12.31.2022

BERKELEY PUBLICATION AND RESEARCH INTERNATIONAL

Journal of Health, Metabolism & Nutrition Studies Vol. 20 No. 3

EFFECTS OF EXTRUSION PROCESSING ON THE CHEMICAL PROPERTIES OF EXTRUDED SNACKS FROM COCOYAM AND BAMBARA GROUND NUT FLOURS

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ABSTRACT

The effects of extrusion variables on the proximate properties of snack produced from blends of cocoyam and Bambara ground nut was determined using Response Surface Methodology (RSM). The moisture content ranged between 2.6 to 4.02%, protein content ranged between 3.40 to 7.01%. The formulation with 23.18% feed composition (cocoyam), 120^{0}C barrel temperature and 16% feed moisture composition has an optimum protein improvement. Lipid (fat content) ranged between 0.95 to 1.03%, fibre composition ranged between 0.18 to 1.94%. Ash ranged from 1.33 to 2.33%. The high ash content is observed on run 2 with extrusion variables of 50% bambara ground nut, 100^{0}C barrel temperature, and a moisture content of 8%. The constant for coefficient of determination for linear, quadratic and interaction are all positive. X_1 has a synsgistic relationship with all the responses, X_2 has an antagonistic relationship with all the responses. At

Introduction:

Cocoyam (*Colocasia escolenta)* contributes to a significant portion of the carbohydrate content of the diets in many regions of the developing countries in the form of edible starchy corms or cormels. Although they are less important than other roots crops such as yam, cassava and sweet potatoes, they are still a major staple in some parts of the tropics and sub-tropics (Opara, 2003). Cocoyam is rich in digestive starch, good quality protein, vitamin C, thiamine, riboflavin, niacin and some scores of essential amino acids (Onayemi and Nwigwe 1987, Lewu *et al.,* 2009). Generally, cocoyam is poor in nutritional quality. Nutritionally cocoyam can be

quadratic level, ($X_1^2X_2^2$, X_2^2) there was a positive relationship with all the variables with the exception of moisture. At interactive X_1X_2, X_1X_3, X_2X_3 all the responses tend to be antagonistic with all the extrusion variables. There was improvement on most of the responses at different formulation levels as stated above.

Key words: Extrusion, Snacks, Proximate, Variables, Responses

Improved by blending with food material rich in lysine which is a limiting amino acid in cocoyam. Combination with legumes which is comparatively rich in lysine can provide an ideal source of cheap and affordable dietary protein for Africa and developing countries

Bambara groundnut remains one of the less researched crops (Bamshaiye *et al.,* 2013), but one with a great nutritional potential. Unfortunately, the Bambara groundnut has less attention in many parts of Africa because of the development of other crops. In Northam Nigeria, most of the bambara groundnut produced is consumed locally. No industrial use of the crop has been reported. The haulm is used for livestock feed, while the fresh pods are boiled and eaten as a snacks. An important reason for underutilization is the hard-to-cook (HTC) phenomenon in combination with inadequate processing techniques (Mubaiwa 2017). HTC in legumes is associated with structural cell modifications (e.g. autolysis of cytoplasm organelles and lignification's of middle lamella) and compositional changes (e.g. formation of insoluble pectate and interactions of proteins and phenolic compounds), which occur in the cotyledons and seed coats (Mubaiwa *et al.,* 2017) Bambara groundnut possesses sufficient quantities of nutrients such as proteins, vitamins and minerals. Bambara groundnut seeds provide an important source of crude protein up to 24%, carbohydrates 63% and fats 6.5%. Awolu *et al.,* (2017) has reported that the protein content composite flour of wheat and cocoyam was improved with the addition of bambara ground nut flour. Major characteristics to be use in flour blends are; they should be readily available, culturally acceptable and provide nutritional requirement's (Kobundu *et al.,*1998).

