International Journal of Scientific Research in Multidisciplinary Studies
Vol.8, Issue.6, pp.38-42, June (2022)

Research Paper
E-ISSN: 2454-9312
P-ISSN: 2454-6143

Response Surface Methodology on Organoleptic and Physical Properties of Extruded Snacks from Blends of African Yam Bean, Sorghum and Moringa Leaf Powder

C.N. Nwakalor

Department Of Food Technology, Federal Polytechnic Oko, Anambra State

Author's Mail Id: chizobanwakalor@ymail.com, 08057675955

Available online at: www.isroset.org

Received: 23/Apr/2022, Accepted: 21/May/2022, Online: 30/Jun/2022

Abstract— Response surface methodology (RSM) based on a three-factor three level central composite rotatable design (CCRD) was adopted for optimization of formulation for production of a moringa leaf powder fortified sorghum- African yam bean based extruded snack. Effects of feed composition (X_1), feed moisture content (X_2) and barrel temperature (X_3) on physical properties such as bulk density and expansion ratio were investigated. Significant regression models that explained the effects of different percentages of feed composition, feed moisture content and barrel temperature on all response variables were determined. The coefficients of determination, R^2, of all the response variables were higher than 0.90. Based on the given criteria for optimization, the basic formulation for production of sorghum- African yam bean based extruded snack with desired sensory quality was obtained by incorporating with 42.38% feed composition, 22.89% feed moisture content and 120^0C barrel temperature.

Keywords— Extruded snack, Sorghum, African yam bean, Moringa leaf powder and Response surface methodology

I. INTRODUCTION

A snack is a portion of food often smaller than a regular meal; a convenient food that provides calories, satisfying short-term hunger and often eaten in a hurry [7]. Snacks come in a variety of forms including packaged and processed foods and items made from fresh ingredients at home. In developed countries, snacks are eaten in between meals to check hunger, provide energy and tasty appeal; while in developing countries, they are eaten as a main meal because of their ready availability and affordability. The small nature of snacks makes them handy, easy to be managed and carried about [12]. Snacks, however, are high in calorie and fat and low in proteins, vitamins and micronutrients [15].

Moringa oleifera and African yam bean are examples of such underutilized crops that have great potentials. The plant *Moringa oleifera* is a small fast growing tree found in the tropical regions. They are used for soup preparation especially in the dry season when there is scarcity of other more popular vegetables. Moringa leaves had been known to combat malnutrition in infants and nursing mothers. Moringa leaves have been reported to be rich in nutrient with dry leaves containing as much as 30% protein. The leaves are sources of the sulphur- containing amino acid such as methionine and cystine which are often in short supply in most legumes [8]. The amino acid balance and micronutrient content is also very good. [4] reported that Moringa leaves are very high in iron, while Moringa leaf powder contain 14 times more iron than roast beef (one of the richest iron sources).

Extrusion is one of the most versatile operations available to the food industry for transforming ingredients into intermediate or finished products. Extrusion has been used to produce a wide variety of foods such as snacks, ready-to –eat cereals, textured vegetable protein, confectioneries and pet foods [17]. These foods have been proven to provide nutritious products and combine quality ingredients and nutrients to produce processed foods that contain precise levels of each required nutrient [2]. Extrusion cooking technology provides a method to process raw ingredients on large scale at a remarkably low cost.

The effectiveness of response surface methodology (RSM) in optimization of ingredient levels, formulations and processing conditions in snack food has been documented by different researchers [11]. Response surface methodology is a statistical mathematical method that uses quantitative data in an experimental design to determine and simultaneously solve multi-variate equations, to optimize processes and products [6]. Response surface methodology (RSM) is also a useful tool to minimize the numbers of trials and provide multiple regression approach to achieve optimization.

II. METHODOLOGY

Flour preparation from African yam bean

Five kilograms of the AYB seeds were sorted, washed and sun dried. The AYB seeds were roasted for 10min, milled (attrition mill) and sieved into fine flour with 1mm mesh sieve.

Flour preparation from sorghum

The sorghum flour was prepared using the method of [10]. Five kilograms of sorghum seed were sorted, cleaned, dehulled, winnowed, milled (attrition mill), sieved into fine flour to remove the dust and contaminants.

