Effect of processing parameters on the proximate composition and sensory characteristics of breadfruit 'elubo'

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Abstract

Introduction. Breadfruit is an underutilized fruit and its utilization as food can be improved by converting it to indigenous foodstuff like elubo that has an established processing technology.

Materials and methods. The breadfruit were washed in clean water to remove adhering latex and dirt, peeled manually and chopped. The chopped breadfruit was parboiled in water at 30, 50 and 60 ºC for 90, 120 and 150 min. The parboiled breadfruit was steeped for 6, 12 and 18 hrs. The steeped breadfruit was drained, dried in the cabinet dryer at 60 ºC for 2 days and milled into flour (elubo) while the breadfruit paste (Amala) produced from the breadfruit flour (elubo) was subjected to sensory analysis.

Results and discussion. The moisture content of breadfruit elubo varied between 9.07 and 12.20%. The moisture content of a food sample reflects the amount of solid matter in the sample. The high ash content of breadfruit elubo (BE) is an indicative of being a good source of mineral for the flour. The values of the ash content varied between 2.00 and 2.90%. The fibre content of the breadfruit elubo varied between 2.86 to 3.60%. Parboiling temperature, parboiling time and steeping time does not significantly ($p>0.05$) affects the fibre content of the breadfruit elubo. The protein content of breadfruit elubo varied between 3.80 and 5.42%. The protein content of the breadfruit elubo decrease irrespectively of parboiling temperature, parboiling time and steeping time. The carbohydrate content for the breadfruit elubo varied from 73.67 to 78.33%. High carbohydrate content in food implies the food is a high in calorie. The carbohydrate content of the breadfruit elubo is not significantly ($p>0.05$) affected by the parboiling temperature, parboiling time and steeping time. The Sensory parameters of breadfruit paste prepared from breadfruit elubo were significantly ($p<0.05$) different from paste of yam elubo (t-value=2.523, degree of freedom=14, p-value=0.01, one tailed).

Conclusion. The result revealed that breadfruit elubo has high fibre and carbohydrate content which implies that breadfruit elubo can serves as high energy food.

Introduction

Elubo is obtained from the conversion of yam tubers into fine flour and the unit operations involved include harvesting, sorting, peeling, slicing, blanching, drying and milling. The resulting product is a white to cream flour, which can be stored for months [1]. The quality of *elubo* is dependent on the process parameters adopted for its production. Elubo can be processed into a thick consistency food popularly called “Amala” which is prepared by reconstituting (cooking and stirring with boiling water) fermented or unfermented yam flour (*elubo*) to achieve starch gelatinization [2, 3, 4]. Amala primarily contains carbohydrates and as a result, it does not provide adequate nutrition. Amala prepared from yam flour contribute more than 200 dietary calories per capita daily for more than 150 million people in West Africa and serve as an important source of income [5].

In Nigeria, yam is the second most important source of carbohydrate after cassava [6].Nigeria is the highest producer of yam in the World [7] producing about 38 million tonnes per annum [8] which is well over half of the world’s yams [9]. It is a seasonal crop that has competing domestic culinary uses and therefore attracts relatively higher prices during off-season period. One way to minimize this higher price during off-season period is the use of under utilized crops in the production of *elubo,* for the purpose of providing cheap and unrestricted access to this staple food.

Breadfruit (*Artocarpus altilis*) is a tropical fruit native to Malaysia and countries of the South Pacific and the Caribbean and it is an important food in these areas [10]. Breadfruits are found from sea level to about 1550 m elevation. It has been reported that breadfruit yields in terms of food are superior to other starchy staples such as cassava and yam [11]. The mature fruit is a good source of carbohydrate (84%) with starch constituting more than 60% of the total carbohydrate [12].The bread fruit pulps are made into various dishes; it can be processed into flour and used in bread and biscuit making [13]. Breadfruit has also been reported to be rich in fat, ash, fibre and protein [14]. Despite the importance of this fruit, its production is faced with several problems including short shelf life and poor yield due to diseases [15]. The fruits are utilized in Nigeria within 5days of harvesting because of their short shelf lives. One way to minimize post-harvest losses and increase the utilization of breadfruit is by processing into flour, which is a more stable intermediate product. Its utilization can be enhanced by converting it to elubo, which is the starting material for processing through reconstitution with hot water to form a paste or dough. In Nigeria, breadfruit is regarded as the poor man’s substitute for yam (*D. Rotundata or D. Alata*), because it can be used in the preparation of several foodsfor which yam was a traditional crop of choice. It also costs less than one third the price of procuring yam [16].