Starch-based snack foods are a popular example of extruded materials. Studies on starch extrusion have shown that two major operations occurring during this

process-heating in the presence of water and shearing – impart structure to the final product through the transformation of starch granules by the mechanism of gelatinization (Owusu-Ansah *et al.,* 1982). It has been used in the cereal industry for several years to produce many foods and food ingredients such as breakfast cereals, snack foods, baby foods, pasta products, extruded bread, modified starches, beverages, powders, meat and cheese analogues, textured vegetable protein, and blended foods such as corn starch and grounded meats (Anderson *et al.,* 1969; Moore *et al.,* 1990; Abd El-Hady *et al.,* 1998; Zang and Hoseney, 1998; Rhee *et al.,* 1999). It is a technology with high versatility and efficiency, low cost, high output per unit time and short reaction time, with relatively no waste generated (Nabeshima and Grossmann, 2001).
This study is aimed at optimizing the extrusion parameters of snacks from composite flours of cocoyam and bambara ground nut.

Materials and Methods

The Cocoyam used for this study was obtained from Kafanchan in Jema, a Local Government Area of Kaduna State (Nigeria). The variety was identified in Root Crop Research Institute
Samaru (ABU) Zaria, while Bambara ground nut was purchased in Kaduna Central Market

Cocoyam flour preparation

Cocoyam flour was produced using the method described by Udensi *et al.,* (2008) with slight modifications. The corms were manually cleaned before removing the diseased corms, washed, peeled, sliced, and blanched at 80°C for 4 min. and was dried to 14% moisture content and mill using attrition mill (locally fabricated) and sieve with fine (150μm) laboratory sieve

Bambara ground nut flour preparation

The Bambara groundnut was soaked for 24hrs to facilitate dehulling. The seed grains were dehulled using mortar and pestle. The dehulled kernels was washed to remove the skin, oven- dried at 65^{0}C to about 14% moisture content before winnowing to have a clean dehulled seeds. The dried seeds were then milled into flour using attrition mill and sieved to pass through a 150μm laboratory sieve

(Xin-Hai type). The samples were packaged in air-tight plastic container at room temperature until needed.

Blend formulation and moisture adjustment

Fifteen (15) formulations were prepared to contain cocoyam and bambara ground nut flours (wet basis) ranging between 8- 29.45% based on the experimental lay out on **Table 1**. The samples were conditioned to appropriate moisture content by spraying with a calculated amount of water and mixing continuously using Hobart laboratory mixer. The samples were put in a closed container and kept overnight (32 + 2⁰C). The samples were kept in a room temperature equilibrate pending extrusion processing.

The amount of water used was calculated using the equation below.

$$Y=\frac{Mf-Mi)x\ Sw}{100-Mf} \quad \text{……………………………………………………………}(1)$$

Where; Y = Amount of water to be added (ml)

Mf = Final moisture content

Mi = Initial moisture content

Sw = Sample weight (g)

Table 1 Composite flour obtained from the optimal mixture model of RSM

	X_1	X_2	X_3	X_1	X_2	X_3
1	-1	-1	-1	30	100	8.00
2	1	-1	-1	50	100	8.00
3	-1	1	-1	30	140	8.00
4’	1	1	-1	50	140	8.00
5	-1	-1	1	30	100	24.00
6	1	-1	1	50	100	24.00
7	-1	1	1	30	140	24.00
8	1	1	1	50	140	24.00
9	-1.682	0	0	23.18	120	16.00
10	1.682	0-1.682	0	56.82	120	16.00
11	0	1.682	0	40	86.36	16.00
12	0	0	0	40	153.63	16.00
13	0	0	-1.682	40	120	2.550

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14	0	0	-1.682	40	120	29.45
15	0	0	0	40	120	16.00

X_1=feed composition, X_2=barrel temperature, X_3=feed moisture composition

Extrusion exercise

The blends were subjected to extrusion cooking. Feeds were manually introduced into extruder through a screw operated conical hopper at a speed of 50rpm which ensures that the flight of the screw was filled and avoiding accumulation of feed in the hopper using a single screw extruder (Brabender, Duisburg DCE-330) equipped with a DC drive of variable speed and a strain gauge torque meter. The screw geometry was at constant and is linearly tapered. The rehydrated samples were then extruded and the extruded were cooled to room temperature and sealed in high density polyethylene films for further analysis.