Preparation of Moringa leaf powder

Moringa leaves were washed and dried at room temperature. The dried leaves were milled into powder and sieved with sieve of 0.3mm aperture size to get Moringa powder.

Blend Preparations and Moisture Adjustment

Sorghum flour (SF) and African yam bean flour were mixed at various weight ratios, and the total moisture contents of the blends adjusted to the desired values with a mixer as described by [19]. Weights of the components mixed were calculated using the following formula

$$C_{SF} = \frac{[r_{SF}\ \ x\ \ M\ \ x(100-w)]}{[100\ \ x\ \ (100-w_{SF})]} \text{------------------------------- (1)}$$

$$C_{AF} = \frac{[r_{AF}\ \ x\ \ M\ \ x(100-w)]}{[100\ \ x\ \ (100-w_{AF})]} \text{------------------------------ (2)}$$

$$W_X = M - C_{SF} - C_{AF} \text{--(3)}$$

Where C_{SF} and C_{AF} are the masses of sorghum flour and African yam bean flour respectively, r_{SF} and r_{AF} are the respective percentages of sorghum and African yam bean flour in the blend, ($r_{SF} + r_{AF} = 100\%$); where M is the total mass of the blend; w, the moisture content of the final blend, percentage wet weight basis (w.w.b); Wx is the weight of water added; and W_{SF} and W_{AF} are the moisture contents of S_F and A_F respectively. One percentage Moringa leaf powder was added to each formulation; and the samples were put in closed plastic buckets and stored overnight (32±2°C).The feed materials were then allowed to stand for 3hrs to equilibrate at room temperature prior to extrusion exercise.

Extrusion Cooking Processing

Extrusion cooking was performed in a locally fabricated FST 001 single screw extruder at the Department of Food Science and Technology, University of Nigeria, Nsukka. The extruder was fed manually through a conical shaped hopper mounted vertically above the end of the extruder. The die has 0.4cm diameter and the variables considered were feed composition, feed moisture content and barrel exit temperature. The barrel temperature ranges were between 100-140^{0}C and feed moisture content was set at 20-30%.

Experimental Design and Statistical Analysis

The extrusion conditions were optimized with a three factor five-level central composite rotatable design (CCRD). Response Surface Methodology (RSM) was used to investigate the effect of the independent variables on the responses. Feed composition (X_1), feed moisture content (X_2) and extruder barrel temperature (X_3) were the independent variables considered and the qualities of the finished products were the response variables measured. In order to objectively define the experimental ranges, preliminary experiments were conducted to establish the narrower, more effective ranges of the independent variables (X_1, X_2, and X_3) prior to the experimental runs. As the design value ranges were established, they were coded to lie at ±1α for the factorial points, 0 for the center points and ±1α for axial points. The experiments were randomized to maximize the effects of unexplained variability in the observed responses due to extraneous factors, while three replicates at the center of the design were used to allow for estimation of pure error sum of square and lack-of-fit. Analysis of variance (ANOVA) was conducted to determine significant differences among the mean treatment combinations.

Process Optimization

A second order polynomial regression equation was modeled on the basis of the experimental data and optimum parameters defined using MINITAB 14.13 Software. From the resulting values, for each of the response variable, the coefficients of the polynomial equation (*βo, βi* and *βij*) are determined and the equation simplified based on the influence of the factors on the final response. The responses were then expressed as second-order polynomial equation according to Eq. 4.

$$Y = f(y) + \sum_{i=1}^{k} \sum \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where Y is the predicted response used as a dependent variable, *k* is the number of independent variables considered in the experiment; *βo* constant coefficient and *βi, βij* and *βii* are the coefficient of linear, interaction and square terms respectively, while *ε* is the random error term. Multivariate regression analysis with model equation (4) was carried out on the data using MINITAB 14.13 statistical software (Manitab Inc. USA) to yield equation 5 which was used to optimize the product responses.

