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Process optimization of deep-fat frying variables and effects on some quality characteristics of *akara* Ogbomoso snacks produced from cowpea

[1,*]Adeyanju, J.A., [1]Abioye, A.O., [2]Adekunle, A.A., [2]Ibrahim, T.H., [1]Oloyede, A.A. and [1]Akinwusi, D.E.

[1]*Department of Food Engineering, Ladoke Akintola University of Technology, P. M. B. 4000, Ogbomoso, Oyo State, Nigeria*

[2]*Bioresources Development Centre, National Biotechnology Development Agency, Ogbomoso, Nigeria*

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Abstract

This study investigated the effect of process variables of frying temperature (150-190°C) and time (11-19 mins) on the moisture content, oil content, colour difference, texture, and shrinkage of *akara* Ogbomoso using the Central Composite Design of the Response Surface Methodology (RSM). Data were analyzed by analysis of variance and regression analysis. The results obtained were moisture content (7.41-7.89%), fat content (12.80–13.79%), colour difference (38.63–48.80), breaking force (47.66–151.5 N) and shrinkage (7.00–8.33 abs). The combination of 170°C frying temperature and 11 mins frying time was found to be the most suitable frying condition. The optimum conditions gave 7.52% moisture content, 12.91% oil content, 38.63 change in colour, 90.4 N breaking force and 7.07 shrinkage. A desirability of 0.78 was obtained for optimization. All dependent variables were significantly influenced by frying conditions at $p<0.05$. The generated models of the coefficients of determination (R^2) ranged from 0.90 to 0.98. The high R^2 indicated that the variables were adequately fitted to the regression equation and could precisely predict the quality characteristics of *akara* Ogbomoso. This study has provided helpful information on improving the frying conditions of *akara* Ogbomoso.

1. Introduction

The increasing popularity of traditionally made snacks has called for studies to enhance their quality. In Nigeria, a few of these traditional snacks; *kokoro* (corn cake), *aadun* (maize pudding), *akara* Ogbomoso (local beans cake), and *donkwa* (maize-peanut ball) among others. Understanding the conditions of the production process and optimizations is necessary to improve these snacks to become world-class foods. For example, *akara* Ogbomoso - a low-fat, healthy snack food that satisfies the taste buds is a popular street snack in Ogbomoso town (Falade *et al*., 2003). Today, people worldwide rely more on the consumption of 'ready-to-eat' snacks which either serve as an appetizer or as a snack food. This trend has made fried food a significant investment in the food industry. In Nigeria, a large number of different locally-produced snacks are commercially available at eateries, fast food outfits and confectioneries and several others along the streets and various strategic locations such as the local marketplaces, industrial sites, motor packs, railway stations, schools, canteens, office centres and the likes.

One of the earliest and most common cooking methods is frying. Deep-fat frying (DFF) is a method to produce dry food where an edible fat heated above the boiling point of water serves as the heat transfer medium, and fat also migrates into the food, providing nutrients and flavour (Fan *et al*., 2005; Adeyanju *et al*., 2016). DFF can be regarded as a short process with high temperature that includes both mass and heat transfer (Vitrac *et al.,* 2002). It is a globally recognized food preparation technology that involves a simultaneous mass and heat transfer process. Moisture leaves the food as vapour bubbles even as the oil is absorbed (Fan *et al*., 2005). Therefore, it is frequently chosen as a method of choice for changing the food's physical, chemical, and sensory characteristics to create distinct flavours and textures (Patterson *et al*., 2004), causing notable changes. Factors affecting heat and mass transfer are food and oil's thermal and physicochemical properties (Krokida and Orepoulou, 2000).

A valuable technique in optimization is Response Surface Methodology (RSM) which represents a collection of statistical and mathematical methods for modelling and optimizing processes. A response of

*Corresponding author.
Email: *jaadeyanju@lautech.edu.ng*

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interest is influenced by several variables (Garayo and Moreira, 2002; Bas *et al*., 2007). RSM is employed to understand the effect of different parameters on specific responses of interest to achieve the best combination of factors that will render the best characteristics of a product and process response (Granato and Calado, 2014). For example, the temperatures and frying duration mainly influence the performance of deep-frying technology. There are various advantages to using statistical methodologies in rapid and reliable shortlisting of process conditions. Thus, RSM experimental design is an efficient approach to dealing with many variables (Montgomery, 2005). Optimization is a method used to improve the performance of a system that gives a high yield at low costs. It is a fundamental and frequently applied task for most engineering activities. Many foods, including *akara* Ogbomoso are traditionally prepared by deep-frying in Nigeria, as in most developing countries. Still, information on process variables, product characteristics, and optimal processing conditions is challenging to find in the literature. However, research has been conducted on the effects of soy flour substitution on the physical compositional and sensory attributes of *akara* Ogbomoso (Falade *et al*., 2003). Therefore, the objective of this study was to optimize the deep-frying conditions of *akara* Ogbomoso using RSM.