Proximate analysis of the of the extrudate

The proximate analysis was carried using Association of Official Analytical Chemists (AOAC, 2012) methods in order to determine the percentage of moisture, protein, crude fat, crude fibre, ash and the carbohydrate was determined by difference in the extrudate.

Results and Discussion

Table 2 Effects of feeds composition(X_1), barrel temperature(X_2) feed moisture content (X_2) on the proximate composition of cocoyam - Bambara groundnut extrudate

EXP RUN	Ind. Variable in their natural forms			Proximate Analysis (%)					
	(X_1	X_2	X_3)	Moist.	Prot.	Lip.	Fib	Ash	Carb.
1	30	100	8	2.65	3.40	1.03	1.94	1.36	89.61
2	50	100	8	3.63	5.99	0.96	1.87	2.33	85.22
3	30	140	8	3.24	5.51	0.96	1.75	1.54	87.02
4	50	140	8	3.29	5.96	0.97	1.76	1.54	86.48
5	30	100	24	4.02	6.25	1.01	1.81	1.54	85.37
6	50	100	24	3.96	6.57	0.93	1.79	1.59	85.46

7	30	140	24	3.48	6.68	0.98	1.78	1.59	85.57	
8	50	140	24	3.91	6.63	1.01	1.83	1.59	85.04	
9	23.18	120	16	3.89	7.01	0.99	1.83	1.59	84.60	
10	56.82	120	16	3.93	5.10	0.95	1.85	2.02	86.15	
11	40	86.36	16	4.02	6.01	0.96	1.88	1.74	85.39	
12	40	153.63	16	3.67	6.29	0.97	1.89	1.71	85.47	
13	40	120	2.55	3.04	6.96	0.97	1.88	1.65	85.50	
14	40	120	29.45	3.82	6.08	0.97	0.18	1.65	87.30	
15	40	120	16	3.49	6.66	0.95	1.79	1.66	85.45	

X_1= Feed composition, X_2= Barrel temperature, X_2= Feed moisture composition, Prot.= protein, crud. Lip. = lipid, fib. fibre, C. carb =carbohydrate

Table 3 Equation coefficients for response variables for Cocoyam/Soybeans Extrudate Proximate Composition

Term	Moisture	Protein	Fat	Ash	Fibre
Constant	3.995	5.212	1.032	1.566	1.8310
X_1	0.00140	-0.011	0.0795	0.1198	0.0790
X_2	-0.0064	-0.038	-0.0640	-0..204	-0.0572
X_3	0.0603	0.086	-0.0473	-0.0903	-0.1012
Quadratic					
X_1^2	-0.2465	0.003	0.013	0.0028	0.046
X_2^2	-0.0149	0.261	-0.005	0.0001	0.046
X_3^2	-0.0759	0.193	0.002	0.0169	0.030
Interaction					
X_1X_2	-0.0937	0.043	-0.1075	-0.0644	-0.1150
X_1X_3	-0.2113	-0.242	-0.1375	-0.2031	-0.1362
X_2X_3	-0.2250	0.012	0.1312	-0.0519	0.1212
R square	84.98%	44.49%	64.20%	70.62%	67.05%
R. adj	57.95%	0.00%	0.00%	17.73%	7.73%

$y= \beta o+ \beta_1 x_1+ \beta_2 x_2+ \beta_3 x_3+ \beta_{11} x_{11} + \beta_{22} x_{22} + \beta_{33} x_{32} +\beta 1x1x2 +\beta 13x1x3 +\beta 23x2x3$ x_1= feed blend composition, x_2= barrel temperature, x_3= feed moisture composition.