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X^2{}_1 + \beta_{22} X^2{}_2 + \beta_{33} X^2{}_3 + \beta_{12} X_1 X_2 + \beta_{13} X_1 X_3 + \beta_{23} X_2 X_3 + \varepsilon \ldots\ldots\ldots\ldots(5)$$

Expansion Ratio (puff ratio)

Expansion ratio can be of two indices, diametral and longitudinal as described by [20]. Diametral expansion is defined as the diameter of the extrudate whilst longitudinal expansion is defined as the length per unit dry weight. The diameter was determined after cooling of the extrudate, 10 samples were assessed for each extrudate and for each sample; diameters at three different positions were taken using vernier calipers and the result averaged. Expansion ratio was expressed as the diameter of the extrudate to the diameter of the die.

Bulk Density of Extrudates

The bulk density (ρ) of extrudates was calculated using the methods described by [14] as follows: Density $(\rho) = (4 \times \dot{m})/(\pi \times D^2 \times L)$ where $\dot{m}$ is the mass of extrudate with length L and diameter D. The samples were randomly selected and replicated 10 times and the average result value taken.

Sensory Evaluation

The sensory evaluation of the extruded snack product were based on attributes such as appearance, taste, flavour, mouth feel, after taste and overall acceptability. The samples were coded and presented in identical containers. A 9 point Hedonic scale with 9= extremely like and 1= extremely dislike was used.

III. RESULTS AND DISCUSSION

Model fitting

The effects of different composition of sorghum, African yam bean and moringa leaf powder on bulk density (BD) and expansion ratio (ER) are shown in Table 1. The independent and dependent variables were fitted to the second-order model and examined for the goodness of fit. The analyses of variance were performed to determine the lack of fit and significance of the linear, quadratic and interaction effects of independent variables on the dependent variables. Suggested quadratic models were chosen for all the factors with highly significant effects ($p<0.001$) on response variables. Coefficient of determination or R^2 is the proportion of variation in the response attributed to the model rather than to random error and was suggested that for good fit model, R^2 should be at least 80% [5]. The results show that the models for all the response variables were highly adequate because they have satisfactory levels of R^2 of more than 90% and that there is no significant lack of fit in all the response variables. Hence, it can be concluded that the proposed models approximate the response surfaces and can be used suitably for prediction at any values of the parameters within experimental range. The regression coefficients for each response variables is given in Table 2, and the equations for each of the response variables could be derived from the predicted values of each response variable.

Table 1: Effects of extrusion parameters on physical properties of the extrudates

Exp. No	Ex.no	Actual factors BRT	Bulk density(gcm^{-3})	ER
1	1	100	1.197	1.600
2	2	100	1.316	1.725
3	3	140	0.886	1.675
4	4	140	1.111	1.500
5	5	100	1.974	1.450
6	6	100	1.606	1.850
7	7	140	0.886	1.675
8	8	140	1.892	1.450
9	9	120	1.655	1.550
10	10	120	1.441	1.675
11	11	86.4	1.526	1.425
12	12	154	1.188	1.675
13	13	120	1.137	1.500
14	14	120	1.149	1.550
15	15	120	1.400	1.500

Values are means of triplicate determinations.
Experimental runs were randomized.

Bulk density (BD)

The BD indicating porosity of the snack varied between 0.886 and 1.974g/cm^3 (Table 1). The multiple regression model for predicting for predicting the bulk density could explain 93.5% of the observed variations (Table 2). It was observed that the bulk density was significantly affected by the amount of sorghum and African yam bean (linear and interaction) terms.

Table 2: Estimated regression equation coefficients for response variables (physical properties) in extruded sample

Coefficient	Bulk density	Expansion Ratio
Constant	1.74378	3.18099
Linear		
X_1	-0.0325*	0.02761*
X_2	-0.24715	-0.08656*
X_3	0.04714*	-0.01865*
Quadratic		
X_1^2	0.00245	0.00010
X_2^2	-0.00002	0.00213
X_3^2	-0.00020	0.00005
Interaction		
X_{12}	0.00062*	-0.00136*
X_{13}	0.00189	0.00025
X_{23}	-0.00018	0.0000
R^2 (%)	93.5	99.5
Adjusted (R^2)%	91.8	99.3
Lack of fit	0.0279	0.001
Model	*	*

$^aY = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_{11} X^2{}_1 + \beta_{22} X^2{}_2 + \beta_{33} X^2{}_3 + \beta_{12} X_1X_2 + \beta_{13} X_1X_3 + \beta_{23} X_2X_3$;
X_1 = Feed Composition, X_2 = Feed Moisture content, X_3 = Barrel Temperature, * and ** = significant at 5% and 1% level of probability respectively.