Extensive research from yam and cassava for “*elubo*” have been reported by several authors [17 3, 18, 4, 19]. Information is however scanty on the use of breadfruit for “elubo” production. Also, if the existing technology for the production of *yam* elubo (YE) is to be adapted for breadfruit elubo (BE), it would be necessary to explore the effect of critical processing parameters on the some quality attributes of the elubo and the paste made from its reconstitution.This study therefore investigated the optimum processing conditions required for the production of breadfruit elubo using response surface methodology (RSM), and the sensory acceptability of the breadfruit elubo (BE) paste (Amala)compared to the one made from yam elubo (YE).

Materials and methods

Materials

Freshly harvested matured breadfruits were purchased from a local market in Idiroko, Ogun State, Nigeria. Equipment used include cabinet dryer, laboratory milling machine, mechanical sieve, digital weighing balance, stirrer, knife, bucket and stainless steel perforated tray, stainless steel pot, electric cooker were obtained from the Food processing Laboratory of Department of Food Science and Technology, Federal University of Agriculture, Abeokuta, Nigeria.

Methods

Production of breadfruit flour ("elubo'')

The method described by [4] for the production of yam flour *elubo* was adopted, with variation in parboiling time, parboiling temperature and steeping time. The fruits were washed in clean water to remove adhering latex and dirt, peeled manually and chopped. The chopped breadfruit was parboiled in water at 30, 50 and 60 ºC for 90, 120 and 150min. The parboiled breadfruit was steeped for 6, 12 and 18hrs. The steeped breadfruit was drained and dried in the cabinet dryer at 60 ºC for 2 days. The dried breadfruit was milled using laboratory milling machine (Fritsch, D-55743, Idar-oberstein-Germany).The milled sample was sieved using 250µm screen and stored in air-tight polyethylene bags.

Preparation of Breadfruit Paste (Amala)

"Amala" was prepared from breadfruit flour using the method described by [20]. Breadfruit paste (Amala) was prepared by adding 200g of breadfruit flour (elubo) to 200 ml of boiling water in a stainless pot. The paste was stirred manually with a wooden spoon over a low flame until a smooth consistency was attained.

Experimental design and process optimization

Box-Behnken design [21] was used for the experiment. The three independent variables used for the process optimisation were parboiling temperature (X1), parboiling time (*X*2) and steeping time (*X*3). Design Expert software version 7.00 (Stat Ease Inc., Minneapolis, MN, USA). The three levels established for each of the independent variables based on a series of preliminary experiments were coded as −1, 0, and 1 with their actual values in Table 1. The design consists of 17 experimental runs to which the dependent variables (Responses) were fitted after the laboratory experiments. The measured responses were the proximate composition (Moisture, ash, protein, fibre and carbohydrate)

Experimental data were fitted to a second order polynomial model and regression co-efficient the various responses were obtained. The generalized second-order polynomial used in response surface analysis was.

Where Y is the response, β_0 is the intercept, where β_1, β_2 and β_3 are linear, quadratic and interaction coefficients respectively,x_1, x_2, x_3 are the various independent variables and € is the error. The statistical significance of the terms in the regression equations was examined by analysis of variance (ANOVA) for each of the responses. The design expert software was used to generate response surfaces models graphs showing the relationship between the independent variable and the responses while holding a variable constant. The parameters were optimized by using the numerical method of RSM based on desirability concept to obtain range of optimised solutions which were used for the verification experiments to determine the validity of the model.

Table 1

The coded values for the independent variables

Processing Variables	Variable	-1	0	+1
Parboiling temperature (ºC)	(X1)	45	30	60
Parboiling time (min)	(X2)	120	90	150
Steeping time (h)	(X3)	6	12	18

Table 2

Response surface analysis different experimental runs

Experimental Runs	Parboiling temperature (X1) ºC	Parboiling time (X2), min	Steeping time (X3), h
1	60	150	12
2	45	90	6
3	60	120	6
4	30	150	12
5	45	90	18
6	45	120	6
7	30	120	6
8	45	120	12
9	30	90	12
10	45	150	18
11	45	120	12
12	30	120	18
13	60	12	18
14	45	120	12
15	45	150	6
16	45	120	12
17	60	90	12

Determination of proximate composition of breadfruit elubo

Moisture content and crude fibre content of breadfruit elubo were determined by AOAC method. Crude protein was determined by the standard khjeldahl method, AOAC method. Fat content of the samples were measured using Soxhlet extraction method according to AOAC method. Ash content was determined by igniting 5g of sample in a furnace for 4hours at 550 ºC until light grey ash colour and constant weight was achieved by [22].Carbohydrate content were determined by difference method. The analyses were carried out in triplicates.