The results of the proximate composition of cocoyam/bambara ground nut extrudate is presented on **Table 2**. The moisture content ranged between 2.6 to 4.02%, protein content ranged between 3.40 to 7.01%. The feed composition, barrel temperature and feed moisture composition of 23.18%, 120^0C and a moisture content of 16% has an optimum protein improvement, (Michela *et al.,*2000) observed that fortification with legumes not exceeding 30% were generally considered able to improve amino acid composition. Lipid (fat content) ranged between 0.95 to 1.03%, fibre composition ranged between 0.18 to 1.94%. The low fibre retention, may be as a result of the hull removal prior to milling, Frohlich *et al.,* (2014) reported that, the hull removal lowers the content of the fibres and mineral but improves the expansion during extrusion. ash ranged from 1.33 to 2.33%. The high ash content is observed on run 2 with extrusion variables of 50% bambara ground nut, 100^0C barrel temperature, and a moisture content of 8%, high feed (bambara g/nut) tend to improve the mineral composition of the extrudate at an average temperature of 100^0C. Of all foods, legume is the food that adequately meet the recommended dietary recommendation of the dietary regulation for healthy eating, they are high in carbohydrate, and dietary fibre, low in fat, good protein and vitamin source and high in minerals (Fennema 2000).

The result of the regression modelling and the coefficients for the effects of extrusion variables on proximate composition (moisture, protein, fat, ash and fibre) of cocoyam- bambara ground for the linear, quadratic and the interaction term are presented on **Table. 4.25,** the range for the coefficient of determination (R_2) was 57.45 % to 80.07 % for cocoyam- bambara g/nut, this result indicates a good fit for the model in describing the effects of feed composition, barrel temperature and feed moisture composition for cocoyam-bambara g/nut extrudate samples. hence, this model could be used in determining the independent variables in the production cocoyam- bambara g/nut base extrudate having optimum protein, moisture, fat, ash and fibre indices. All the responses in the various extrudates (samples) have positive coefficients. Filli, Nkama, Jideani, and bubakar, (2012) posits that a negative coefficient denotes decrease in the response with increase in the level of the parameter where as a positive coefficient indicates increase in the response as the level of parameter increase**s.**

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3.1 Regression models for proximate composition of cocoyam/bambara nut extrudates

Moisture= $3.498 + 0.108X_1 - 0.0679X_2 + 0.284X_3 + 0.101X_1^2 + 0.079X_2^2 - 0.069X_3^2 - 0.054X_1X_2 - 0.082X_1X_3 - 0.104X_2X_3$ ………………………………………………….. (2)

The eq. (2) above show the moisture response from the regression model for cocoyam/ bambara ground nut. The result of the ANOVA showed that the model X_1, X_3, (linear) X_1^2, X_2^3, (quadratic) were all significant ($P \leq 0.05$) while the interactive terms X_1^2, X_2^2, X_3^2, had an antagonistic relationship at ($P \leq 0.05$). The R^2 and $R_{adj.}$ were 84.98% and respectively. Upward increase in moisture at the linear and quadratic level which will have a positive effect on the product quality.

Protein = $6.678 - 0.142X_1 + 0.075X_2 + 0.126X_3 - 0.244X_1^2 - 0.205X_2^2 - 0.070X_3^2 - 0.064X_1X_2 - 0.097X_1X_3 + 0.052X_2X_3$…………………………………………………….. (3)

Table 2 protein content ranged between 3.40 to 7.01%. The bambara ground nut protein is of good quality and has surplus lysine which complement cereals in the diet (Ocran *et al*., 1998). Amandikwa (2012) reported that cocoyam is a good source of carbohydrate. From the result (Table 2), the carbohydrate content ranged from 84.60% to 89.61%, which clearly indicates that composite flours consisting root/ tubers and legumes in the level obtained in this studies will produce a good snack that is rich in protein. The ANOVA indicated a significance ($P \leq 0.05$) model, linear; X_2 and X_3, and interactive; X_2X_3 while the R^2 and R_{adj} were 44.49% and 0.00%. These low values indicate low contribution of protein to cocoyam flour (Awolu and Oseyemi 2016).