African yam bean had more significant positive effect on bulk density than sorghum. This could be due to high fiber and protein content of African yam bean that may affect the starch gelatinization. The non-starch polysaccharides in fiber may bind water more tightly during extrusion than do protein and starch. This binding may inhibit water loss at the die and thus reduces expansion and increases bulk density [3]. The relation of protein to expansion of extrudates has been reported by [16]. More the protein, less be the expansion so increased bulk density. However, moringa leaf powder level did not exhibit any significant effect at linear, quadratic and interactive levels. This might be due to lower proportion of moringa leaf powder in the blend contributing less amount of protein. The quadratic between sorghum, African yam bean and moringa leaf powder exhibited no significant effect on bulk density.

Expansion ratio (ER)

Extrusion process forms pockets of air cells that give a porous expanded structure to the extrudates. Porosity created during extrusion can be used to describe the expansion properties of the extruded product [18]. The correlation of expansion ratio with bulk density has been reported by many researchers [1]. Higher the bulk density, lower is the expansion ratio. The coefficient estimates of bulk density model shows that the levels of sorghum and African yam bean had highly significant (P< 0.01) negative effects in linear and interaction terms. This might be due to high starch-protein interactions and formation of inter-molecular disulphide bonds in the protein upon heat treatment that renders the swelling of extrudate, thus exhibited low expansion ratio [9]. The negative effects on expansion ratio might also be due to fiber enriched ingredients [13]. Moringa leaf powder did not exhibit any influence on expansion of extrudates. This might be due to lower proportion of moringa leaf powder in the blend.

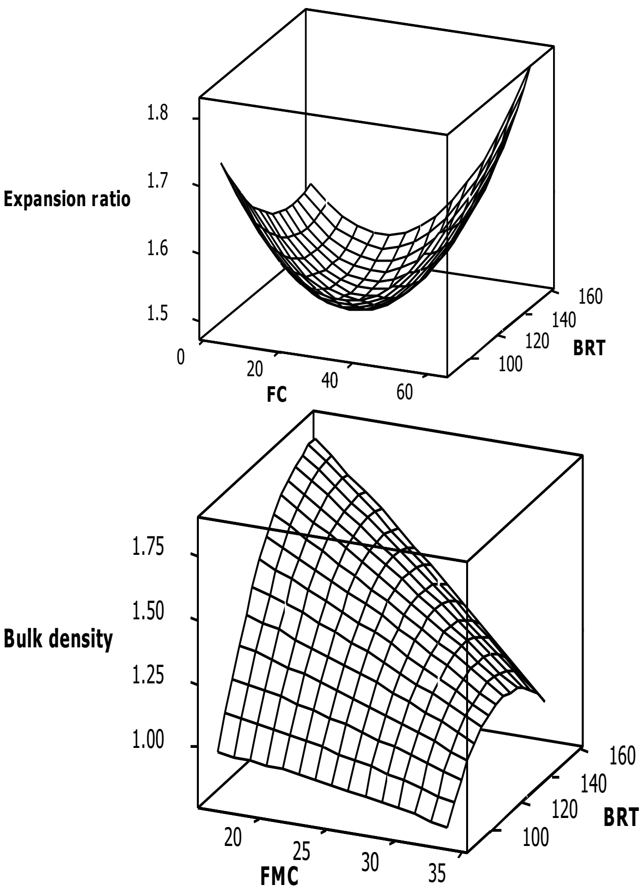

Fig.1. 3D plot of the effects of barrel temperature (BRT) and feed composition (FC) on expansion ratio and bulk density of extrudates holding feed moisture content (FMC)

Optimization

Numerical optimization of flour levels was carried out for the preparation of extruded snack. Minitab soft ware program (version 14.13) was used for simultaneous optimization of the responses. Desired goals were assigned for all the parameters for obtaining the numerical optimum values for the responses. All the blend ratios (the levels of sorghum, African yam bean and moringa leaf powder) were kept in range. The response parameters like expansion ratio and bulk density were kept at maximum. The optimum values obtained for percentage levels for the blend ratio was 42.38. The corresponding optimum values of expansion ratio and bulk density were 1.491 and 1.398g/cm^3 respectively.