2. Materials and methods

2.1 Materials

Cowpea (*Vigna unguiculanta*), free of weevils were purchased from *Waso* market in Ogbomoso. Refined vegetable oil (Devon King's®) obtained from Ace Supermarket, Ogbomoso, Nigeria.

2.2 Production of cowpea flour

Cowpea seeds are cleaned by hand to remove stones, grit and stems. Cowpea flour was made using a modified form of the method described by Ngoddy *et al*. (1986). The cowpea seeds are cleaned and soaked in distilled water for 5 mins to condition them and easily remove the seed coat. The conditioning beads were decorated and drained before being dried for 24 hrs at 50°C in a forced drying oven (BS Model OV160 Size Two Gallenkamp Oven). The dried cotyledons were dry-ground in a consumable mill and sieved to obtain a grain size between 45 and 150 µm (60 to 70%).

2.3 Preparation of sample

The method used by Falade *et al*. (2003) was slightly modified to produce *akara* Ogbomoso. First, cowpea flour was measured and mixed following the experimental design. Then, 200 g of each flour mixture was mixed with 60 g of common salt and 30 mL of water to form stiff pastes. The paste was formed into flat sheets and cut into discs with diameters of 40.0±0.3 cm and thicknesses of 0.50±0.05 cm. The batters obtained were fried to light brown colour and heated in vegetable oil for 11 - 19 min to produce a desired pleasant aroma in a non -stick frying container with a series of units for controlling and executing frying operations at temperatures of 150 – 190°C. This temperature range and time were chosen based on the results of preliminary experiments carried out in the laboratory.

2.4 Experimental design

A central composite approach was adopted to design this experiment involving two independent variables: frying temperature and time and denoted as X_1 and X_2, respectively. Each factor was varied at five levels with an alpha value of -1.414, -1, 0, +1, and +1.414, with thirteen runs altogether as presented in Table 1.

2.5 Determination of product quality characteristics

The moisture and fat contents of the *akara* Ogbomoso were determined using the standard analytical procedure (Association of Official Analytical (AOAC), 2005). The gravimetric method was used to obtain the moisture content of the samples. Approximately 3 g of sample was measured using a weighing balance into an already-weighed clean dried dish. The dish was placed in a well-ventilated oven maintained at 103±2°C for 24 hrs. The loss in weight was recorded as moisture.

The oil content of the sample was determined by grinding in a porcelain mortar and pestle after drying in an oven at a temperature of 60±2℃ for about 2 hrs. Crude fat was extracted from 3 g of the sample with hexane using a fat extractor (Soxtec System HT2 fat extractor), and the solvent evaporated off to get fat.

Snack texture was measured at room temperature (~25±1°C) using a slightly modified puncture test by Segnini *et al*. (1999). The measurements were made using a computer-aided TA XT-Plus texture analyzer (model M500, Testometric AX, Rochdale, Lancashire, England) with a 5 kg load cell. The fried snacks were

Table 1. Experimental design.

		Level				
Process variables	Coded variables	-1.414	-1	0	+1	+1.414
Frying Temperature (℃)	X_1	150	160	170	180	190
Frying Time (min)	X_2	11	13	15	17	19

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placed separately on a three-point stand with a distance of 15 mm from the punch diameter and a transverse head speed of 2 mm and 60 mm/min, respectively. The force versus distance curves based on the puncture test and data were analyzed with an inbuilt software of the texture analyzer. The shrinkage was determined with the help of a stainless steel calliper. Before and after frying, the sample dimension (thickness and diameter) was measured. Measurements were made at three different places on each sample. Shrinkage was expressed as percentage changes in volume (Kawas and Moreira, 2001). The surface colour of *akara* Ogbomoso was determined with a colourimeter (Nippon Denshoku Σ90 colour difference meter, Japan) and given as Hunter L (lightness), a (redness), and (yellowness) values. Colour difference (Hunter ΔE) was calculated according to the equation:

$$\Delta E = \left[\left(L - L_{ref}\right) + \left(a - a_{ref}\right) + \left(b - b_{ref}\right)\right] \quad (1)$$

Where L_{ref}, a_{ref} and b_{ref} were the L, a and b values of samples used as references.

