IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 8, Issue 5 Ver. V (May. 2014), PP 29-34
www.iosrjournals.org

Effect of Extrusion Parameters on the Physical and Functional Properties of Cocoyam (Colocasia esculenta) Flour

[1*]O. A. Peluola-Adeyemi , [2] M. A Idowu
[1*]Department of Food Technology, Lagos State Polytechnic, Lagos, Nigeria.
[2]Department of Food Science and Technology, University of Agriculture, Abeokuta, Nigeria

Abstract: *Cocoyam (Colocasia esculenta) flour was cooked and extruded in a single screw extruder (DD85G, 201132, IBG Monforts Gmbhi & Co, D-4050 Monchengladbach, Germany). A second order central composite response surface design was adopted in designing the experiment which generated 20 runs on selected process parameters including feed moisture (22,24,26%), screw speed (60,70,80rpm) and barrel temperature (200,220,240^{0}C) on the functional and physical properties (density, expansion, water absorption index (WAI), water solubility index (WSI) and textural characteristics) of the extrudates. At high feed moisture content there was increase in extrudates density, decrease in expansion, increase in WAI, decrease in WSI and increase in hardness while high barrel temperature lead to decrease in extrudates density, WAI and hardness but increased the expansion ratio and WSI of the extrudates.*

Keywords: *Cocoyam, single screw extrusion, physical and functional properties*

I. Introduction

Cocoyam is one of the oldest cultivated crops in the world, belonging to the sub-class of monocotyledon plant (1). Cocoyam is next to yam and cassava in ranking of the most important tuber crops in West Africa. It is a major tuber crop in forest areas of Ghana and Nigeria where it is an important source of carbohydrate. In Nigeria, cocoyam is common in the South-Eastern and South-Western parts (2), it is an important food security crop and variously grown by resource poor farmers, mostly women as reported by Okoye (3). Cocoyam is available all the year-round making it preferable to others, more resistant to drought, pest and diseases (4). The world production of the crop is estimated to be 5.5 million tonnes annually and more than three quarter of the world cocoyam production comes from Africa (5) and Nigeria is the World largest producer of cocoyam accounting for up to 3.7 million metric tones annually (6). The main nutrient supplied by cocoyam is dietary energy provided by the carbohydrates. Cocoyam is a good source of Na, K, P, Mg, and Ca and is fairly rich in carotene, ascorbic acid, thiamine, riboflavin and nicotinic acid. The leaves contain beta-carotene, iron and folic acid (7, 8). Calcium oxalates have been implicated in the acridity effect of some cultivars of taro cocoyam. Cocoyam contains oxalate and acridity as anti-nutritional factors. Consumption of large dose was reported to be associated with corrosive gastroenteritis, shock, convulsive symptoms, low plasma calcium, renal damage, sharp irritation, burning of the throat and death. The effectiveness of some processing techniques such as removing the thick layer skin, cooking at high temperature by boiling or roasting, grating and fermentation have been reported to eliminate the toxic substances in the corm (7, 9).

Extrusion cooking is one of the most versatile and well established food processes and is used world wide for the production of expanded snack foods, pastes, modified starch, flat breads, meat and cheese analogues, ready to eat cereal foods and porridge (10, 11). The main purpose of extrusion is to increase the variety of foods in the diet, by producing a range of products with different shapes, textures, colours and flavours from basic ingredients (12). It has been reported that small variations in processing conditions affect process variables as well as product quality, which can vary considerably depending on the extruder type, screw configuration, feed moisture, temperature profile in the barrel session, screw speed and feed rate (13).

A response surface methodology (RSM), is a statistical method for determining and simultaneously solving multivariate equation. It uses an experimental design such as central composite rotatable design (CCRD) to fit a first or second order polynomial by least significant techniques. An equation is used to describe how the test variables affect the response and to determine interrelationship among the test variables in the response (14). The main objective of this research was to determine the effect of extrusion parameters on the physical and functional properties of cocoyam flour.

II. Materials And Methods

2.1 Preparation of flours

Cocoyam tubers (Colocasia esculenta) were purchased in Abeokuta, Ogun State. The processing of the tubers to flour as described by Idowu (15) was employed. Cocoyam tubers were selected, cleaned, hand peeled, washed and sliced into chips of 3-4 mm thickness. The chips were steeped for 12hrs, rewashed and sulphited in

0.1% potassium metabisulphite solution for 3hrs. The sulphited chips were dried in cabinet dryer at 60^0C for 24 hours, milled in attrition mill, and sieved (600µm) into flour.