Sensory Evaluation

The sensory evaluation scores for the African yam bean, sorghum and Moringa leaf based snack extrudates are presented in Table 3. The mean scores for crumb appearance ranged from 4.00 to 7.00. There were significant difference (p<0.05) in crumb appearance with sample 9 having the highest mean score of 7.00 and sample 13 had the least mean score of 4.00. Crumb appearance appeared to improve with increased inclusion of the legume flour (sample 9). Also at the highest exit barrel temperature (sample12), the crumb appearance improved with a score of 5.91. [2] reported that colour changes in extruded products were due to decomposition of pigments and product expansion. There may also be fading of colour and reaction with other food components as in browning reaction and caramelization of carbohydrates.

The mean scores for the crust appearance ranged from 4.09 to 6.91. There were significant differences (p<0.05) in crust appearance of the extrudates. Sample 7 had the least mean score (4.09) while sample 9 had the highest mean score (6.91) for crust appearance. Crust appearance perception of the extrudates followed similar trend as the crumb appearance with values ranging from 4.09 to 6.91. The mean scores for flavour ranged from 5.27 to 6.27. There was no significant (p>0.05) difference in the flavour of the extrudates. The flavour of the samples appears to show more uniform preference scores. This indicates that the beany flavour associated with legumes was significantly reduced in the extruded products.

Texture mean scores of the extrudates ranged from 4.64 to 6.27 with sample 13 having the least mean score (4.64) while sample 9 had the highest mean score (6.27). The texture of sample 9 differed significantly (p<0.05) from sample 13 while the rest of the samples were showed comparable texture rating. Marginal increases were observed in texture scores as the level of legume flour increased and decreases with decrease in exit barrel temperature.

The mouth-feel mean scores ranged from 4.46 to 6.00 with sample 11 having the highest mean scores (6.00) and sample 8 had the least mean scores (4.46). There was no significant (p>0.05) difference in the mouth-feel of the extrudates. The mouth-feel of the samples seemed to show more uniform preference scores.

The overall acceptability mean scores ranged from 4.82 to 6.73 with sample 13 having the least mean score (4.82) and samples 2 and 9 had the highest overall acceptability score (6.73). Although the trends of the results suggest that the panelists may be biased, the results implied that legumes could be incorporated into carbohydrate based extruded snacks without impairment of products sensory qualities and acceptability.

Table 3: Sensory scores of African yam bean, sorghum and Moringa leaf powder based extrudates