Sensory evaluation of breadfruit paste (Amala)

Simple paired comparison was used to compare the difference between *amala* made from breadfruit elubo (BE) and yam elubo (YE). Thirty untrained panelists were asked to rate the colour, mouldability, taste, aroma, smoothness, elasticity, stickiness and hardness of the respective *amala* samples

Statistical analysis

Apart from the statistical method used as an integral part of the RSM. Independent t-test was also used to evaluate the result of the sensory analysis conducted on the amala.

Results and discussion

Effect of process variables on moisture content of breadfruit elubo (BE)

In Table 3, the regression coefficients of the quadratic models for the response variable, along with the corresponding p-value are presented. Coefficient values less than 0.05 indicated that the model was significant. In this case, the linear coefficient of parboiling temperature (X_1), steeping time (X_3) had a significant impact on the moisture content. The quadratic effects of the parboiling temperature, time and steeping time had negative significant ($p<0.05$) effect on the moisture content. However, the interactive effects of all the process variables except for parboiling temperature and steeping time (X_1X_3) had no significant ($p>0.05$) impact on the moisture content. Moisture content of breadfruit elubo varied between 9.07 and 12.20%. The moisture content of a food sample reflects the amount of solid matter in the sample. The higher the moisture content, the higher the rate of spoilage. Adebowale *et al.,* [23] stated that moisture content is a measure of the water content and also an indicator of shelf stability. Figure 1 shows the effect of the process variables on the moisture content of breadfruit elubo. From the figure, increase in parboiling temperature (PT) and parboiling time (Pt) brought about an increase in moisture content at constant steeping time (ST). A similar trend was observed when increasing ST and PT using a constant level of Pt. From the results, at a higher ST and Pt, there was an increase in moisture content of the breadfruit elubo. This may be as a result of decrease in porosity which will lead to an increase in moisture content. The higher moisture content observed for breadfruit elubo may be due to the thick slices (50–60 mm) used. Babajide *et al.,* [4] earlier reported that thick slices (30–50 mm) had significant higher moisture content than slices less than 30mm. Increase in moisture content can enhance microbial growth which leads to deterioration in foods. FAO [6] recommended a safe level of 12 to 14% moisture content for flour or powdered food

Table 3

Regression Coefficients for moisture content of BE

Factors	**Coefficient Estimate**	**Standard error**	**p-values**
Constant	12.16	0.078	< 0.0001
Parboiling Temp(x_1)	0.096*	0.061	0.1605
Parboiling Time(x_2)	0.14	0.061	0.0547
Steeping Time(x_3)	1.37*	0.061	< 0.0001
P Temp·P Time(x_1x_2)	0.013	0.087	0.8894
P Temp·S Time(x_1x_3)	-0.25*	0.087	0.0236
P Time·S Time(x_2x_3)	0.030	0.087	0.7395
P Temp·P Temp(x_1^2)	-0.81*	0.085	< 0.0001
P Time·P Time(x_2^2)	-1.03*	0.085	< 0.0001
S Time·S Time(x_3^2)	-0.52*	0.085	0.0004

*Significant at $p<0.05$, P=parboiling, x_1=parboiling temperature, x_2=parboiling time and x_3=steeping time

