	Time (min)	PEIA*	PEI B	Actual peels removed (%)	Washing conditions	
	X1	X2	X3				AW	SW
1	9	90	4	0.74	1.01	11.0	p	Up
2	9	83	6	0.37	0.51	5.6	p	Up
3	9	80	10	1.33	1.82	20.0	p	Up
4	6	90	5	0.56	0.76	8.3	P	Up
5	6	81	3	0.61	0.83	9.0	P	Up
6	6	78	10	0.24	0.33	3.6	p	Up
7	3	90	3	0.27	0.36	4.0	p	Up
8	3	94	7	0.66	0.90	10.0	p	P
9	3	94	10	1.05	1.43	15.7	OP	p
10	12	92	4	0.98	1.33	14.6	OP	p
11	12	88	7	0.38	0.51	5.67	P	Up
12	9	85	4	0.72	0.99	10.9	P	UP
13	12	88	7	0.23	0.32	3.5	P	UP
14	9	78	8	0.78	1.07	11.8	P	p
15	9	85	8	1.03	1.39	15.4	P	UP
16	12	88	7	0.80	1.09	12.0	P	UP
17	12	90	5	0.63	0.91	10.0	P	UP
18	10	80	5	0.80	1.09	12.0	P	UP
19	10	90	2.5	0.80	1.09	12.0	P	P
20	4	75	5	0.19	0.26	2.9	P	UP
21	4	100	5	0.78	1.07	11.8	P	UP
22	4	85	10	0.10	0.91	1.40	P	UP
23	4	100	7	0.48	0.61	7.2	P	UP

*PEIA= Peeling efficiency based on 15% mass of peels (i.e. removal of periderm with cortex)
PEIB= Peeling efficiency based on 11 mass of peels (i.e. removal of some periderm with some cortex)
(%) = Peeling efficiency based on actual mass of peels removed from root 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	Cassava		
Lye- concentration	%	X1	-1	0	+1
Immersion	OC	X2	3	7.5	12
Immersion time	Min	X3	75	87.5	100
			2.5	6.25	10

These factors may include; variation in agronomic characteristics within and among cultivars, strength of adhesion of periderm to the cortex and the cortex to the pulp (starchy flesh of cassava). Contrary to the conventional way of peeling by women in which about 15% mass of the root is removed as peels, values of R^2 in Table 3 also indicated that calculation of peeling efficiency index of cassava is best explained when it is based on the removal of the thin periderm with a little bits of the cortex (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 (Tables 3). ANOVA of the regression parameters of the predicted response surface models for peeling efficiency of the root indicated that 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 were 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 variable is illustrated in the contour plots of the response surfaces concreted by the models for the entire peeling efficiencies. The plot depicts the response surfaces of the effect of two variables on the various peeling efficiency index (PEI) for cassava, while keeping the third variable constant. Since analysis of the surface response revealed that the stationary points for Peeling Efficiency indices were a saddles (Table 5); a 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 cassava suggest the desirability of using lower concentration of lye (9.01%), temperature (92.3°C) immersion time (5.76 min) to achieve the peeling of the root on the basis of 11% mass of peels (PEIB) than to use the other peeling efficiency responses.

Verification experiment

Results (0.39,0.43 and 0.42) and (0.3225, 0.3935 and 4.6621) for R^2 and root mean square error respectively (Table 3) indicated the inadequacy of the model but suggested the desirability of basing the peeling efficiency index (PEI) of cassava on 11% mass of peel (PEIB) or % peeled. Result of ridge analysis (Table 4) had also indicated that maximum efficiency responses at these (PEIB and % peeled) of peeling efficiency for cassava were 9.01 to 9.81% lye concentrations, 91.46°C to 92.34 immersion temperature and 5.72 to 5.76 min immersion time.

Verification experiments were performed as these predicted conditions that were derived from ridge analysis of 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 cassava was achieved within the predicted range (9.7%, 86°C & 5 min) irrespective of the washing conditions that was employed; thus confirming the fairness of the models.

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

Coefficient	aPEI A	bPEIB	% PEELEDc
BO (intercept)	0.509	0.773	7.524
LINEAR			
B1	0.313	0.305	4.718
B2	0.124	0.122	1.747
B3	0.028	0.087	0.364
QUADRATIC			
B11	-0.191	-0.219	-2.706
B22	0.185	0.067	2.840
B33	0.388	0.476	5.702
CROSS PRODUCT			
B12	-0.391	-0.442	-5.979
B13	0029	-0.104	0.328
B23	0.236	0.190	3.386
R2d	0.39	0.43	0.42
C.Ve	52.43	43.96	49.11
MSE	0.3225	0.3935	4.6621

a….Peeling efficiency index (PEL A) based on 15% mass of peels
b….Peeling efficiency index (PEI B) based on 11% 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

	Analysis	Of	Variance		[b]Critical Values	Critical Values
Source	DF[a]	Sum of squares	Mean Squares	F-Values	Coded	Uncoded
PEIA						
NaOH conc(%)	4	0.6207	0.1552	1.49	0.6865	10.59
Temperature (° C)	4	0.5943	0.1486	1.43	-0.6154	79.80
Time (min)	4	0.3441	0.0860	0.83	-0.0585	6.03
PEIB						
NaOH conc(%)	4	0.9625	0.2419	1.56*	0.3357	9.01
Temperature (° C)	4	0.7036	0.1759	1.14*	0.3877	92.34
Time (min)	4	0.7562	0.1891	1.22	-0.1321	5.76
% Peeled4						
NaOH conc (%)	4	183.33	45.832	2.11	0.5133	9.81
Temperature (° C)	4	141.83	35.457	1.63	0.3167	91.46
Time (min)	4	64.62	16.16	0.74*	-0.1407	5.72

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 cassava

Efficiency index	Eigen values	Stationary point	Predicted val-uesa	Observedb
PEIA	0.4761, 0.1454, -0.2938	Saddle	0.5566	0.463
PEIB	0.5116, 0.1507, -0.3396	Saddle	0.8418	1.15
% peeled	6.648, 3.271, -4.082	Saddle	9.035	11.46

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

ACKNOWLEDGEMENTS
The authors appreciate the late Dr. J.O. Aina for his input into the compilation of the report. Prof. C. T. Akanbi edited the manuscript while Mrs. Bossey of the International Institute of Tropical Agriculture (IITA) Ibadan provided relevant professional advice.

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(Manuscript received: 25th October, 2010; accepted: 25th May, 2012).