Run	Crumb appearance	Crust appearance	flavour	Texture	Mouth feel	Overall Acceptability
1	$5.73^{abc}\pm0.65$	$5.6^{abc}\pm0.8$	$5.73^{a}\pm1.74$	$5.09^{ab}\pm1.5$	$5.46^{a}\pm1.21$	$6.00^{ab}\pm1.10$
2	$6.27^{ab}\pm1.49$	$6.00^{ab}\pm1.18$	$5.46^{a}\pm1.37$	$6.09^{ab}\pm0.94$	$5.91^{a}\pm1.14$	$6.73^{a}\pm1.27$
3	$5.73^{abc}\pm1.42$	$5.55^{abc}\pm1.04$	$5.73^{a}\pm1.10$	$5.64^{ab}\pm1.29$	$4.91^{a}\pm1.51$	$5.82^{ab}\pm1.17$
4	$5.36^{bcd}\pm1.69$	$5.46^{abcd}\pm1.37$	$5.82^{a}\pm1.08$	$5.18^{ab}\pm1.47$	$5.36^{a}\pm1.36$	$5.64^{ab}\pm1.57$
5	$6.46^{ab}\pm1.44$	$6.09^{ab}\pm1.05$	$5.64^{a}\pm1.43$	$5.82^{ab}\pm1.25$	$5.36^{a}\pm1.63$	$6.09^{ab}\pm1.58$
6	$4.73^{cde}\pm2.10$	$5.09^{bcd}\pm2.12$	$5.46^{a}\pm1.51$	$4.82^{ab}\pm1.83$	$4.55^{a}\pm1.86$	$5.00^{b}\pm1.34$
7	$4.18^{de}\pm1.54$	$4.09^{d}\pm1.22$	$6.00^{a}\pm0.89$	$4.91^{ab}\pm1.58$	$5.18^{a}\pm1.54$	$5.73^{ab}\pm1.49$
8	$5.73^{abc}\pm1.35$	$5.64^{abc}\pm1.43$	$5.91^{a}\pm1.38$	$5.64^{ab}\pm1.63$	$4.46^{a}\pm1.92$	$5.73^{ab}\pm1.19$
9	$7.00^{a}\pm1.34$	$5.64^{abc}\pm1.43$	$6.27^{a}\pm1.01$	$6.27^{a}\pm1.56$	$5.55^{a}\pm1.44$	$6.73^{a}\pm1.10$
10	$5.91^{abc}\pm1.30$	$6.00^{ab}\pm1.95$	$5.55^{a}\pm1.21$	$6.00^{ab}\pm1.90$	$4.91^{a}\pm1.87$	$5.36^{ab}\pm1.86$
11	$5.55^{abc}\pm1.21$	$5.46^{abcd}\pm1.70$	$6.18^{a}\pm0.98$	$5.09^{ab}\pm1.14$	$6.00^{a}\pm1.41$	$6.00^{ab}\pm1.00$
12	$5.91^{abc}\pm1.70$	$6.00^{ab}\pm1.41$	$5.27^{a}\pm1.19$	$5.27^{ab}\pm1.35$	$5.36^{a}\pm1.50$	$6.00^{ab}\pm1.34$
13	$4.00^{e}\pm1.34$	$4.46^{cd}\pm1.44$	$5.46^{a}\pm0.93$	$4.64^{b}\pm1.21$	$5.36^{a}\pm1.03$	$4.82^{b}\pm1.66$
14	$6.00^{abc}\pm1.27$	$5.91^{ab}\pm1.22$	$5.55^{a}\pm0.69$	$5.09^{ab}\pm1.22$	$5.09^{a}\pm1.30$	$5.82^{ab}\pm0.98$
15	$6.55^{ab}\pm1.86$	$6.36^{ab}\pm1.91$	$5.82^{a}\pm0.98$	$6.09^{ab}\pm1.97$	$5.00^{a}\pm1.79$	$6.64^{a}\pm1.50$

Values are means of 15 determinations ± standard deviation. Means with different superscripts in the same column are significantly different ($p<0.05$).

IV. CONCLUSION

The RSM was found to be effective technique to investigate physical properties of the extruded snack.
From the result it shows that the three extrusion variables were found to influence the extrudate properties either independently or interactively.

After complete evaluation of all the attributes for physical parameters like bulk density and expansion ratio, it was found that there were strong relationship between the bulk density and the levels of sorghum, African yam bean and moringa leaf powder.

Sorghum and African yam bean levels had highly negative correlation with the expansion ratio of extrudates. The optimum conditions for maximum acceptability of the extruded snack were found to be 42.38% blend ratio. Successful utilization of under- utilized legumes with added functionality in snack food sector will definitely open up new dimensions to the food industries.

REFERENCES

[1]. S.Bhattacharya, “Twin- screw extrusion of rice green gram blend: extrusion and extrudates characteristics,” Journal of Food Engineering, **32:83-99, 1997.**

[2]. Chen, F.L. Serafin, R.N. Pandya, H. Daun, “Effect of extrusion conditions on sensory properties of corn meal extrudates,” Journal of Food Science, **56: 84-89, 1991.**

[3]. H.W. Deshpande, A. Poshadri, “Physical and sensory characteristics of extruded snacks prepared from foxtail millet based composite flour,” International Food Research Journal, **18: 730-735, 2011.**

[4]. L.J. Fuglie, “The Miracle Tree. Moringa oleifera: Natural Nutrition for the Tropics. Church World Service,” Dakar. P.68; revised in 2001 and published as The Miracle Tree: the multiple attributes of Moringa. P172.