The cocoyam flour was stored in high density polyethylene films until processed.Before extrusion, cocoyam flour (500g) was rehydrated according to each moisture content (Table 1) by calculated amounts of water being sprayed into each sample. After that, the samples were sealed in high density polyethylene films and kept at ambient temperature for 12h to reach homogeneous moisture distribution.

2.2 Extrusion process

The cocoyam flours were extruded using a single screw extruder (model 1993 DD85G, 201132, IBG Monforts Gmbhi & Co, D-4050 Monchengladbach, Germany). The extruder was equipped with 254mm barrel, a screw diameter of 200mm and was fitted with a die nozzle of 4mm diameter. The rehydrated samples were then extruded and the extrudates were cooled to room temperature and sealed in high density polyethylene films until measurements were taken.

2.3 Experimental design

A centre composite RSM design was used to show interactions of feed moisture, screw speed and temperature on the extrudates. This comprised of 20 runs, of which six were centre point and 14 for non-centre point (16).

Table 1: Coded Levels for the Response Surface Design

Variables	Levels				
	-α	**-1**	**0**	**+1**	**+α**
Feed Moisture (%), X_1	20.32	22	24	26	27.68
Screw speed (rpm), X_2	58.32	60	70	80	81.68
Temperature (^{o}C), X_3	198.32	200	220	240	241.68

Where α =1.682

Second order polynomial model was fitted to measure dependent variables (Y) such as bulk density (Y_1), expansion rate (Y_2), water absorption index (Y_3), water solubility index (Y_4), texture (Y_5). The following equation was used:

$$\mathbf{Y = \beta_0+\beta_1X_1+\beta_2X_2+\beta_3X_3+\beta_{11}X_1^2+\beta_{22}X_2^2+\beta_{33}X_3^2+\beta_{12}X_1X_2+\beta_{13}X_1X_3+\beta_{23}X_2X_3}$$

Where β_0, β_1- β_3, β_{11}- β_{33} and β_{12}- β_{23} are regression coefficients for interception, linear, quadratic and interaction coefficients, respectively, X_1-X_3 are coded independent variables and Y is the response (17). An Anova test was carried out using Design Expert 6.0.8 (Stat-Ease Inc., Minneapolis, USA) to determine the significance at different levels (0.1%, 1% and 5%) (16).

2.4 Physical and function properties of cocoyam extrudates

2.4.1 Bulk density

The bulk density was calculated by measuring the actual dimensions of the extrudates according to the method described by Ding et al. (13). The diameter and length of the extrudates were measured using vernier caliper. The bulk density was then calculated using the following formula,

$$\text{Density (g/cm}^3\text{)} = \frac{4 \text{ x } M}{\pi \text{ x } D^2 \text{ x } L}$$

where: M= Mass (g), D= diameter (cm), L= length (cm). Six replicates of extrudates were randomly selected and an average taken.

2.4.2 Expansion Ratio

The ratio of diameter of extrudate and the diameter of die was used to express the expansion of extrudate according to Ding et al., (13). Six replicates of extrudates were randomly selected and an average taken.

2.4.3 Water absorption index (WAI) and Water solubility index (WSI)

The WAI and WSI were measured using the method of Ding et al., (13). The extrudate samples were milled and sieved through 600µm sieve. 2.5g samples was dispersed in 25ml distilled water, using glass rod to break up any lumps and then stirred for 30min, centrifuged at 4000rpm for 15 mins. The supernatant was decanted into an evaporating dish of known weight and dried at 105^0C until constant weight. The weight of the gel remaining in the centrifuge tube was noted. The results were expressed as the average of the two measurements.

$$\text{WAI (g/g)} = \frac{\text{Weight gain of gel}}{\text{Dry weight of extrudate}}$$

$$\text{WSI (\%)} = \frac{\text{Weight of dry solids in supernatant} \times 100}{\text{Dry weight of extrudate}}$$

2.4.4 Hardness

The hardness measurement was determined by using Erweka (Gmbh D 63150, TBH200, Heusenstamm /Germany) hardness tester fitted with a 2mm cylinder probe. The samples were punctured by the probe to a distance of 6mm and the hardness recorded.