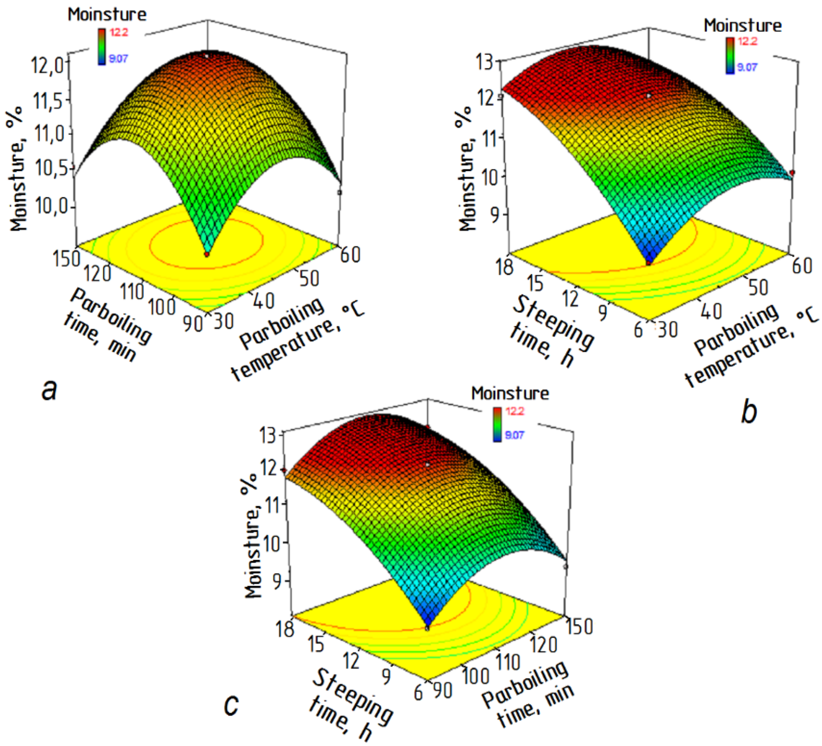

Figure 1. Response surface plot for Moisture content (%) of BE
(*a* – steeping time = 12; *b* – parboiling time – 120; *c* – parboiling temperature = 45)

Effect of process variable on protein content of breadfruit elubo (BE)

An acceptable second-order polynomial regression equation (2) as a function of parboiling temperature, time and steeping time was generated for the protein content after the removal of non-significant terms as follows:

$$Y = 4.41 + 0.04X_2 - 0.77X_3 + 0.36X_1^2 - 0.36X_2^2 - 0.19X_3^2 \quad (2)$$

where X_1, X_2 and X_3 represent coded values of parboiling temperature and steeping time, respectively and Y is the response variable (BE protein content).

In table 4, the regression coefficients of the quadratic models for the response variable, along with the corresponding p-value were presented. Coefficient values less than 0.05 indicate that the model is significant. In this case, the linear coefficient of parboiling time (X_2), steeping time (X_3) had a great impact on the protein content. The quadratic effects of the parboiling temperature, time and steeping time had negative significant ($p<0.05$) effect on the protein content. However, the interactive effects of all the process variables had no significant ($p>0.05$) impact on the protein content. The protein content of the breadfruit *elubo* varied between 3.80 and 5.42%, within the experimental conditions. The response surface plots for protein content at different experimental conditions are presented in Figure 2. From the figures, it can be observed that increasing PT and Pt at constant ST decreases protein content at constant Pt increase in ST and PT results in low protein content. Also, increasing ST and Pt when PT is constant lowers the protein content of the breadfruit *elubo*.

The effect of parboiling and steeping on the protein content of the breadfruit *elubo* probably maybe due to the denaturation of protein caused by the effect of heat on the breadfruit slices during parboiling. This is an indication that protein content of breadfruit flour can be influenced by using appropriate set of processing parameters. This shows that protein content will decrease irrespectively of parboiling temperature, parboiling time and steeping time [27].

Table 4

Regression coefficient for protein content of BE

Factors	Coefficient Estimate	Standard error	p-values
Constant	4.41	0.018	< 0.0001
Parboiling Temp(x_1)	0.02	0.014	0.3186
Parboiling Time(x_2)	0.04*	0.014	0.0313
Steeping Time(x_3)	-0.77*	0.014	< 0.0001
P Temp·P Time(x_1x_2)	0.00	0.020	1.0000
P Temp·S Time(x_1x_3)	-0.02	0.020	0.3451
P Time·S Time(x_2x_3)	-0.03	0.020	0.1727
P Temp·P Temp(x_1^2)	0.36*	0.019	< 0.0001
P Time·P Time(x_2^2)	0.36*	0.019	< 0.0001
S Time·S Time(x_3^2)	-0.19*	0.019	< 0.0001

*Significant at $p<0.05$, P=parboiling, x_1=parboiling temperature, x_2=parboiling time and x_3=steeping time