[5]. H.E. Gan, R. Karim, S.K.S. Muhammad, J.A. Bakar, D.M. Hashim, R.Abd. Rahman, “Optimization of the basic formulation of a traditional baked cassava cake using response surface methodology,” Lebensmittel-Wissenschaft und-Technologie, **40:611-618, 2007.**

[6]. M.Giovanni, “Response surface methodology and product optimization,” Food Technology, **37:41-45, 1983.**

[7]. A.S. Hornby, “Oxford Advanced Learners’ Dictionary of Current English,” (Wehmier, S., Mcintosh, C., Turnbull, J. and Ashby, N., Eds). New 7th Edition. Oxford University Press, Oxford, **2006**.

[8]. F.W. Martin, R.M. Ruberte,L.S. Meitzner, “Edible Leaves of the Tropics,3rd ed.Educational Concerns for Hunger Organisation ,” Inc., N.ft.Meyers, Fl.194pp, **1998.**

[9].K.Mahasukhonthchat, P.A. Sopade, M.J. Gidley, “Kinetics of starch digestion and functional properties of twin-screw extruded sorghum,” Journal of Cereal Science, **51: 392-401, 2010.**

[10].D.S.Murty, L.R.House, “Sorghum food quality. Its assessment and improvement 5th Joint meetings of the UNDP-CIMMYT policy,” Advisory committee, P 14, **1980.**

[11]. A. Nath, P.K. Chattopadhyay, “Optimization of oven toasting for improving crispness and other quality attributes of ready to eat potato-soy snack using response surface methodology,” Journal of Food Engineering, **80:1282-1292, 2007.**

[12]. O.B. Ocheme,“Comparative analysis of proximate composition and sensory properties of dakuwa products,” Nigerian Food Journal, **27 (1):59-65, 2009.**

[13]. D.A. Pai, O.A. Blake, B.R. Hamaker, O.H. Campanella, “Importance of extensional rheological properties on fiber-enriched corn extrudates,” Journal of Cereal Science, **50:227-234, 2009.**

[14]. D. Qing – Bo, P. Ainsworth, G. Tuker, H. Marson, “The effect of extrusion conditions on the physicochemical properties and sensory characteristics of rice – based expanded snacks,” Journal of Food Engineering, **66: 284-289, 2005.**

[15]. G.S. Ranhotra, J.L. Vetter, “Foods considered for nutrient addition,” In: Snacks and Confectionaries. Marcel Dekker, Inc. New York. **Pp 208-213, 1991.**

[16]. D. Shannon, H.N. Robert, T. Tyler, “Effect of protein, moisture content and barrel temperature on the physicochemical characteristics of pea flour extrudates,” Food Research International, **43: 659-663, 2010.**

[17]. G.Toft, “ Snack foods: continuous processing technical,” Cereal Foods World, **24:142-143, 1979.**

[18]. S.Yanniotis, A. Petraki, E. Soumpasi, “ Effect of pectin and wheat fibers on quality attributes of extruded cornstarch,” Journal of Food Engineering, **80:594-599,2007.**

[19]. D.V.Zasypkin, L. Tung- Ching, “ Extrusion of Soybean and wheat flour as affected by moisture content,” Journal of Food Science, **63(6):1058-1061, 1998.**

[20].P.A. Sopade, G.A. Le Grys, “ Effect of added sucrose on extrusion cooking of maize starch,” Food Control, **2:103-109,1991.**

AUTHORS PROFILE

Dr. C.N. Nwakalor obtained her B.Sc., M.Sc. and Ph.D. in Food Science & Technology from University of Nigeria Nsukka, Nigeria in 2007 & 2018 respectively. She is currently working as a lecturer in Department of Food Technology at Federal Polytechnic Oko, Anambra State, Nigeria since 2011. She is a professional member of the Nigerian Institute of Food Science and Technology. She has published many research papers in reputed international journals and it’s also available online. Her main research work focuses on processing. She has 10 years teaching experience and 14 years of research experience.