2.6 Optimization

Optimum conditions for *akara* Ogbomoso that produced the best result were achieved using a computer software package (Design expert version 6.0.1 Stat. Ease Minneapolis, USA). The optimization of this research work was performed by minimizing the moisture content, oil content, shrinkage, and crispness, while the colour and shrinkage were kept at an acceptable recommendable range. Then the coefficients of determination, R^2 were fitted into the regression equation.

3. Results and discussion

3.1 Quality characteristics of akara Ogbomoso

The results of *akara* Ogbomoso quality characteristics are shown in Table 2. The moisture content of *the* snacks ranged from 7.41 to 7.89%. The processing conditions such as frying temperature, X_1 and frying time, X_2 significantly affected the moisture content of *akara* Ogbomoso (Table 2). As shown in the table, the value of $p<0.05$ signifies the significance of the model. Response surface plots (Figure 1) of moisture content showed that the moisture content of *akara* Ogbomoso decreased with increasing frying time. It showed that the moisture content was affected by frying temperature and time (Kondaiah *et al.*, 2000). The value for R^2 was 0.90, indicating that the model is fit because a value closer to 1.0 gives the best fit. As shown in Table 3, the lack of fit test for the model was not significant at $p>0.05$.

The oil content of *akara* Ogbomoso ranged from 12.82% to 13.80%. Frying temperature and time

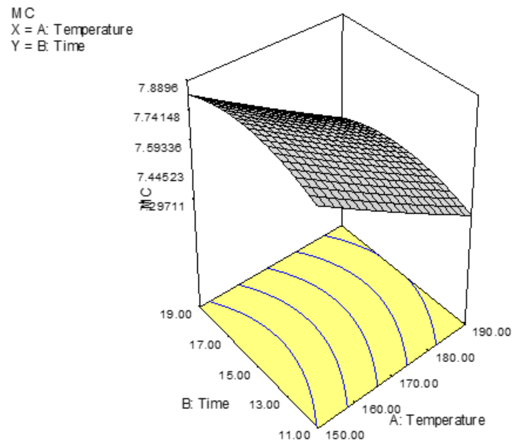

Figure 1. Surface plot of moisture content.

Table 2. Layout of the CCD and corresponding mean values of quality attributes of *akara* Ogbomoso.

Runs	Coded Variable		Responses				
	X_1	X_2	MC (%)	OC (%)	ΔE	BF (N)	S
1	-1	-1	7.73	12.89	41.18	136.27	7.10
2	1	-1	7.49	13.36	41.05	121.99	7.66
3	-1	1	7.72	13.32	46.34	105.45	7.66
4	1	1	7.47	13.79	46.21	106.53	8.21
5	0	1.414	7.59	13.77	48.80	47.66	8.21
6	0	-1.414	7.52	12.94	38.63	90.99	7.00
7	1.414	0	7.41	13.75	45.68	135.48	8.33
8	-1.41	0	7.89	12.80	42.24	114.25	7.33
9	0	0	7.60	13.34	43.70	140.10	7.66
10	0	0	7.64	13.28	43.96	139.50	7.66
11	0	0	7.65	13.28	42.80	140.20	7.66
12	0	0	7.64	13.28	43.60	151.50	7.66
13	0	0	7.65	13.28	43.96	140.16	7.33

X_1: Frying temperature (°C), X_2: Frying time (min), MC: Moisture content (%), OC: Oil content (%), ΔE: Colour difference, BF: Breaking force (N), S: Shrinkage.

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Table 3. Summary of the analysis of variance for response surface model.

Responses	Sum of square	Mean square	F-value	P-value	Models
MC	0.19	0.03	70.54	0.0001	Quadratic
OC	1.19	0.59	395.98	0.0001	Linear
ΔE	81.93	40.96	121.68	0.0001	Linear
BF	9274.74	184.95	40.85	0.0001	Quadratic
S	1.85	0.92	52.61	0.0001	Linear

influenced the results significantly at $p<0.05$. The response surface plot (Figure 2) shows that an increase in time and temperature of the process increases the oil content of the snacks. They indicated the variation of frying temperature and time on the oil content of the fried snacks. The frying temperature and time increase oil content, preserve the natural colour and flavour of the fried product, and have common adverse effects on the oil quality (Kondaiah *et al.*, 2000). The value for R^2 was 0.97, indicating that the model is fit, and the lack of fit test for the model was not significant at $p>0.05$ (Table 3).