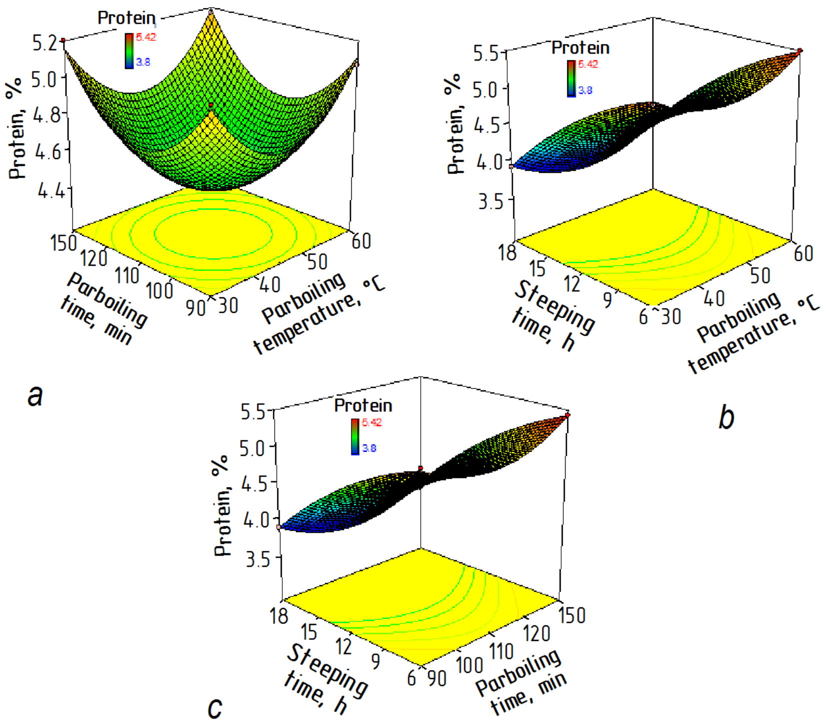

Figure 2. Response surface plot for Protein (%) content of BE
(*a* – steeping time = 12; *b* – parboiling time – 120; *c* – parboiling temperature = 45)

Effect of process variable on ash content of breadfruit elubo (BE)

In table 5, the regression coefficients of the quadratic models for the response variable, along with the corresponding p-value were presented. Coefficient values less than 0.05 indicate that the model is significant. The quadratic, interactive and the linear effect has no significant effect on the ash content. The values of ash content for breadfruit *elubo* varied between 2.00 and 2.92%. Ash content is a reflection of mineral status, even though contamination can indicate a high concentration in a sample. The ash content of breadfruit elubo (BE) was higher than 2.07% reported for sweet potatoes elubo by Fetuga *et al.*, [20] and 2.03% reported by Babajide *et al.,* [24] for yam elubo. The high ash content of the flour is indicative of being a good source of minerals. Breadfruit *elubo* would therefore, be a better source of minerals than sweet potatoes and yam elubo. Figure 3 shows the effect of the process variable on the ash content of breadfruit elubo. From the figure, It was observed that increasing PT and decrease in Pt when ST is constant increases ash content while decreasing ST and increasing PT at constant Pt increases ash content. At a constant PT, increase in ST and Pt decreased the ash content of the breadfruit *elubo* .This maybe because of the leaching of soluble minerals from the breadfruit [4]

Table 5

Regression coefficient for ash content of BE

Factors	Coefficient Estimate	Standard error	p-values
Constant	3.09	0.081	0.2391
Parboiling Temp(x_1)	-0.07	0.064	0.8072
Parboiling Time(x_2)	-0.01	0.064	0.3275
Steeping Time(x_3)	0.11	0.064	0.1194
P Temp·P Time(x_1x_2)	0.04	0.064	0.9153
P Temp·S Time(x_1x_3)	-0.13	0.091	0.6916
P Time·S Time(x_2x_3)	$-2.5\cdot10^{-3}$	0.091	0.0496
P Temp·P Temp(x_1^2)	0.11	0.091	0.1826
P Time·P Time(x_2^2)	-0.14	0.088	0.1658
S Time·S Time(x_3^2)	-0.06	0.088	0.3146

*Significant at $p<0.05$, P=parboiling, S=steeping, x_1=parboiling temperature, x_2=parboiling time and x_3=steeping time