Fat = $0.947 - 0.0107X_1 - 0.0009X_2 - 0.004X_3 + 0.0065X_1^2 + 0.00654X_2^2 + 0.0109X_3^2 + 0.0262X_1X_2 + 0.0050X_1X_3 + 0.011X_2X_3$……………………………………………………. (4)

The fat content ranged between 0.93% to 1.03%. One of the major concerns in extrusion is excessive amount of fat which affects the shearing effectiveness on the screws in the barrel during the transition or compression in the barrel. During extrusion fat provides lubrication effects in the compressed polymer mix in the extruder as well as modifies the eating quality of the samples (Guy, 1994; Asare *et al.,* 2011). The amount of fat in this formulation showed a negative linear

(X_1, X_2, X_3) coefficient, While the quadratic (X_1^2, X_2^2, X_3^3) and the interactive (X_1X_2, X_1X_3, X_2X_3) has an antagonistic relationship from the model.

Ash $= 1.630 + 0.046X_1 - 0.0579X_2 - 0.0421X_3 + 0.124X_1^2 + 0.0005X_2^2 - 0.0339X_3^2 \quad 0.01038X_1X_2 - 0.0925X_1X_3 + 0.1050X_2X_3$ ………………………………………………… (5)

The ash content ranged from 1.36mg/100g to 2.33mg/100g which shows that the extrudate contains an appreciable amount of minerals. The model terms; linear X_1, quadratic X_1^2 and the interactive terms were significant ($P \leq 0.05$). The R^2 and the R_{adj} were 70.62% and 17.73% this indicates that the raw materials are not good sources for minerals. Minerals are very important to the body, they are needed for maintenance of osmotic balance of the body fluids and for regulating muscle and nerve irritability (National research council 1980). The ash content is an index of inorganic elements that are present as minerals.

Fibre = $1.793 - 0.0034X_1 - 0.0230X_2 + 0.0003X_3 + 0.008X_1^2 + 0.0230X_2^2 + 0.0115X_3^2 + 0.0237X_1X_2 + 0.0063X_1X_3 + 0.0363X_2X_3$ ………………………………………………… (6)

The fibre content varied between 0.08mg/100g to 1.94mg/100g. It has been observed that insoluble dietary fibre decreased apparently as the process parameters changes. These changes may probably be due to disruptions of covalent and non-covalent bonds in the carbohydrate and protein moieties leading to smaller and more soluble molecular fragments. (Danbaba *et al.,* 2016). The fibre showed a negative linear, and a positive quadratic and interactive (X_3), (x_1^2 X_2^2 $X_3 2$), and (X_1 X_2, X_1X_3, and X_2X_3) terms respectively. The ANOVA indicates that the processing variables are significant ($P \leq 0.05$).

4.0 Conclusion

In this studies, Response Surface Methodology (RSM) was use to evaluate the effect of processing variables on the Proximate composition of snacks produced from cocoyam and Bambara ground nut. The moisture response from the regression model for cocoyam/ bambara ground nut.from the ANOVA showed that the model X_1, X_3, (linear) X_1^2, X_2^3, (quadratic) were all significant ($P \leq 0.05$) while the interactive terms X_1^2, X_2^2, X_3^2, had an antagonistic relationship at ($P \leq 0.05$). The R^2 and $R_{adj.}$ were 84.98% and respectively. Upward increase in moisture and protein at the linear and quadratic level will have a positive effect on the product quality. The amount of fat in this formulation showed a negative linear (X_1, X_2, X_3) coefficient. It therefore, showed that processing variable has a significant effect on the responses.

Acknowledgements

The Authors are highly indebted Educational Trust Fund (TETFund) for funding the research programme in its entirety.

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