III. Results And Discussion

3.1 Effect of Extrusion Parameters on Bulk Density

The effect of extrusion parameters on extrudates density are shown in 3-D surface plot (Fig. 1). The bulk density of the extrudates increased at high feed moisture content and decreases at high barrel temperature. The model for bulk density (R^2 = 0.763) had positive quadratic terms (moisture content and temperature) and negative quadratic term (screw speed). There were negative linear terms (moisture content and screw speed) and positive linear term (temperature). The bulk density was significantly ($p<0.05$) affected by feed moisture and temperature (X_1 and X_3). The increase in bulk density at high feed moisture during extrusion of cocoyam flour could probably be due to a reduction in the elasticity of the dough through plasticization of the melt, causing reduction in gelatinization and increase in the density of the extrudates as confirmed by Ding et al., (13). High barrel temperature could have increase the degree of superheating of water in the extruder which encourage the bubble formation and a decrease in melting viscosity (18) leading to reduced density in all the extrudates.

3.2 Effect of Extrusion Parameters on Expansion ratio

The expansion ratio of extrudates decreased at high feed moisture content while high barrel temperature increases the expansion ratio of the extrudates. The regression model for expansion ratio was R^2 = 0.765. There were significant negative quadratic effect (moisture content, screw speed and temperature), positive linear effects (moisture content and temperature) and negative linear effect (screw speed). The expansion ratio was significantly ($p<0.05$) affected by X_3 and X_1^2 (temperature and quadratic effect on feed moisture). Decrease in expansion ratio at high feed moisture content during extrusion could have lead to changes in the amylopectin networks and in the melting rheology characteristics leading to greater elastic effect and changes in product density and expansion. High barrel temperature could have decreased the melt viscosity and the degree of superheating of water in the extruder leading to greater expansion in the cocoyam extrudates (18, 19).

3.3 Effect of Extrusion Parameters on WAI and WSI

High feed moisture content and screw speed significantly increases the WAI of the extrudates. However, high barrel temperature was observed to cause a significant decrease in WAI of the extrudates. The regression model for WAI (R^2 = 0.896) shows a significant positive quadratic effects (moisture content, screw speed and temperature), negative linear effect (moisture content) and positive linear effects (screw speed and temperature). The WAI was significantly ($p<0.05$) affected by X_3, $X_2{}^2$ and X_3^2 (temperature, quadratic effect on screw speed and temperature).

WSI decreased at high feed moisture content but increased significantly at high barrel temperature of the extrudates. The regression model for WSI (R^2 = 0.882) shows significant positive quadratic terms (moisture content, screw speed and temperature) and negative linear terms (moisture content, screw speed and temperature). The WSI was significantly ($p<0.05$) affected by X_3 and X_1^2 (temperature and quadratic effect on feed moisture). During the extrusion of the cocoyam flour, water is absorbed and bound to the starch molecule with a resulting change in the starch granule structure. Barrel temperature and feed moisture was observed to have the greatest effect on gelatinization. The maximum gelatinization could occur either at low moisture content and high temperature or vice versa as reported by Ding et al., (13). Decrease in WAI could probably be due to dextrinization, which also could have led to increase in WSI.

3.4 Effect of Extrusion Parameters on Hardness

An Increase in feed moisture content caused an increase in the hardness of the extrudates, while increasing in screw speed and barrel temperature resulted in a decrease in hardness of the extrudates. The regression model for texture (R^2 = 0.870) shows significant positive quadratic terms (moisture content and screw speed), negative quadratic term (temperature), positive linear term (moisture content) and negative linear terms (screw speed and temperature). The texture was significantly (p<0.05) affected by X_1, X_3, X_1^2, and X_2^2 (feed moisture, temperature, quadratic effect on feed moisture and screw speed). The hardness is the average force required for a probe to penetrate the extrudates. Increase in hardness of the extrudates with an increase in feed moisture content could probably due to decreased in expansion which resulted in increase in moisture content (20). Increasing temperature causes decrease in hardness which could be due to reduction in melting viscosity favouring bubble growth, increasing expansion and lowering the density giving a softer extrudates. An increase in screw speed could have lowered the melting viscosity of the mix resulting in a less dense and softer extrudates.