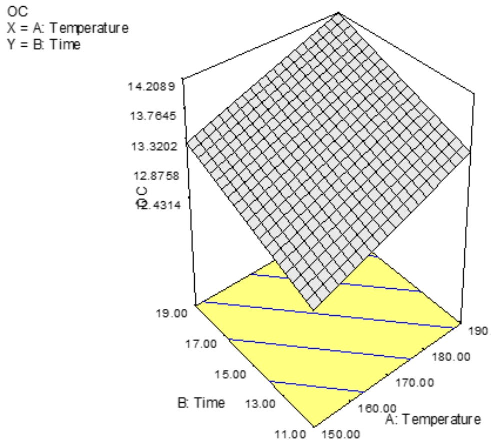

Figure 2. Surface plot of oil content.

Table 2 reveals that the maximum ΔE value (48.80) was accomplished at 170°C frying temperature and 19 mins frying time, while the minimum ΔE value (38.63) was achieved at 170°C frying temperature after frying for 11 mins. The majority of the product colour was retained when deep-fried. It indicates that the model is significant; the value for R^2 was 0.96, indicating that the model fit is good. As shown in Table 3, lack of fit test for the model was not significant at $p>0.05$. Frying temperature and time were significant at $p<0.05$ on the colour difference. Figure 3 shows the surface plot of colour difference as affected by frying temperature and time. The sample's colour changes were due to the Maillard reaction, which depends on the content of reducing sugars and amino acids or proteins at the surface and temperature and time of frying (Krokida *et al.*, 2001). It has been reported that colour is among the first quality characteristics that influence the choice of consumers for purchasing or consuming any food products (Luo *et al.*, 2019; Obajemihi *et al.*, 2020). The response surface plot in Figure 6 revealed that the changes in the colour value of *akara* Ogbomoso increased with increased temperature.

The texture (breaking force) of the *akara* Ogbomoso samples ranges from 151.5 to 47.66 N (Table 2). *Akara* Ogbomoso should be firm and snap easily when bent, thus revealing crunchiness. Therefore, a lower breaking force was considered to have a higher crispness. In the case of *akara* Ogbomoso, a very crispy texture was expected since crispness was an indicator of freshness and high quality (Akinlua *et al.,* 2000). The coefficient of determination is 0.98, which is not far from unity. Furthermore, statistical analysis showed a significant effect of frying temperature and time on the breaking force at $p<0.05$ level of significance (Table 3). The relationship between the process variables and breaking force is shown in Figure 4.

The shrinkage of the *akara* Ogbomoso samples

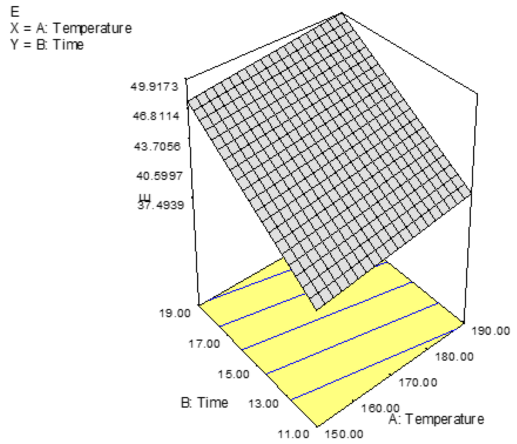

Figure 3. Surface plot of colour difference.

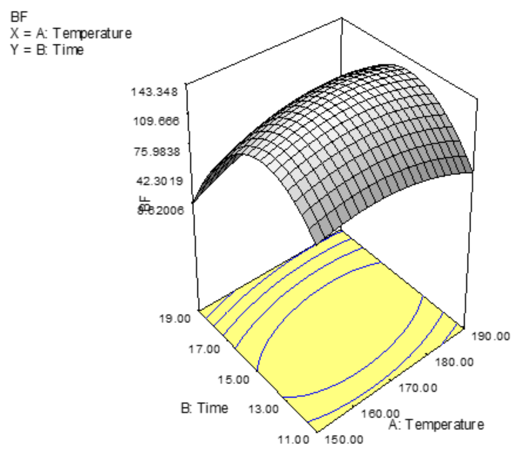

Figure 4. Surface plot of breaking force.

ranged between 7.00 and 8.33. As shown in Table 3, data analysis revealed that frying temperature and time significantly ($p<0.05$) affected the degree of shrinkage. The response surface plot of shrinkage against frying temperature and time is shown in Figure 5.