Effect of process variable on crude fibre content of breadfruit elubo (BE)

The quadratic effect linear effect and the interaction effect of the parboiling temperature, parboiling time and steeping time does not significantly ($p>0.05$) affects the fibre content of the BE. The fibre content of breadfruit *elubo* varied between 2.86 to 3.60%. The fibre content of breadfruit *elubo* was higher than yam elubo (1.65%) reported by Babajide *et al.,* [24], but lower than 3.2% reported by Fetuga *et al.,* [20] for sweet potato elubo. Fibre is reported to plays a significant role in the prevention of several diseases such as; cardiovascular diseases, diverticulosis, constipation, irritable colon, cancer and diabetes [25, 26]. Figure 4 shows the response surface plots for the crude fibre at different experimental condition. From the figure, it was observed that increasing PT and Pt when steeping time is constant decreases fibre content while increasing ST and PT at constant Pt increases fibre content. At a constant PT, increase in ST and Pt increases the fibre content of the breadfruit *elubo*. It was shown that parboiling temperature, parboiling time and steeping time does not significantly ($p>0.05$) affects fibre content of the breadfruit, this was in accordance with Adejumo *et al.,* [27].

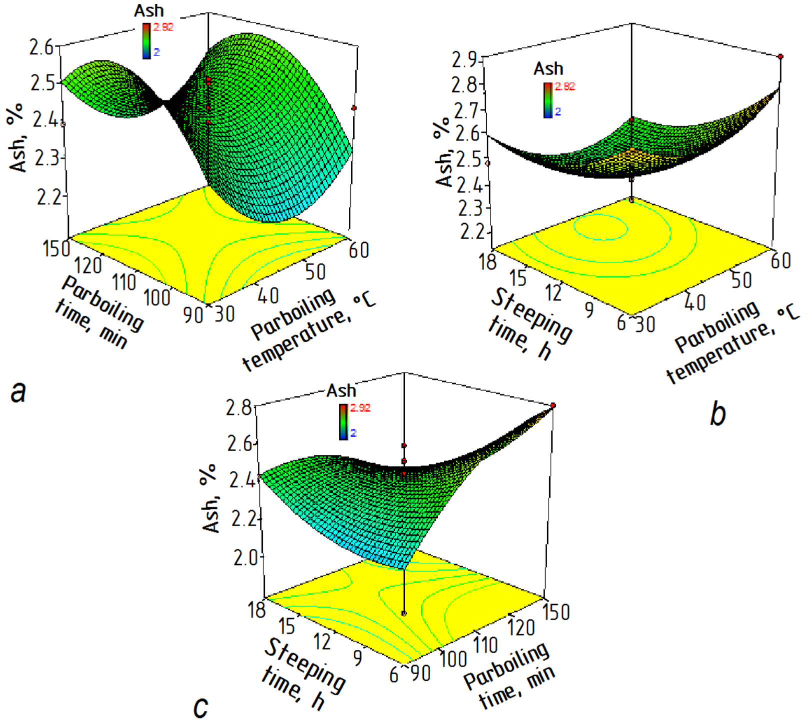

Figure 3. Response surface plot for Ash (%) content of BE
(*a* – steeping time = 12; *b* – parboiling time – 120; *c* – parboiling temperature = 45)

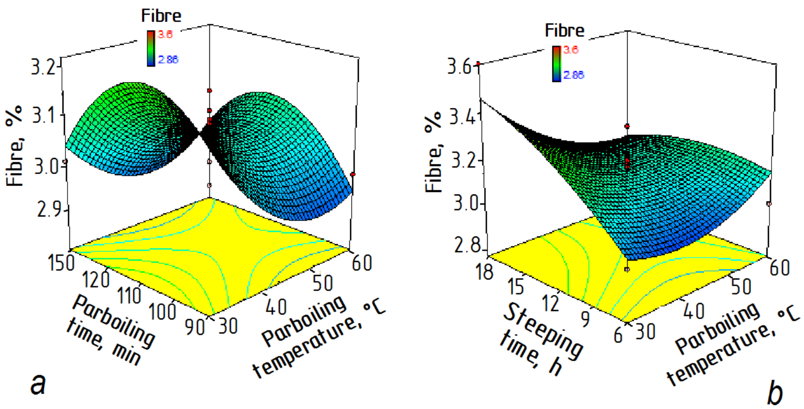

Figure 4. Response surface plot for Fibre (%) content of BE
(*a* – steeping time = 12; *b* – parboiling time – 120)