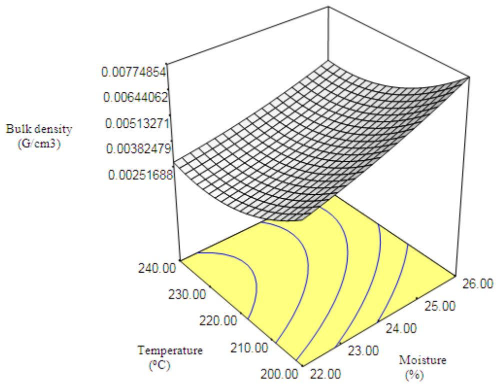

Fig. 1: Effect of moisture content and temperature at constant screw speed on the extrudates bulk density

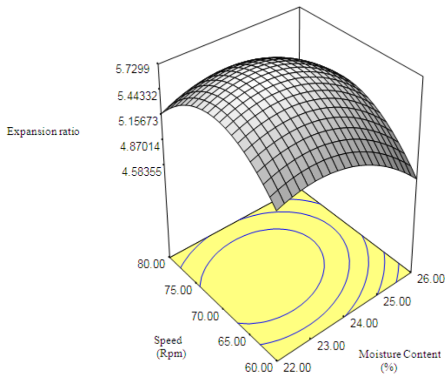

Fig. 2: Effect of moisture content and screw speed at constant temperature on the expansion ratio of The extrudates

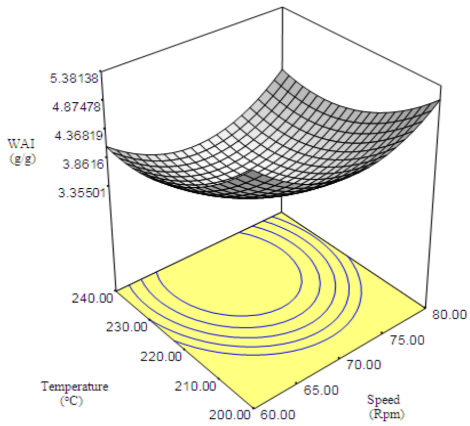

Fig. 3: Effect of screw speed and temperature at constant moisture content on the WAI of the Extrudates

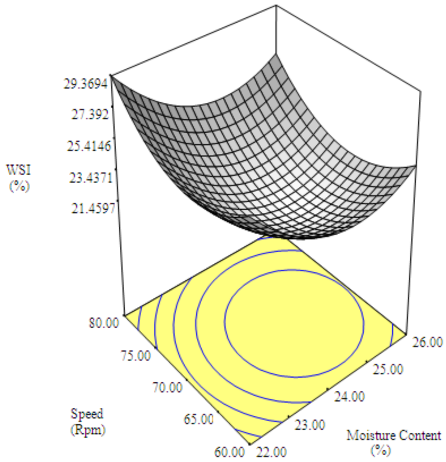

Fig. 4: Effect of moisture content and screw speed at constant temperature on the WSI of the Extrudates

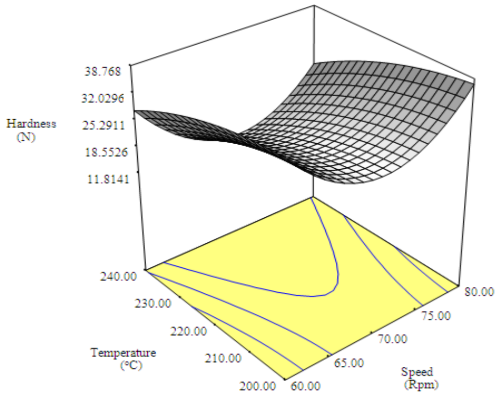

Fig. 5: Effects of screw speed and temperature at constant moisture on the hardness of the Extrudates

Table 2: Significant coefficients of regression equation for the responses

	Bulk Density (g/cm^3)	Expansion Ratio	WAI (g/g)	WSI (%)	Hardness (N)
β_0	0.123*	-84.607*	113.135**	377.040**	1035.631**
β_1	0.000**	3.895	-0.260	-24.663	-60.843***
β_2	0.000	0.565	-1.100	-3.4 27	-18.066
β_3	-0.001*	0.205*	-0.592***	0.392***	3.002*
β_{11}	0.000	-0.073*	0.005	0.668**	1.434**
β_{22}	-0.000	-0.004	0.007**	0.026	0.136**
β_{33}	0.000	-0.000	0.001*	0.001	-0.006
β_{12}	-0.000	0.003	-0.000	0.006	0.011
β_{13}	-0.000	-0.003	0.000	-0.035	-0.011
β_{23}	0.000	0.000	0.000	-0.000	-0.003
R^2	0.763	0.765	0.896	0.882	0.870

X_1: feed moisture, X_2: screw speed, X_3: temperature
*** Significant at the 0.1%
** Significant at the 1%
* Significant at the 5%

IV. Conclusion

The functional and physical properties of cocoyam extrudates on single screw extrusion process were dependent on the process parameters. The feed moisture and barrel temperature had significant effect on the extrudates properties, with feed moisture content having the greatest influence.