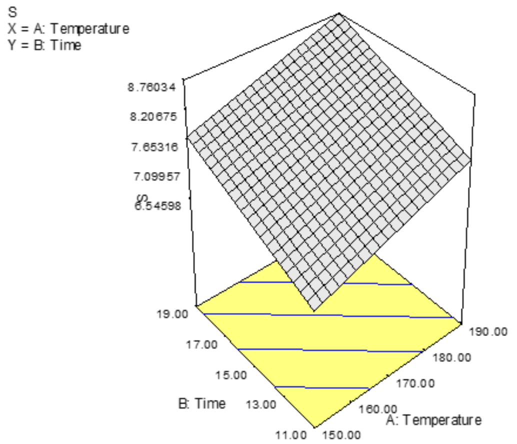

Figure 5. Surface plot of shrinkage.

The degree of shrinkage was decreased due to the corresponding increase in oil temperature and decrease in frying time. The results obtained correlated with the report by Garayo and Moreira (2002) on the case of potato chips. The volume of water loss was equal to the shrinkage observed during the early stages of frying; nonetheless, there was a decrease in shrinkage in the final stages of frying. Therefore, the shrinkage value observed was a function of water transfer within the product. The higher the temperatures and mass diffusivity, the higher the water loss and lower shrinkage volume. Furthermore, high oil temperature caused the *akara* Ogbomoso surface to become more rigid and resistant to shrinkage. The model's coefficient of determination R^2 is 0.95. This confirmed that there would be minimal error while using the model. The lack of fit test for the model was not significant at $p>0.05$ (Table 3).

3.2 Models

Model equations to predict the effects of frying temperature and time on moisture content, fat content, colour, breaking force, and shrinkage of the snacks were presented in Equations 2 to 6 using the obtained empirical data.

$$MC = +9.01100 - 0.018690X_1 + 0.16248X_2 + 1.90232E - 005X_2^2 - 5.26257E - 003X_1^2 + 1.40686E - 016X_1X_2 \quad (2)$$

$$OC = +7.77074 + 0.023333X_1 - 0.10552X_2 \quad (3)$$

$$\Delta E = +15.16849 + 0.055191X_1 + 1.27698X_2 \quad (4)$$

$$BF = -1624.04078 + 12.29296X_1 + 98.88842X_2 - 0.043915X_1^2 - 4.56964X_2^2 + 0.19213X_1X_2 \quad (5)$$

$$S = +1.04179 + 0.025889X_1 + 0.1473 \quad (6)$$

The quadratic model was appropriate for moisture content and breaking force, while the linear model was suitable for expressing the oil content, colour difference, and shrinkage.

3.3 Optimization

Five possible optimum conditions with desirability ranging from 0.53 to 0.78 were obtained using the computer software package (Design Expert Version 6.0.1) as the optimization tool. As a result, the overall desirability of 78% was achieved at frying temperature and time of 170°C and 11 mins, respectively. The optimized conditions for the *akara* Ogbomoso were as follows: moisture content of 7.52%, oil content of 12.90%, change in colour of 45.65, breaking force of 90.40 N, and shrinkage of 7.07.

4. Conclusion

This study demonstrated that the synergetic effects made between frying temperature and time on the moisture content, oil uptake, texture, colour changes, and shrinkage were significantly ($p<0.05$) influenced by the frying variables. The models demonstrated good fits with coefficients of determination (R^2) of 0.90, 0.97, 0.96, 0.98 and 0.95 for moisture content, oil uptake, texture, colour changes, and shrinkage. The optimum process variables were 190°C frying temperature and 19.75 mins frying duration with desirability of 0.78. This produced 7.52% moisture content, 12.90% oil uptake, 45.65 change in colour, 90.40 N breaking force, and 7.07 shrinkage. The use of response surface methodology effectively optimizes process variables for the deep-frying of *akara* Ogbomoso from cowpea.

References

Adeyanju, J.A., Olajide, J.O. and Adedeji, A.A. (2016). Development of optimum operating conditions for quality attributes in deep-fat frying of *dodo* produced from plantain using response surface methodology. *Food and Nutrition Sciences*, 7(14), 1423-1433. https://doi.org/10.4236/fns.2016.714129

Akinlua, O., Sobowale, S.S., Adebo, O.A. and Olatidoye, O.P. (2013). Studies on the characteristics of deep fried pretreated cocoyam slices (*Xanthosoma sagittifolium*). *Journal of Agriculture and Veterinary Sciences*, 5(1), 40-50.