Effect of process variable on carbohydrate content of breadfruit elubo (BE)

The main effect and the interaction effect of the parboiling temperature, parboiling time and steeping time does not significantly (p>0.05) affects the carbohydrate content of the BE. The carbohydrate content for the *breadfruit elubo* ranged from 73.67 to 78.33%. High carbohydrate content in food implies the food is a high in calorie. The carbohydrate of the breadfruit *elubo* in this research is lower than Fetuga *et al.,* [20], which reported a value of 87.68% for sweet potatoes *elubo*. The response surface plots for carbohydrate content at different experimental conditions are presented in Figure 5. It was observed that increasing PT and Pt at constant ST resulted in decrease in carbohydrate content increasing ST and PT at constant Pt decreases carbohydrate content. At a constant PT, increase in ST and Pt decreases the carbohydrate content of the breadfruit *elubo*. The carbohydrate content of the breadfruit *elubo* is not significantly (p>0.05) affected by the parboiling temperature, parboiling time and steeping time. The result obtained in this work is similar to the findings of Akissoe *et al.,* [28], which reported that different cultivars have varied carbohydrate content of yam *elubo*.

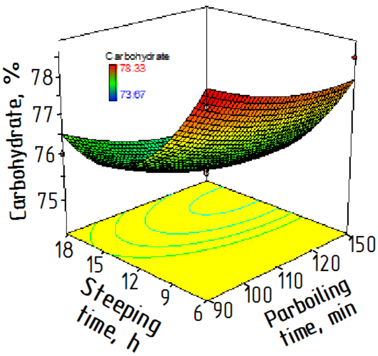

Figure 5. Response surface plot for Carbohydrate (%) content of BE (parboiling temperature = 45)

Comparison of amala made from breadfruit elubo and yam elubo

The mean difference between conditions was 5.00 and the 95% confidence interval for the estimated population is between 0.68 and 6.57. The independent t-test showed that the difference between conditions were significantly different (t-value=2.523, degree of freedom=14, p-value=0.01, one tailed). This implies that the sensory attribute of cooked paste prepared from breadfruit elubo were different from paste of yam flour. This could be due to the familiarity of the panel to traditionally processed yam paste (amala) which is free from odour, stickier, and darker in colour than breadfruit amala.

Conclusion

It can be inferred from this study that breadfruit elubo can be developed into a cooked paste *(Amala)*. Response surface methodology was successfully utilized for optimization of the proximate composition of breadfruit *elubo*. However, the breadfruit elubo has high fibre and carbohydrate content which implies that breadfruit elubo can serve as high energy food and can be used to improve the health benefit of the consumer.