References

[1]. S.Chandra, Edible aroids development studies centre, Australian. (National University Camberra, Clarendon Press Oxford, 1984).
[2]. I.A.Ojiako, G.N. Asumugha, and C.N.E. Ezedinma, Analysis of production trends in the major root and tuber crops in Nigeria, 1961-2005. Research in Crops 8(2) 2007,371-380.
[3]. B.C. Okoye, C.E. Onyenweaku, O.O. Ukoha, G. N. Asumugha and O.C. Aniedu, Determinants of labour productivity on small-holder cocoyam farms in Anambra State, Nigeria. Scientific Research Essay Vol (3) 2008, 559-561.
[4]. L.T. Ogunniyi, Profit efficiency among cocoyam producers in Osun State, Nigeria. International Journal of Agricuture Economics & Rural Develop. 1(1) 2008,38-46.
[5]. S. Sefa-Dedeh and E.A Agyir- Sackey, Chemical composition and the effect of processing on oxalate content of cocoyam (Xanthosoma sagittifolium and Colocasia esculenta) cormels. Food Chemistry 85, 2004, 479-487.
[6]. I.O. Baruwa and J.T.O Oke, Analysis of the technical efficiency of small holder cocoyam farmers in Ondo State, Nigeria. Tropicultura, 30 (1) 2012, 30-40.
[7]. O.U. Eka, Nutrition quality of plant foods. (Afro-Orbis Publication Ltd, 1998) Pp 1- 31.
[8]. FAO, Roots, tubers, plaintain and bananas in human nutrition. Food and Agriculture Organization of the United Nations, Rome, 1990.
[9]. C.S. Tang and W.W. Sakai, Acridity to taro and related plants in araceae. (University of Hawaii Press, 1983) Pp148
[10]. M. Li and T. Lee, Effect of extrusion temperature on the solubility and molecular weight of lentil bean flour proteins containing low cysteien residues. Journal of Agricultural and Food Chemistry 48, 2000, 880-884.
[11]. S.Thymi, M.A. Krokida, A. Pappa, Z.B. Maroulis, Structural properties of extruded corn starch. Journal of Food Engineering 68, 2005, 519-526.
[12]. P. Fellow, Food processing technology: Principles and Practices. (Woodhead Publishing Limited, Cambridge England, 1997) Pp 267.
[13]. Q. Ding, P. Ainsworth, G. Tucker and H. Marson, The effect of extrusion conditions on the physiochemical properties and sensory characteristics of rice-based expanded snacks. Journal of Food Engineering 66, 2005, 283-289.
[14]. O.P. Sobukola, Influence of some processing parameters on quality attributes and sorption kinetics of fried white yam crisps, doctoral diss., University of Agriculture, Abeokuta, Ogun State Nigeria 2007.
[15]. M. A. Idowu, A. Oni and B. M. Amusa, Bread and Biscuit Making Potentials of Some Nigerian Cocoyam Cultivars. Nigerian Food Journal (14) 1996 1-12.
[16]. Stat-Ease, Design expert 6.0.8, (stat-ease, Inc. 2021 Ease Hennepin Avenue Suite 480 Minneapolis, MN 55413, 2002).
[17]. R.H. Myers and D.C.Montgomery, Response surface methodology: process and product optimization using designed experiment, (New York Wiley, 1995).
[18]. S.I. Fletcher, P. Richmond and A.C. Smith, An experimental study of twin screw extrusion cooking of maize grits. Journal of Food Engineering 4, 1985, 291-312.
[19]. S. Ilo, Y. Liu and E. Berghofer, Extrusion cooking of rice flour and amaranth blends. Lebensm Wiss.U. Technology, 322, 1999, 79-80.
[20]. Y. Liu, F. Hsieh, H. Heymann and H.E. Huff, Effect of process conditions on the physical and sensory properties of extruded oat-corn puff. Journal of Food Science 65, 2000, 1253-1259.