Association of Official Analytical (AOAC). (2005). Official Methods of Analysis, 15th ed. Washington DC, USA: AOAC.

Bas, D., Ismail, H. and Boyaci, J. (2007). Modelling and optimization I: Usability of Response Surface Methodology. *Journal of Food Engineering*, 78(3), 836-845. https://doi.org/10.1016/j.jfoodeng.2005.11.024

Falade, K.O., Adedeji, A.A. and Akingbala, J.O. (2003). Effect of soybean substitution for cowpea on physical, compositional, sensory and sorption properties of *akara* Ogbomoso. *European Journal of Food Research and Technology*, 217, 492–497. https://doi.org/10.1007/s00217-003-0776-2

Fan, L., Zhang, M. and Mujumdar, A.S. (2005). Vacuum frying of carrot chips. *Drying Technology*, 23(3), 645-656. https://doi.org/10.1081/DRT-200054159

Fan, L., Zhang, M., Xiao, G., Sun, J. and Tao, Q. (2005). The optimization of vacuum frying to dehydrate carrot chips. *International Journal of Food Science and Technology*, 40(9), 911–919. https://doi.org/10.1111/j.1365-2621.2005.00985.x

Garayo, J. and Moreira, R. (2002). Vacuum frying of potato chips. *Journal of Food Engineering*, 55(2), 181-191. https://doi.org/10.1016/S0260-8774(02)00062-6

Granato, D. and Calado, V.M.D.A. (2014). The use and importance of design of experiments (DOE) in process modelling in food science and technology. In Granato, D. and Ares, G. (Eds.), Mathematical and Statistical Methods in Food Science and Technology. 1st ed., p. 18. United Kingdom: John Wiley and Sons, Ltd. https://doi.org/10.1002/9781118434635.ch1

Kawas, M.L. and Moreira, R.G. (2001). Characterisation of product quality attributes of tortilla chips during the frying process. *Journal of Food Engineering*, 47 (2), 97-107. https://doi.org/10.1016/S0260-8774(00)00104-7

Krokida, M.K. and Orepoulou, V. (2000) Water loss and oil uptake as a function of frying time. *Journal of Food Engineering*, 44(1), 39-46. https://doi.org/10.1016/S0260-8774(99)00163-6

Krokida, M.K., Oreopoulou, V., Maroulis, Z.B. and Marinos-Kouris, D. (2001) Effect of pre-drying on quality of french fries. *Journal of Food Engineering*, 49(2), 347-354. https://doi.org/10.1016/S0260-8774(00)00233-8

Luo, D., Yu, L., Westland, S. and Mahon, N. (2019). The influence of colour and image on consumer purchase intentions of convenience food. *Journal of the International Colour Association*, 24, 11-23.

Montgomery, D.C. (2005). Design and analysis of experiments: Response surface method and designs. New Jersey, USA: John Wiley and Sons, Inc,

Ngoddy, P.O., Enwere, E. and Onworah, P. (1986). Cowpea flour performance in akara and moin-moin preparations. *Tropical Science*, 26, 101–119.

Obajemihi, O.I. and Asipa, A.A. (2020). Effective moisture diffusivity and rehydration characteristics of osmo-air dehydrated tomato. *Agricultural Engineering International: CIGR Journal*, 22(4), 184-192.

Obajemihi, O.I., Olaoye, J.O., Ojediran, J.O., Cheng, J.H. and Sun, D.W. (2020). Model development and optimization of process conditions for colour properties of tomato in a hot-air convective dryer using box–behnken design. *Journal of Food Processing and Preservation*, 44(10), e14771. https://doi.org/10.1111/jfpp.14771

Patterson, S.P., Phillips, R.D., Mc Watters, K.H., Hung, Y.C. and Chinnan, M.S. (2004). Fat reduction affects quality of fried cowpea paste. I*nternational Journal of Food Science and Technology*, 39(6), 681-693. https://doi.org/10.1111/j.1365-2621.2004.00827.x

Segnini, S., Dejmek, P. and Oste, R. (1999). Reproducible texture analysis of potato chips. *Journal of Food Science*, 64(2), 309–312. https://doi.org/10.1111/j.1365-2621.1999.tb15889.x

Vitrac, O., Dufour, D., Trystram, G. and Raoult-Wack, A. (2002). Characterization of heat and mass transfer during deep-fat frying and its effect on cassava chip quality. *Journal of Food Engineering*, 53(2), 161–176.