Reference

1. Adedeji K.K. (2010), *Physical, functional and sensory properties of yam flour 'elubo' obtained from Kuto- market, Abeokuta. B.Sc Thesis*, Federal University of Agriculture, Abeokuta.
2. Akingbala J.O., Oguntimien T.B, Sobande A.O. (1995), Physio-chemical properties and acceptability of yam flour substituted with soy flour, *Plant Food for Human Nutrition*, 48, pp. 73–80.
3. Akissoe N., Hounhouigan D.J., Bricas N., Vervier P., Nago C.M, Olorunda A. (2001), Physical, chemical and sensory evaluation of dried yam (*Dioscorea cayenensis rotundata*) tubers, flour, and amala a flour-derived product, *Tropical Science*, 4, pp. 151–155.
4. Babajide J. M., Henshaw F.O, Oyewole O.B. (2006), Effect of Processing Variables on the Quality of Traditional Dry Yam Slices, *European Journal of Science*, 14, pp. 102–113.
5. Babaleye T. (2003), *Raising the status of the yam, a major food crop in West Africa*, Anbbia supplement issue/edition, No. 463.
6. F.A.O. (1994), *Tropical root and tuber crops. In: Production, perspectives and future prospects. FAO plant production and protection paper,* 126, Rome, Italy.
7. F.A.O. (2008), *Food and agriculture organisation. Action programme for the prevention of food losses, improving post-harvest handling, storage and processing of root and tuber crops*, Rome, Italy.
8. F.A.O. (2012), *Production yearbook, vol. 55, collection FAO statistics, No. 170. FAO,* Rome, Italy.
9. Onwueme I.C. (1978), The tropical root crops, John Wiley and Sons, New York.
10. Taylor M.B, Tuia V.S. (2007), Breadfruit in the pacific region, *Acta Horticulturae,* 757, pp. 43–50.
11. Singh H. (2009), *Tapping into breadfruit`s bounty,* Available at: http://www.universityaffairs.ca/tapping-into-breadfruits_bounty.aspx
12. Oladunjoye I.O., Ologhobo A.D, Olaniyi C.O. (2010), Nutrient composition, energy value and residual anti-nutritional factors in differently processed breadfruit (*Artocarpus altilis*) meal, *African Journal of Biotechnology,* 9(27), pp. 4259–4263.
13. Amusa N.A., Kehinde I.A, Ashaye O.A. (2002), Bio-deterioration of breadfruit (*Artocarpus communis)* in storage and its effects on the nutrient composition, *African Journal of Biotechnology,* 1(2), pp. 57–60.
14. Ragone D. (1997), *Breadfruit (Artocarpus altilis): Promoting the conservation and use of underutilized and neglected crops*, Institute of plant genetics and crop plant research, Gatersleben International Plant Genetic Resources Institute, Rome.
15. Olaoye O.A., Onilude A.A, Oladoye C.O. (2007), Breadfruit flour in biscuit making: Effects on product quality, African Journal of Food Science, pp. 20–23.
16. Olutayo M.M., John O. A., Gail S.O., Baccus H.T, Sydney T.O. (2003), Evaluation of breadfruit (*Artocarpus communis*) in traditional stiff porridge foods, *Food, Agriculture and Environment,* 1(2), pp. 54–59.
17. Oyewole O.B, Odunfa S.A. (1988), Microbiological Studies on Cassava Fermentation for Lafun Production, *Food Microbiology*, 5, pp.125–133.
18. Mestres C., Dorthe S., Akissoe N, Hounhouigan J.D. (2004), Prediction of sensorial properties (colour and taste) of amala: A paste from yam chips flour of

West Africa, through flour biochemical properties", *Plant Foods Human Nutrition*, 59, pp. 93–99.
19. Nwabueze T.U, Odunsi F.O. (2007), Optimization of process conditions for cassava (*Manihot esculenta)* lafun production, *African Journal of Biotechnology*, 6, pp. 603–611.
20. Fetuga G.O., Tomlins K., Bechoff A., Henshaw F.O., Idowu M.A, Westby A. (2014), Effect of variety and processing method on functional properties of traditional sweet potato flour (elubo) and sensory acceptability of cooked paste (amala), *Food Science and Nutrition,* 2(6), pp. 682–691.
21. Box G.E.P, Behnken D.W. (1960), Some New Three Level Designs for the Study of Quantitative Variables, *Technometrics,* 2, pp. 455–462.
22. AOAC. (2000), *Official methods of analysis. 17th edn.,* The Association of Official Analytical Chemists, Virginia.
23. Adebowale A.A., Sanni L.O, Awonorin S. O. (2005), Effects of texture modifiers on the physicochemical and sensory properties of dried fufu, *International Journal of Food Science and Technology*, 11(5), pp. 373–382.
24. Babajide J.M., Oyewole O.B, Obadina A.O. (2005), An assessment of the microbiological safety of dry yam (gbodo) processed in south west Nigeria, *African Journal of Biotechnology*, 5(2), pp. 157–161.
25. Slavin J.L. (2005), Dietary fibre and body weight, *Journal of Nutrition*, 21, pp. 411–418.
26. Elleuch M., Bedigian D., Roiseux O., Besbes S., Blecker C., Attia H. (2011), Dietary fibre and fibre-rich by-Products of food processing: characterization, technological functionality and commercial applications: A Review, *Food Chemistry*, 124, pp. 411–421.
27. Adejumo B.A., Okundare R.O., Afolayan O.I, Balogun S.A. (2013), Quality attributes of yam flour (elubo) as affected by blanching water temperature and soaking time, *The International Journal of Engineering and Science,* 2(01), pp. 216–221.
28. Akissoe W.H., Hounhouigan J.D., Mestres C., Nago M. (2003), How blanching and drying affects the colour and functional characteristics of yam (D. *cayenesis rotundata*) Flours, *Food Chemistry*, 82, pp. 257–264.